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Original Article

Internal Medicine Section

Clinical Competency in Pulse Oximetry among Medical Professionals and Nursing Personnel in a Tertiary Care Hospital

SOMASHEKHAR MARUTIRAO NIMBALKAR[1], SATVIK CHAITANYA BANSAL[2], CHINTAN LABHUBHAI PATEL[3], DIPEN VASUDEV PATEL[4], KARAMCHAND HUKUMCHAND PATIL[5], ARCHANA SOMASHEKHAR NIMBALKAR[6]

ABSTRACT

Introduction: Pulse oximetry is used for monitoring of patient care with early and reliable detection of hypoxemia. Inadequate knowledge amongst medical and nursing personnel can lead to reduced patient safety .

Aim: To assess competency in pulse oximetry among the residents and nursing personnel.

Materials and Methods: This was a cross-sectional study conducted at a tertiary care teaching hospital, Karamsad, Anand, Gujarat, India. The survey had 34 questions based on principles and correct interpretation of pulse oximetry. Data were entered into the Android mobile devices. Descriptive analysis, univariate analysis, and Student's t-test were used.

Results: A total of 264 subjects participated in the study-155 nursing personnel and 109 residents. The number of correct responses was low overall, with a mean (SD;CI) of 13.76 (2.56; 13.45-14.07) out of 26 for the "True/False" questions; and a mean (SD;CI) of 3.27 (1.57; 3.08-3.56) out of 8 for the "Multiple Choice" questions. The overall score of residents was significantly higher than nursing personnel ($p<0.001$). No significant difference was observed to be made by any formal training, work experience and working in acute care setting.

Conclusion: There is marked deficiency in the knowledge of pulse oximetry in the healthcare professionals. Strategies directed at improving the competency correct interpretation of pulse oximetry are urgently needed, to improve patient care and safety.

Keywords: Knowledge, Nurses, Residents, Saturation

INTRODUCTION

Pulse oximetry is a ubiquitous method of assessing the percentage of haemoglobin saturated with oxygen. It can give a rough estimate of the blood oxygen content in most cases. Oxygen saturation has been increasingly referred as the "fifth vital" sign [1].

Pulse oximetry measures the change in absorbance of specific wavelengths of light, when the light is passed through a well-perfused area. The wavelengths used are red (660 nm) and infrared (940 nm). The inbuilt algorithm compares the amount of absorbed wavelengths, and calculates the oxyhaemoglobin/deoxy-haemoglobin ratio. This ratio is recorded as the percentage of arterial haemoglobin saturation.

Pulse oximetry was first developed in Japan during the early 1970s, and started being used commercially about a decade later [2]. It can be rightly regarded as the greatest advancement in patient monitoring since the electrocardiogram [3]. Pulse oximetry offers a rapid, non-invasive, cost effective and reliable measurement of oxygen saturation of blood and is widely used in different clinical settings, especially in intensive care settings [4]. Recently, it's use begun as a screening tool for the detection of congenital heart disease [5].

While the measurement of oxygen saturation is quite simple, interpretation of the results is complicated. Moreover, pulse oximetry is not without limitations. It is inaccurate during low perfusions, during motion, and in the presence of arrhythmias and dyshaemoglobinemias (e.g., meth-haemoglobinemia). Other factors interfering with photo detection of absorbed wavelengths include ambient lightening, and nail-polish. Factors that are known to cause shifts in the oxy-haemoglobin dissociation curve, such as pH and temperature, can confound the results. Also, pulse oximetry cannot determine the adequacy of ventilation, and should not be used as a measure of the same.

Therefore, failure of health professionals to acknowledge the broader picture while interpreting the results can result in inappropriate decisions and compromised patient safety. It is imperative for clinicians to have understanding of the basic principles and technicalities of pulse oximetry functioning and conditions that can affect its readings [6].

Data on Indian healthcare professionals' knowledge of pulse oximetry is scarce in published literature. The objective of this survey was to assess competency in pulse oximetry among the residents and nursing personnel at a tertiary care setup, for the purpose of patient safety and care improvement.

