Knowledge and views of paediatricians about pulse oximetry: a nationwide online survey in Nigeria

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Abstract

Pulse oximetry is a non-invasive method of measuring oxygen saturation in clinical settings. This study was carried out to determine the level of knowledge and competencies relating to pulse oximetry and the ability to interpret the information.

We conducted a nationwide, multi-centre, and questionnaire-based online survey between January and June 2010. A 32-item questionnaire relating to the use of pulse oximetry in children was answered by 224 in-training and 157 qualified paediatricians (median duration of practice 6 years) working in 24 states in Nigeria. Knowledge of pulse oximetry was evaluated on a scale of 0–100%. Data were analysed using Chi-square and *t*-test statistics at 5% level of significance.

The overall mean test score was 36.6±20.8% (range 0–76.5%). The mean knowledge score among in-training and qualified paediatricians was 35.4±19.1% and 38.3±23.1%, respectively (p>0.05). Only 16.3% of the respondents answered all three questions correctly relating to the relationship between oxygen saturation and partial pressure of oxygen. Pertaining to the accuracy of pulse oximeters, 3.9% of the respondents answered all 14 questions correctly. On indications for use of pulse oximetry, 29% correctly answered all nine questions. Only 18% of respondents correctly answered the seven questions on interpretation of pulse oximeter reading. Some 73% of respondents believed that training in the use of pulse oximetry was inadequate.

A significant proportion of the paediatricians were untrained in pulse oximetry, lacked knowledge of basic principles, and made serious errors in interpretation of readings from pulse oximeters. We suggest that medical schools and residency training programmes place more emphasis on teaching the principles and uses of pulse oximetry.

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Background

Pulse oximetry is a diagnostic method that enables indirect measurement of the percentage of oxygenated haemoglobin in an individual's capillary blood.[1] The use of a pulse oximeter provides a non-invasive, painless, and reliable method for measuring arterial oxygen saturation. Pulse oximetry is often used in the assessment of children with symptoms suggestive of hypoxia because of the difficulty in subjecting them to taking repeated blood gases.[2] This technology could add valuable information to physicians' evaluation of sick children, especially in resource-poor settings where more expensive methods for arterial blood gases estimation are often not available. The pulse oximeter measures the discrepancy in the absorption of red and infrared light by haemoglobin and oxy-haemoglobin in fractions of blood under the sensor probe. It then calculates the percentage of haemoglobin saturated with oxygen.[3] Limitations and factors affecting the accuracy of pulse oximetry have been previously reviewed.[4–6] There are many potential sources of error that must be considered for the assessment and appropriate use of pulse oximeters, some of which include probe placement, signal quality, poor perfusion, dyshaemoglobin, dyes, pigments, ambient light, and motion.[4–7] In clinical practice, patients with a saturation reading below 90% are usually considered to be seriously hypoxic.

Pulse oximeters have been widely used in many tertiary and secondary care centres for decades in developed countries.[8] In the past, these devices were mainly found in operating rooms and some intensive care units in many developed countries but it has recently become a vital tool used routinely for both continuous and episodic measurement of oxygen saturation of patients in clinics, physician's offices, emergency departments, and ambulances. The measurement of oxygen saturation is now considered by many to be an important component of vital signs in hospital care. Like other vital signs – pulse rate, heart rate, blood pressure, and respiratory rate –oxygen saturation values need to be interpreted such that the significance of the reading in relation to patient condition may be assessed. This requires physicians to be familiar with the equipment to decide if accurate data have been obtained as well as knowing what is being measured and the potential physiological impact of the results.

However, healthcare providers' knowledge may not always be sufficient. Elliot and colleagues[9] in a review of 14 studies examined clinicians' comprehension of pulse oximetry and reported that many of the participants in those studies were very experienced, yet had significant knowledge deficits.

