Do clinicians know how to use pulse oximetry? A literature review and clinical implications

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Abstract

Pulse oximetry has become one of the most commonly used tools in the clinical environment for assessing patients' oxygenation status. It is employed almost continuously in critical care areas and frequently in the general ward environment. Although it is a much better tool for determining hypoxia than the human eye, its use is limited if clinicians do not understand relevant physiological principles, such as the oxyhaemoglobin dissociation curve and the inherent limitations of the device. Furthermore, the risk for compromised patient safety is significant if clinicians fail to recognise the potential for false or erroneous readings.

This paper explores the research which has examined clinicians' comprehension of pulse oximetry. Fourteen studies examining clinicians' knowledge of pulse oximetry were reviewed. These studies revealed significant knowledge deficits about pulse oximetry amongst nurses, doctors and allied health professionals, all of whom used this technology frequently. Alarmingly, those lacking an adequate understanding of pulse oximetry included senior, experienced clinicians. The studies were limited by their use of convenience sampling and small sample sizes. Further research is needed to better understand the significance of this problem and to examine how principles of pulse oximetry are taught to nurses and other health professionals at the undergraduate and postgraduate levels. Educators and clinicians alike must ensure that a safe level of knowledge for the use of pulse oximetry is maintained in order to ensure that patient outcomes are not compromised.

Introduction

Pulse oximetry has become one of the most commonly used tools in the clinical environment for assessing arterial blood oxygenation. It is employed almost continuously in critical care areas and frequently in the general ward environment. The widespread uptake of pulse oximetry reflects the recognised risk of hypoxaemia in hospitalised patients [1].

Invented in Japan in the early 1970s [2], pulse oximetry has been described as the greatest advance in patient monitoring since the invention of the electrocardiogram [3] and has been referred to as the "fifth vital sign" for both adult and paediatric patients [4, 5]. A great advantage of pulse oximetry is its ability to rapidly detect changes in oxygen saturation, potentially identifying problems before the patient becomes compromised [6]. Furthermore, it is cost effective [7, 8, 9] and has been shown to reduce the need for arterial blood gas analysis [10, 11].

Seemingly easy to use, pulse oximetry is a non-invasive method of measuring peripheral arterial oxygen saturation (SpO_2) via an externally applied infrared probe. An accurate measurement is dependent on two factors – the generation of an arterial pulsatile signal and the differing absorption spectra of oxyhaemoglobin and deoxyhaemoglobin [12]. The calculated parameter SpO_2 reflects the amount of oxygen being carried by haemoglobin compared to the maximum amount of oxygen that haemoglobin can carry [13].

In order to correctly interpret a reading, knowledge of several other factors is required. These include respiratory anatomy and physiology, oxygen transport and the oxyhaemoglobin dissociation curve. This curve explains the non-linear relationship between SpO_2 and PaO_2 (partial pressure of arterial oxygen) [14]. PaO_2 is a measurement of oxygen that has diffused across the alveolar-capillary membrane and is dissolved in the blood. Most of the oxygen that enters the blood moves rapidly through the plasma as dissolved oxygen, entering the red blood cells where it chemically binds to haemoglobin and is measured as SpO_2 [15]. The sigmoid shape of the oxyhaemoglobin curve reflects the cooperative binding and releasing of oxygen and haemoglobin [16].

Understanding the physiology represented by the curve is important because certain clinical conditions can affect the relationship between PaO_2 and SpO_2. For example, if a patient has an abnormally high pH or low body temperature, the curve may shift to the left, resulting in a much higher than expected SpO_2 for a given PaO_2 because, under these conditions, oxygen is less likely to be released to the tissues [17]. In this situation, the patient may actually be hypoxic, despite having an oxygen saturation within normal range.

As with any monitoring system, pulse oximetry has a number of limitations. It is inaccurate in low perfusion states, when

dyshaemoglobins or arrhythmias are present and when the patient is moving ('motion artifact'). Additionally, it does not provide information to indicate the patient's haemoglobin level, efficiency of oxygen delivery or adequacy of ventilation [18]. Such limitations are particularly relevant in the intensive care (ICU) setting where the oxygenation status of critically ill patients is likely to be compromised by at least one or more of these variables.