MATERIALS AND METHODS

Study setting: The study was conducted at a tertiary care teaching hospital in Gujarat. There is an approximate total of 350 nursing personnel and 120 residents at the hospital.

Study design and study tools: This was a questionnaire survey of residents and nursing personnel of the hospital, which was conducted over a period of two months during January-February 2016. Consent was taken from all study participants.

The questionnnaire was similar to the ones used in previous studies. The objective was to generate comparable data [7-15]. The questionnaire used was detailed, covering several topics that included: the basic mechanisms and technicalities of pulse oximetry (how it works, what it measures, how measurements should be interpreted), and common fallacies of interpretation (conditions affecting the accuracy and reliability of its measurements, device limitations). Based on these topics, 34 questions were formulated. Out of these 34 questions, 26 were "True/False" type and 8 were "Multiple Choice" type questions. Close-ended questions were used to increase the response rate. The "Multiple Choice" questions were added to better assess the knowledge of participants while maintaining the ease of applicability of the questionnaire. Pilot testing of the questionnaire was performed on 10 study subjects randomly selected from the study population. Data regarding ICU experience, work and training was also collected from the study population.

Data collection and analysis: Data were entered into the Android mobile devices of the investigators, using the Magpie (Datadyne) application, and later uploaded onto a server website on a daily basis. Authors approached 189 nurses and 120 residents and no one declined. There were no exclusion criteria and all were eligible to be included. However many could not take the survey as the survey had to be entered on the investigators device and hence fewer completed due to issues of scheduling compatibility between investigator and participant. It was ensured that none of the respondents skipped any questions, by making all questions mandatory to answer in the Magpie application. The services provided by the server website were free of charge. The data collected onto the server had restricted access and was password-protected. Due care were taken to prevent data loss or errors in data entry.

Ethical approval for the survey was taken from the Human Research Ethics Committee, HM Patel Centre for Medical Care and Education, Karamsad, Anand, Gujarat, India.

STATISTICAL ANALYSIS

The data were transcribed to Microsoft Office Excel 2010 and then imported to SPSS version 14.0 for validation, cleaning, and subsequent analysis and descriptive statistics were performed. Univariate analysis was done between the two groups for each question. Student's t-test was used for group analysis on the basis of experience, training and clinical department.

RESULTS

A total of 264 subjects participated in the study-155 nursing personnel and 109 residents. The number of correct responses was low overall, with a mean (SD;CI) of 13.76 (2.56; 13.45-14.07) out of 26 for the “true/false” questions; and a mean (SD;CI) of 3.27 (1.57; 3.08-3.56) out of 8 for the “multiple choice” questions. Even so, there was significant difference in the scores of nurses and residents ($p<0.001$). The question-wise response rate is given in [Table/Fig-1a,b]. Sample characteristics are given in [Table/Fig-2].

Only a few nurses and residents had received any sort of formal training (lectures/equipment training); n=30. However, there were no significant difference in overall knowledge between the two groups ($p=0.6124$). There was also no significant difference between the knowledge of participants with more than one year work experience in an acute care setting and the knowledge of participants with less than one year acute care work experience ($p=0.1342$). In a sub-group analysis, the nursing personnel were divided into two groups -those working in an ICU and those not working in an ICU setup. There was no significant difference in the correct response rate between the two groups ($p=0.42$) [Table/Fig-3]. There was difference when True/False and MCQs are independently compared but the difference disappeared when the score was checked as a whole. This results from the fact that the trained personnel scored higher on True/False questions but lower on MCQs. The reasons for this were unclear and possibly due to higher cognitive processing required for MCQs. Residents were not divided as almost everyone