Data on Nigerian physicians' knowledge relating to pulse oximetry are scarce in published literature. In a study conducted among 25 health professionals working in a tertiary health facility in Nigeria, Faponle and Erhabor[10] reported that only 28% claimed to have been trained on the use of pulse oximeters and 'the answers to the clinical questions generally reflected a poor understanding of the principles of pulse oximetry.' The authors concluded that lack of knowledge may affect clinicians' decisions and adversely affect patient outcome. Moreover, the fact that they included consultant medical staff in their study,[10] suggests that regular use of, or 'exposure' to, pulse oximeters does not result in competency in its use.

While the use of pulse oximetry in clinical settings has been expanded into all neonatal and paediatric care in many developed countries, it is still largely limited to perioperative care in the majority of hospitals in Nigeria. This study was conducted to assess paediatricians' knowledge of pulse oximetry and their clinical interpretation as well as the availability of pulse oximeters in various children healthcare centres in Nigeria.

Methods

This was a nationwide, multi-centre, and questionnaire-based online survey conducted in Nigeria between January and June 2010. Nigeria has a total population of practising paediatricians (both in training and qualified) of about 500. This estimate varies yearly as professionals move in and out of the country. The majority are working in secondary and tertiary health facilities located mostly in urban areas of the country.

A list of study participants was initially drawn from the register at the past Paediatric Association of Nigerian Conference and a snow-balling method was used to enrol more participants until a total of 518 paediatricians were contacted via email for consent and participation.

A self-administered questionnaire containing a 32-point knowledge scale was used to collect information on demography, knowledge, accuracy, and clinical aspects of the use of the pulse oximeter. Demographic questions related to the level of training, perceived adequacy of training on the pulse oximeter, and its availability in different clinical settings. The knowledge questions related to what a pulse oximeter measures and the relationship between partial pressure of oxygen in arterial blood (PaO_2) and various O_2 saturations. The questionnaire was developed from three similar previous studies.[11-13] It was piloted among 10 paediatric residents and interns to assure clarity and ease of understanding and then sent electronically to an additional 518 physicians practising in paediatric units/departments in Nigeria.

Data were analysed using SPSS 15.0 for Windows. A score of one was allotted to each correct answer. Categorical variables were compared using either the uncorrected Chi square test while mean scores were compared using Student's *t*-test. Statistical significance levels were set at $p<0.05$.

A written informed consent was obtained from each participant. The online questionnaire was sent to a specified email address and responses were confidential.

Results

A participant-specific electronic survey link was sent to a total of 518 paediatricians, of which 381 were returned by 224 in-training and 157 qualified paediatricians, giving a response rate of 74%. There were 189 male and 192 female respondents. The age of respondents ranged from 26 to 62 years (mean 38±7.6) and they had been in paediatric practice for 1–33 years (median 6 years) with the majority in the 0–5 year bracket (see Table 1). The majority (86%) were practising in health facilities located in the urban area of their respective states. The median number of admissions at their emergency units per week was 30 (range 22–100).

Of the 96 (25%) respondents who claimed to have had previous training on pulse oximetry, 88 (92%) considered it adequate. Training had been in the form of lectures (29%), self-training (58%), and formal in-service training (13%). The majority (53%) had first learnt about pulse oximetry during their postgraduate training. At the time of the study, 234 (61%) had at least one pulse oximeter in their hospital but only 178 (47%) used it for patient care within the 2 weeks preceding the study. Most respondents reported that they had no pulse oximeters in their neonatal care units (79%) and emergency units (70%). Over half (52%) reported that although they had

Table 1 Characteristics of study participants

Characteristics	In-training n (%)	Qualified n (%)	Total n (%)	p
Gender				
Male	106 (47)	83 (53)	189 (50)	0.287
Female	118 (53)	74 (47)	192 (50)	
Previous training				
Yes	77 (34)	19 (12)	96 (25)	0.000
No	147 (66)	138 (88)	285 (75)	
Adequacy of training				
Adequate	36 (19)	52 (36)	88 (27)	0.001
Inadequate	150 (81)	91 (64)	241 (73)	
Place of current practice				
Private health facility	0 (0)	18 (12)	18 (5)	0.000
Government secondary facility	21 (9)	24 (15)	45 (12)	
Tertiary/teaching hospital	203 (91)	115 (73)	318 (83)	

seen pulse oximeters before the study their institutions did not have them at the time of the study. Other characteristics of the respondents were as shown in Table 1.