Casey [19] stated that "it can be difficult for nurses to critically evaluate information given by the pulse oximeter if they do not have sufficient knowledge of the physiology associated with oxygen transport and delivery in the body". The risks associated with knowledge deficits are not limited to the nursing profession as pulse oximetry is also a routine component of patient assessment for medical and many allied health clinicians. Whilst the measurement of patients' oxygen saturation seems quite simple, in reality the correct interpretation of the results is much more complicated. Failure by any clinician to appreciate the broader clinical picture or identify factors that can result in false high or low readings could lead to a significant risk for compromised patient safety, management and outcomes.

Aim

A literature review of studies examining clinicians' knowledge of this technology was performed to explore whether nurses and other health care professionals had an adequate level of knowledge to safely use pulse oximetry in the ICU and other hospital settings. The aim of the review was to critically analyse published research which has examined clinicians' knowledge of pulse oximetry, and to make recommendations for clinical practice, education and future research based on the findings. It is anticipated that the insight generated by this review will stimulate debate and critique about how pulse oximetry is taught and used at the bedside by clinicians. It should also prompt clinicians to question their own knowledge and use of pulse oximetry.

Methods

A number of databases were used to locate studies which specifically explored clinicians' knowledge of pulse oximetry. These databases were Medline (1966-present), Cumulative Index of Nursing and Allied Health Literature (CINAHL) (1982-present), Current Contents, Database of Abstracts of Reviews of Effectiveness (DARE), PsychINFO and the Cochrane Library. The following search terms were used in combination: pulse AND oximetry; oxygen AND saturation; respiratory assessment AND support; monitoring; knowledge OR understanding OR comprehension.

The worldwide web was also used as a source of data using the above search terms in three popular search engines (yahoo.com, googlescholar.com, askjeeves.com). This was to identify studies not published in traditional sources (i.e. 'grey literature'). Further studies were also identified by hand searching relevant journals and from the reference lists of published studies. The inclusion criterion was any study whose primary aim was to examine clinicians' knowledge or understanding of pulse oximetry. Studies were included irrespective of the methodology employed. This was to ensure that a comprehensive understanding of clinicians' knowledge of pulse oximetry was achieved. The search yielded no other published systematic or literature reviews on the topic. Articles were excluded if they were not published in the English language or if they did not address the specific topic of the review. As pulse oximetry has only been used clinically for the past 2 decades, year of publication was not an exclusion criterion. No studies were subsequently excluded.

The methodological quality of each study was critically evaluated using recommended guidelines described by Burns & Grove [20], Heermann & Craft [21] and Polit & Beck [22]. These guidelines informed a structured examination of the credibility, accuracy, meaning and importance of the results. The most common limitations identified were small sample sizes, failing to describe how the reliability or validity of the survey tool used was verified, and the use of convenience samples. Although a number of studies contained limitations, none were deemed significant enough to warrant exclusion in view of the small number and scale of studies available.

Results

The search strategies identified a total of 14 studies conducted since 1994 which specifically investigated clinicians' knowledge of pulse oximetry.

Design

All of the identified studies used a prospective design. Questionnaires were the primary survey tool used, which consisted of either multiple choice or short answer questions and case studies. Some of these were designed by the actual researchers, whilst others were used with permission of the original authors.

Population

The populations studied were clinicians employed in general hospitals. Participants included nurses, doctors and other allied health professionals (e.g. anaesthetic technicians, respiratory therapists), though not all studies included all three groups. Participants varied in experience from as little as 1 year postgraduate to more than 20 years (e.g. consultant medical officers). They were employed in a variety of clinical environments including ICUs, specialised areas such as operating theatres and general medical wards.

Findings

Overall, the literature revealed that the majority of clinicians had a poor understanding of how pulse oximetry worked (Table 1). Only 26% of the paediatric nurses and 60% of the medical residents surveyed by Popovich *et al.* [24] demonstrated an understanding of the principles behind oximetry. Similarly, only 29% of the doctors and nurses surveyed by Davies *et al.* [26] and 48% of those surveyed by Faponle & Erhabor [29] understood oximetry. Bilgin *et al.* [30] found that only 14% of doctors and ICU nurses were aware of the key principles of oximetry, whilst in Kruger & Longden's [33] study, only 18% of doctors and 0.6% of nurses correctly answered three questions about how oximetry worked. Stoneham *et al.* [35] found that only 3% of doctors and nurses knew that pulsatile blood flow is required, whilst 32% of the nurses surveyed by Harper [25] thought an oximeter measured absorption of electrical waves by haemoglobin.