True and False Questions	Staff Nurse (n=155)	Residents (n=109)	p-value
1. Pulse oximetry has been found to be accurate for oxygen saturation between 70-100%	140 (90.32%)	106 (97.25%)	0.028
2. Pulse oximetry is used for rapid detection of tissue hypoxia	46 (29.68%)	28 (25.69%)	0.477
3. Clinical assessment alone has been shown to be as effective as pulse oximetry monitoring in the detection of hypoxemia	45 (29.03%)	56 (51.38%)	<0.001
4. Pulse oximetry may be unreliable in severely anaemic patients	77 (49.68%)	55 (50.46%)	0.901
5. During vasoconstriction, sensor placement on finger nail provides more accurate reading than its placement on central sites (ear, nose)	42 (27.10%)	21 (19.27%)	0.142
6. Coloured nail polish and synthetic nails do not affect the accuracy of pulse oximetry readings	72 (46.45%)	66 (60.55%)	0.024
7. Pulse oximetry readings are less accurate when the patient is moving	106 (68.39%)	91 (83.49%)	0.006
8. An oxygen saturation value of 90% provided by pulse oximetry corresponds to a partial oxygen pressure in arterial blood of 90 mmHg	41 (26.45%)	87 (79.82%)	<0.001
9. Oxygen saturation values provided by pulse oximetry are equally accurate to those provided by the analysis of arterial blood gases	38 (24.52%)	41 (37.61%)	0.022
10. Accurate pulse oximetry readings are more difficult to obtain when peripheral perfusion is poor	104 (67.10%)	87 (79.82%)	0.023
11. Pulse oximetry readings are usually not affected by body position or ambient light	57 (36.77%)	56 (51.38%)	0.018
12. Patients are at increased risk for desaturation during invasive procedures	98 (63.23%)	95 (87.16%)	<0.001
13. Pulse oximetry is not an indicator of adequacy of ventilation	80 (51.61%)	72 (66.06%)	0.019
14. Pulse oximetry provides real time readings when the sensor is placed on the fingernail	106 (68.39%)	77 (70.64%)	0.696
15. Use of pulse oximetry is strongly recommended during cardiopulmonary resuscitation	34 (21.94%)	10 (9.17%)	0.006
16. Use of pulse oximetry is strongly recommended when the patient is on supplemental oxygen	123 (79.35%)	101 (92.66%)	0.003
17. The majority of pulse oximetry alarms are correct	58 (37.42%)	79 (72.48%)	<0.001
18. Conventional pulse oximetry is based on the absorption of red and infrared light by blood	87 (56.13%)	70 (64.22%)	0.187
19. Pulse oximetry sensor is highly sensitive to mechanical damage	106 (68.39%)	88 (80.73%)	0.025
20. Pulse oximetry readings are not affected by smoke inhalation	55 (35.48%)	74 (67.89%)	<0.001
21. The probe should be first attached to the neonate and then to the oximeter	48 (30.97%)	29 (26.61%)	0.443
22. Pulse oximetry should be used for monitoring hyperoxaemia in premature neonates	100 (64.52%)	46 (42.20%)	<0.001
23. 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	109 (70.32%)	71 (65.14%)	0.373
24. Pulse oximetry sensors should be applied at the level of the patients heart because pulse oximetry readings may be lower in dependent extremities	69 (44.52%)	52 (47.71%)	0.609
25. In older (>4 years) children who are receiving vasoactive medications, changes in oxygenation are more accurately detected by pulse oximetry than by any other non invasive method	99 (63.87%)	46 (42.20%)	<0.001
26. Pulse oximetry is useful to assess adequacy of ventilation	55 (35.48%)	36 (33.03%)	0.679
Total Score {Mean (SD)}	12.87 (0.18)	15.04 (0.22)	<0.001

[Table/Fig-1(a)]: Correct response rate in “True/False” questions.