The mean test score was 36.6%±20.8 (range 0–76.5%). The comparison of the mean scores between male and female, in-training and qualified, participants with and without previous training, as well as across the institutions are shown in Table 2. There was no significant correlation between the test score and duration of practice (r=0.092, p=0.072). There was no significant difference in the overall mean knowledge scores of in-training (35.6%±19.1) and qualified (38.3%±23.1) paediatricians (p=0.182). Some 26% of the study participants did not know what a pulse oximeter measures, with the common erroneous response being that it measures transcutaneous partial pressure of oxygen (12%) and arterial partial pressure of oxygen (14%). Relating to the knowledge of the relationship between oxygen saturation and partial pressure of oxygen, only 16% of the respondents answered all three questions correctly and 29% answered two of the three questions incorrectly. Only 16% correctly mentioned that the relationship of partial pressure of oxygen in arterial blood (PaO_2) to oxygen saturation SaO_2 results in an S-shaped curve/graph while others described the relationship as linear and inverse.

Table 2 Comparison of mean knowledge scores by participants' characteristics

Characteristics	Mean knowledge score	SD	p
Gender			
Male	37	21.2	0.434
Female	36	20.5	
Professional status			
In-training	35	19.1	0.182
Qualified	38	23.1	
Previous training			
Yes	38	20.1	0.425
No	36	21.1	
Adequacy of training			
Adequate	39	23	0.619
Inadequate	37	19.5	
Place of current practice			
Private health facility	35	27.2	0.828
Government secondary facility	38	20.1	
Tertiary/teaching hospital	37	20.6	

Table 3 Critical conditions affecting the accuracy of pulse oximetry measurement (correct answers are shown in bold; values show percentage of respondents giving each answer)

Conditions	Decrease in readings	Failure to pick up signal	Not affected	Not answered
Cardiac arrest	39	**39**	1	21
Respiratory arrest	**65**	13	2	21
In shock	**60**	19	2	19

Table 4 Physiologic and environmental factors affecting the accuracy of pulse oximetry measurement (correct answers are shown in bold; values show percentage of respondents giving each answer)

Factors	No effect	Falsely decrease	Falsely increase	Failure to pick up signal	Not answered
Physiologic					
Dark nail polish	20	**28**	7	24	21
Dark skin	**51**	18	6	6	20
Shivering/motion	9	17	16	**39**	20
Jaundice	**52**	17	6	4	21
Anaemia	**18**	44	13	5	21
Carbon monoxide poisoning	5	40	**27**	5	23
Cardiac arrhythmias	13	30	6	**24**	28
Peripheral vasoconstriction	2	59	4	**15**	19
Chronic smoker	16	38	**13**	6	28
Environmental					
Bright overhead light	39	11	**17**	12	21
Cold environment	6	55	3	**15**	21

Regarding factors (critical, physiological and environmental situations) that might influence the accuracy of pulse oximetry, the numbers of respondents who gave correct and incorrect responses are summarised in Tables 3 and 4. Only 4% of the respondents answered all 14 questions correctly. Of the three critical conditions affecting the accuracy of pulse oximetry measurement, respondents correctly answered that pulse oximeters would fail to pick up signal during cardiac arrest (39%) and decrease in readings would occur when patients are in respiratory arrest (65%) or shock (60%). Respondents correctly mentioned that dark skin (51%), jaundice (5%), and anaemia (18%) have no significant effect on the readings from pulse oximeters. Falsely increased reading was correctly mentioned as a consequence of high carbon monoxide (27%), chronic smoking (13%) and bright overhead light (17%). Respondents also correctly recognised that failure to pick up a signal could occur when the patient is shivering or moving (39%), suffers cardiac arrhythmias (24%), peripheral vasoconstriction (15%) or is in an excessively cold environment (15%).

The proportion of the respondents and answers to the

various statements on indications for use of pulse oximetry were as shown in Table 5. About a third (29%) of the respondents correctly answered all nine questions on indications for use of pulse oximetry. Fifty-eight percent gave the correct answer when asked if pulse oximetry is a good method for continuous non-invasive monitoring of arterial oxygenation during ventilation. On whether clinical observation alone such as detection of cyanosis has been shown to be as effective as pulse oximetry monitoring in the rapid detection of hypoxaemia, 57% answered 'false'. About two-thirds (63%) correctly answered 'false' to the statement 'significant hypoxaemia is unlikely during transport of ill patients thus no need for pulse oximetry.' About half (53%) correctly answered 'true' to the statement 'pulse oximetry can be used safely and effectively in the place of frequent analysis of arterial blood gases when decreasing the fraction of inspired oxygen ($FIO_{2)}$ to wean patients from mechanical ventilation.' 'False' was correctly given by 43% as the response to the statement: 'pulse oximetry sensors should be applied at the level of the patient's heart because pulse oximetry readings may be lower in dependent extremities.' Almost half (49%) of the respondents did not know that the use of the less-pigmented nail bed rather than the skin as a sensor site is preferred in darkly pigmented patients. Spot checks of pulse oximetry readings are as helpful in assessing a patient's oxygenation status as the evaluation of continuous monitoring over time, correctly elicited 'false' as a response from 44%. Only 27% correctly answered 'true' to the statement that pulse oximetry is not an indicator of adequacy of ventilation and 37% correctly answered that pulse oximetry cannot be used for monitoring hyperoxaemia in premature neonates.

Seven questions were related to interpretation of pulse oximeter readings and only 18% of respondents correctly answered all of them. The unit of measurement for pulse oximetry was correctly given as a percentage by 275 (72%). Normal oxygen saturation for a 2-year-old and for a full-term newborn, in room air, after the first 4 hours of life were correctly given as 90% to 100% by 28% and 17% of the respondents, respectively. Pulse oximeter readings were reported as being inaccurate at values less than 70% by only 19% of the respondents. About half (50%) of the respondents correctly answered that shock may affect the accuracy of a pulse oximeter reading while others gave wrong answers. Only 34% correctly answered that the PaO_2 of a 1-month-old infant on 30% oxygen with a oxygen saturation of 99% could not be determined from the pulse oximetry reading while others gave wrong answers.

Of the 381 respondents, 306 (90%) suggested that increasing the awareness and knowledge among paediatricians concerning the importance of pulse oximetry can promote use of pulse oximeters among paediatricians. Other suggestions include: provision of adequate pulse oximeters and other equipment in all paediatric practising facilities (81%), inclusion of lectures and training on pulse oximetry and its application in residency training (80%), formulation of appropriate policies for promoting pulse oximetry application in all health facilities in Nigeria (74%), and a public enlightenment programme in print and electronic media targeted at making caregivers whose children need pulse oximetry-related care actively seek for (63%).

Table 5 Knowledge about use of pulse oximetry (correct answers are shown in bold; values show percentage of respondents giving each answer)

Statement on indication for pulse oximetry	Responses		
	True	False	Don't know
Pulse oximetry is a good method for continuous non-invasive monitoring of arterial oxygenation during ventilation.	**58.0**	13.4	28.6
Clinical observation alone such as detection of cyanosis has been shown to be as effective as pulse oximetry monitoring in the rapid detection of hypoxaemia.	12.6	**57.2**	30.2
Significant hypoxaemia is unlikely during transport of ill patients thus no need for pulse oximetry	3.9	**62.7**	33.4
Pulse oximetry can be used safely and effectively in place of frequent analysis of arterial blood gases when decreasing FIO_2 to wean patients from mechanical ventilation.	**52.8**	14.4	32.8
Pulse oximetry sensors should be applied at the level of the patient's heart because pulse oximetry readings may be lower in dependent extremities.	16.5	**42.8**	40.7
Use of the less-pigmented nail bed rather than the skin as a sensor site is preferred in darkly pigmented patients.	**36.5**	14.7	48.8
Spot checks of pulse oximetry readings are as helpful in assessing a patient's oxygenation status as the evaluation of continuous monitoring over time.	20.5	**43.5**	35.9
Pulse oximetry is not an indicator of adequacy of ventilation.	**27.3**	45.4	27.3
Pulse oximetry can be used for monitoring hyperoxaemia in premature neonates.	26.0	**37.3**	36.7

Discussion

Existing data showed that while the use of pulse oximetry in clinical settings has been expanded into all aspects of paediatric care in developed countries, it is still largely limited to perioperative (during surgical operation) care and care of critically ill children in a few hospitals in Nigeria. This study was conducted to assess knowledge of pulse oximetry and its clinical interpretation among paediatricians working in Nigeria.