Multiple Choice Questions	Staff Nurse (n=155)	Residents (n=109)	p-value
27. The pulse oximeter measures	10 (6.45%)	73 (66.97%)	<0.001
28. Which of the following corresponds to a greater decrease in PaO_2?	30 (19.35%)	69 (63.30%)	<0.001
29. A healthy patient is under general anaesthesia on 100% oxygen. Approximately how much time would pass between the onset of apnea and a change in your pulse oximeter reading	86 (55.48%)	60 (55.05%)	0.944
30. Normal saturation for a 18-year-old is described in which one of the following ranges	91 (58.71%)	86 (78.90%)	0.001
31. A 9-month-old infant with broncholitis has been stable with an O_2 saturation of 97% on 35% FiO_2. You are notified that the O_2 saturation has dropped to 88%. On the cardiorespiratory monitor his heart rate is 140 beats/minute and the respiratory rate is 60 breaths/minute. The pulse oximeter reading shows an O_2 saturation of 88% and a heart rate of 110/minute. The first thing you would do is	78 (50.32%)	31 (28.44%)	< 0.001
32. Which of the following may affect the ability of a pulse oximeter to obtain a reading	15 (9.68%)	7 (6.42%)	0.346
33. An oxygen saturation of 90%, under normal metabolic conditions, will correspond to PaO_2 of approximately	12 (7.74%)	63 (57.80%)	<0.001
34. Which of the following (if any) statements is true about oximeter probes	99 (63.87%)	55 (50.46%)	0.030
Total Score {Mean (SD)}	2.71 (0.09)	4.07 (0.16)	<0.001

[Table/Fig-1b]: Correct response rate in "Multiple choice" questions.
Studies consulted for preparation of questionnaire - Kiekkas P et al., Seeley MC et al., Milutinović D et al., Faponle AF et al., Rodriguez LR et al., Teoh L et al., Popovich DM et al., Giuliano KK et al., WHO manual [7-15]

Characteristics	Observations
Gender	
Male	79
Female	185
Training	
Yes	30
No	234
Nurses	155
Junior doctors	109
Experience	
<1 year in critical care	77
>1 year in critical care	187
Clinical department (nurses)	
ICU	69
Non ICU	86

[Table/Fig-2]: Sample characteristics.

Training details	Number (n)	Mean score	Std. Deviation	p-value
True/false" questions				
Formal training	30	15	2.27	0.005
No training	234	13.6	2.56	
Multiple choice" questions				
Formal training	30	2.33	1.74	0.0004
No training	234	3.39	1.51	
Overall				
Formal training	30	17.33	2.61	0.61
No training	234	17.00	3.37	

[Table/Fig-3]: Impact of training on pulse oximetry competence.

has exposure to emergency and/or ICU setup and hence they were not divided into groups.

DISCUSSION

The present study demonstrates a limited understanding of pulse oximetry amongst both residents and nurses. This has been reflected in a number of previous studies. A review of 14 studies assessing clinicians' knowledge of pulse oximetry demonstrated poor understanding in 13 of the included studies [16]. All studies used convenience sampling and had a wide range of sample sizes. These studies sampled nursing professionals, respiratory therapists and physicians.

The overall mean score in the Kiekkas P et al., study, using a similar questionnaire, was 12.8 out of 21; however, this study only assessed the knowledge of nurses [7]. A study by Seeley MC et al., which used the "True/False" questionnaire from the Kiekkas P study and scenario-based "Multiple Choice" questions, reported a mean knowledge score of 11.64 in the "True/False" group [8]. In another recent study, participants had a median score of 12 (out of 22) [9]. These values are similar to those seen in present study.

The commonly proposed reason for these low correct response rates is lack of training [10,11]. However, there was no overall difference observed in knowledge between groups that received formal training and groups that did not. On further analysis, it was found that the in the "True/False" question group, which had more questions on theoretical knowledge, the formal training group fared significantly better. In the "multiple choice" questions group, which had more scenario based/practical questions, the other group fared better, which was unexpected [Table/Fig-3]. A few recent studies, by Teoh L et al., Popovich DM et al., and Davies G et al., suggested that having good knowledge of pulse oximetry did not imply competent application and interpretation in clinical scenarios [12,13,17]. Another study by Attin M et al., proposed an educational initiative to improve knowledge of pulse oximetry among nurses, physicians and respiratory therapists [18]. Education was provided in the form of posters, newsletters, staff meetings and conferences. The educational intervention was successful, demonstrated by an increase in correct response rate from 66% to 82% ($p<0.01$).

There was no significant difference in the correct response rate when comparing groups with <1 year experience and >1 year experience in an acute care setting; the same can be stated regarding nurses working in an ICU versus those working in a non-ICU setting. A 2006 literature review by Elliot M et al., stated that a majority of the studies reported poor knowledge among clinicians, irrespective of their clinical area of employment or years of experience [16]. Of the included studies, just one study by Giuliano KK and Liu LM, demonstrated that critical care nurses had better knowledge than clinicians. However, the study sample comprised of specialist nurses with over 15 years of experience in critical care. The study by Kiekkas P et al., using a questionnaire similar to the one used in present study, demonstrated that ICU nurses had a better knowledge score than emergency department and anaesthesia department nurses [7]. In addition to these, there are studies by Faponle AF and Erhabor G, Davies G et al., and Harper JP which have surveyed nurses with an average of 12-years experience, and consultant grade medical professionals, and have demonstrated poor correct response rates [10,17,19]. These wide variations may be explained by the fact that appropriate use and interpretation of pulse oximetry requires both, an adequate knowledge of respiratory physiology and how pulse oximetry works; and the clinical skills that come with experience.

A majority of the "true/false" questions with low correct response rates were similar in both groups (nurses and residents). These were question numbers 2,5,15,21 and 26.

Inadequate knowledge regarding the principles of pulse oximetry, such as whether it measures tissue hypoxia and ventilation, was observed in both groups. Many studies evaluating knowledge of pulse oximetry in nurses and physicians have reported similar deficiencies [7,18,19]. Most of these studies showed poor understanding of healthcare workers of the fact that pulse oximeter does not measure adequacy of ventilation (around 50%). This is, however, marginally better than our experience. Another recent survey reported a lower correct response rate, 38.9%, for the same question [9].

Interestingly, in this study 74.3% of resident doctors falsely believed that pulse oximetry measures tissue hypoxia; and 66.7% also correctly believed that pulse oximetry measures the percentage of haemoglobin saturated with oxygen. This may reflect confusion between the two different terminologies, "hypoxia" and "hypoxemia". Similar findings were also observed by Milutinović D et al., [9].

Most were wrong about the correct attachment of probe during neonatal resuscitation; this is understandable, since just 40 out of 264 participants belonged to the Paediatrics department and just 11 amongst these 40 had exclusive work experience in the Neonatal Intensive Care Unit.

Another question which was poorly answered in this study was regarding placement of pulse oximetry probe on fingernail as compared to central sites during vasoconstriction. Milutinović D et al., study had a correct response rate of 34%, which is slightly higher than the rate observed in present study [9]. However, in the studies by Kiekkas P et al., and Seeley MC et al., the correct response rates were high: 69.1% and 71.8%, respectively [7,8].

In pulse oximetry there is a response delay as the result of signal averaging and this can range from 8-90 seconds, depending on the site of probe placement and type of pulse oximetry [20]. Previous studies have showed poor knowledge of the respondents of this fact [7-9]. Interestingly, in this study a much higher correct response rate was observed.

A particular question regarding the requirement of pulse oximetry during cardiopulmonary resuscitation was poorly answered in this study and in others. The rates of correct responses were 38.1%, 41.1% and 11.1% in few previous studies [7-9]. This implies a misconception among health professionals that pulse oximetry is strongly recommended during cardiopulmonary resuscitation; however, the authors feel that the framing of the question is a culprit here, and may even reflect the correct belief that pulse oximetry is essential after return of spontaneous circulation.

In the "multiple choice" section, a poorly answered question common to both groups was whether dark skin colour, motion or both affect pulse oximeter reading. As per the WHO manual, dark skin colour does not affect pulse oximeter readings, and the authors have considered it as the gold standard for now [15]. However, there is some published literature suggesting that pulse oximeters are specifically calibrated for lightly skinned individuals, and that, in low saturation states, they can overestimate the oxygen saturation in dark skinned individuals [21].