The level of knowledge and skills of in-training and qualified paediatricians were also compared. Our data revealed a deficiency of knowledge in the use of pulse oximetry and lack of formal training among paediatricians working in Nigeria. These data also indicate that there are reasons to be concerned about the wide-ranging competence of paediatricians in various hospitals in Nigeria when using pulse oximeters.

To the best of our knowledge this is the first study evaluating knowledge, appropriate use and application of the data obtained from pulse oximeters among paediatricians in Nigeria. Paediatric practitioners who participated in this survey expressed relatively low confidence in general knowledge related to pulse oximetry and the level of understanding was unacceptably low as reflected in their responses to survey questions. In this study, only 26.7% of the participants felt they had adequate training in pulse oximetry and as many as 26% did not know that pulse oximeters measured oxygen saturation. These findings are comparable to the report by Kruger and Longden[14] who reported a general lack of knowledge of pulse oximetry in a sample of physicians in an Australian paediatric hospital. Though the qualified (consultant) paediatricians had higher knowledge score, it was not statistically different from the average score of those in training. The absence of correlation between clinical experience and test score gives us a clue that knowledge on the use of pulse oximetry cannot be improved simply by accumulating experience. There are no obvious explanations for the small but not significant differences in mean test scores between male and female, in-training and qualified, participants with and without previous training as well as across the institutions.

Participants' answers to questions on principles of pulse oximetry, normal ranges, measurement errors, and physiology of oxygen haemoglobin dissociation varied and reflected limited understanding. Stoneham et al[15] also reported similar results among 30 medical and surgical house staff members and 30 nursing staff members. Ninety-five percent of the doctors and nurses in that study did not understand the physiological basis for pulse oximetry measurement and were confused about factors that influence SpO_2 (saturation of peripheral oxygen) values. Over 40% of the participants were not aware of the basic relationship between oxygen saturation and the partial pressure of oxygen in arterial blood (oxygen dissociation curve). Previous studies[11,13,15-17] also demonstrated a marked lack of understanding of the oxy-haemoglobin dissociation curve, lack of knowledge of other technology, and inadequate interpretation of data leading to delayed interventions and changes in plans of care. That only 18.1% of respondents correctly answered all the seven questions on interpretation of pulse oximeter readings reflects the fact that over half of the participants reported that though they had seen pulse oximeters before the study their institutions did not have the equipment as at the time of the study. The implications of this situation lie in the consequence of missing the diagnoses and failure to treat significant hypoxic episodes when the equipment is available unless adequate trainings is given to the participants.

One main limitation of this survey is that the questionnaire was completed online. This may result in limited participation by some paediatricians as internet access is not readily available.

Competencies in the use of pulse oximetry are vital to ensure a good clinical outcome. Those who participated in this study are often responsible for monitoring the patients and are most likely to make decisions. Early detection of hypoxic episodes should lead to earlier corrective measures and prevent adverse consequences of hypoxaemia, such as arrhythmias, myocardial ischaemia, and brain ischaemia.[18] The full value of the addition of oximetry to monitor paediatric patients will not be realised in Nigeria until paediatric knowledge is improved. Therefore formal and informal education programmes need to be developed. Policy makers, especially the heads of paediatric departments in various healthcare settings, should give training on pulse oximetry to interns and residents through additional lectures during training and by update courses and continuous medical education activities. Additionally, an annual review of critical decision-making should include oximetry as a high-risk, problem-prone skill using a clinical scenario-based approach. Continued medical education and future research will help facilitate the appropriate integration of pulse oximetry technology into childcare in Nigeria.

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