There was a huge disparity in the correct response rate for some questions ($p<0.001$) between the two groups of nurses and doctors. Although, this was poorly answered by both groups, a significantly less number of nurses believed pulse oximetry to be a better monitor of hypoxia. Before the use of pulse oximetry, physical assessment of skin was considered to be the gold standard for detecting hypoxia. However, studies have shown that central cyanosis is a late indicator of hypoxia, with the requirement that saturation should be below 80% in order to clearly detect hypoxia upon inspection [14].

Questions on the theoretical knowledge of oxygen haemoglobin dissociation (Q8, Q33) were answered significantly better by doctors, as compared to nurses. Interestingly, when disguised in a scenario and asked whether pulse oximetry could be used to monitor hyperoxemia in newborns, the ratio reversed with significantly more nurses than doctors answering correctly (64.52% versus 42.20%). This is another example, which demonstrates that knowledge alone does not lead to clinical competence in pulse oximetry. The sample included many paediatric and neonatal nurses, who were taught, monitor limits as a caution against hyperoxemia, but the junior doctors apart from few Paediatric residents would have been unaware of this fact.

The theoretical knowledge of the nurses in this study was observed to be poor. Due to poor knowledge regarding the oxygen haemoglobin dissociation curve, just 6.45% of the nurses correctly answered that pulse oximetry measures the percentage of haemoglobin saturated with oxygen. In studies by Kiekkas P et al., and Milutinović D et al., 84.5% and 98% of the nurses knew that pulse oximetry measured arterial oxygen saturation, respectively [7,9]. Another question regarding gas exchange physiology, asking whether smoke inhalation affects pulse oximetry readings, was correctly answered by only 35.48% of the nurses. This question had higher correct response rates in previous studies on nursing personnel [7,9].

The various current studies on pulse oximetry show that there is significant variability in the understanding related to its use. Knowledge regarding pulse oximetry was found to be unsatisfactory among junior doctors and nurses, who are the individuals most commonly involved with the monitoring of patients. Deficient areas include factors affecting accuracy, basic principles and knowledge of the oxy-haemoglobin dissociation curve, respiratory physiology and correct clinical application of the same. There were no significant differences on the basis of clinical department (nurses) or experience. Although, formal training also did not show any difference, the sample size was very small.

LIMITATION

We acknowledge following limitations of this study: 1) There were very few questions in the multiple choice section; 2) The sample size of the formal training group was also comparatively small.

CONCLUSION

The consistency of these findings across geographic regions and different kind of healthcare workers and various specialities suggests that the solution may not be uniform. Pulse oximeters have undergone rapid advancements in technology and there may be different generations of oximeters being used in any single institution, which may compound the problem. However, there is uniformity in absence of a standardised training program model for pulse oximeters. It appears that pulse oximeters have slipped into clinical practice without there being sufficient training about it during medical school, nursing school or residency and healthcare workers have learned on the job. Thus, to ensure quality patient care and safety, we recommend the implementation of focused formal short training programs to educate all staff members regarding the principles behind, and correct clinical application of pulse oximetry, with periodic knowledge assessments. The training program needs to take into context the physics of oximeters, the clinical situations the healthcare workers face, the physiology of oxygen transport, the complexity of pulse oximeters in use and other technical issues such as identifying faulty oximeters and replacement of probes, etc.

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PARTICULARS OF CONTRIBUTORS:
1. Professor and Head, Department of Paediatrics, Pramukhswami Medical College, Karamsad, Gujarat, India.
2. Senior Resident, Department of Paediatrics, Pramukhswami Medical College, Karamsad, Gujarat, India.
3. Junior Resident, Department of Paediatrics, Pramukhswami Medical College, Karamsad, Gujarat, India.
4. Professor, Department of Paediatrics, Pramukhswami Medical College, Karamsad, Gujarat, India.
5. Statistician, Department of Central Research Services, Charutar Arogya Mandal, Karamsad, Gujarat, India.
6. Associate Professor, Department of Physiology, Pramukhswami Medical College, Karamsad, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Somashekhar Marutirao Nimbalkar,
Professor and Head, Department of Paediatrics, Pramukhswami Medical College, Karamsad, Anand-388325, Gujarat, India.
E-mail: somu_somu@yahoo.com

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