Clinicians also lacked knowledge about what a pulse oximeter actually measures. Rodriguez *et al.* [34] found that 43% of the paediatric doctors surveyed could not indicate what an oximeter measured, whilst 40% of the registered nurses in Howell's [18] study thought it measured venous oxygenation. In Harper's [25] study, 42% of nurses thought oximetry was a reliable indicator of ventilation, with 21% believing that SpO_2 and PaO_2 were the same parameter. Stoneham *et al.* [35] found that 30% of doctors and 93% of nurses could not correctly indicate what a pulse oximeter measured; of their study population, 7% of nurses and 10% of doctors believed that it measured respiratory rate or tidal volume. In Attin *et al.*'s [28] study, only 34% of nurses and 39% of doctors could correctly indicate what parameter is measured by an oximeter.

Table 1. Summary of identified studies.

Author(s)	Year	Country	Design	Sample	Main findings
Giuliano & Liu [23]	2006	USA	7 item questionnaire	551 experienced critical care nurses	• 86% knew that poor perfusion affected the accuracy of readings • 63% knew that readings are less likely to be accurate during patient motion • 70% knew that oximetry should not replace arterial blood gas analysis
Popovich *et al.* [24]	2004	USA	19 item questionnaire	42 registered nurses, 15 physicians, 9 respiratory technicians/therapists	• 26% of nurses and 60% of medical residents knew how an oximeter worked • Majority of participants had a poor understanding of the oxyhaemoglobin dissociation curve
Harper [25]	2004	USA	32 item questionnaire	19 nurses employed in post-anaesthesia care units	• 21% of participants thought SpO_2 and PaO_2 reflected the same parameter • 42% thought SpO_2 was a reliable indicator of ventilation status • 42% thought a false low SpO_2 reading may occur in smokers
Davies *et al.* [26]	2003	New Zealand	Questionnaire	34 doctors and 29 nurses from general medical, respiratory and emergency wards	• 29% did not know how an oximeter worked • Most failed to recognise an acutely ill hypoxic child who required intubation
Teoh *et al.* [27]	2003	Australia	16 item multiple choice questionnaire	74 'senior' doctors (>10 years' experience) and 47 'junior' doctors (<5 years' experience) employed in paediatrics	• 8% correctly answered three questions about the oxyhaemoglobin dissociation curve • 36% correctly answered three questions about the accuracy and limitations of oximetry
Howell [18]	2002	UK	Questionnaire of true/false statements	8 doctors, 30 registered nurses, 12 'untrained' nurses	• 57% of registered nurses and 63% of doctors knew how an oximeter worked • 40% identified a false high SpO_2 reading in a patient who was cyanotic
Attin *et al.* [28]	2002	USA	17 item true/false questionnaire	331 registered nurses, 82 doctors, 29 respiratory therapists	• 34% of nurses and 39% of doctors could indicate what parameter was measured by pulse oximetry
Faponle & Erhabor [29]	2002	Nigeria	Questionnaire (adapted from Kruger & Longden [33])	25 doctors, nurses and medical students	• Participants' responses reflected a poor understanding of the principles of oximetry • 28% claimed to have received training in the use of oximetry
Bilgin *et al.* [30]	2000	Turkey	17 item multiple choice questionnaire	44 nurses and 12 junior doctors employed in an ICU	• Majority did not understand the relationship between PaO_2 and SpO_2 • 19% knew the normal SpO_2 range for adults • 14% understood the technological principles of oximetry
Alshehri [31]	2000	Saudi Arabia	16 item multiple choice questionnaire	106 nurses, interns and residents	• 51% of participants did not know what a pulse oximeter measured • 53% did not know that motion might affect the accuracy of an oximetry reading • 22% of participants answered all three questions about the oxyhaemoglobin dissociation curve correctly
Kyriacou [32]	1998	UK	7 item questionnaire	13 senior doctors and 4 nurses employed in an endoscopy unit	• No participant answered all seven questions correctly • Limited knowledge of factors influencing oximetry readings
Kruger & Longden [33]	1996	Australia	14 item questionnaire	33 doctors, 164 nurses, 6 anaesthetic technicians employed in various clinical areas	• 60% identified the normal SpO_2 range for adults • 88% were not aware of physiology relevant to the oxyhaemoglobin dissociation curve
Rodriguez *et al.* [34]	1994	USA	16 item multiple choice questionnaire	134 junior doctors employed in paediatric hospitals	• 43% did not know what an oximeter measured • 39% did not know that poor perfusion affected the accuracy of readings • 37% did not know the normal saturation for a newborn
Stoneham *et al.* [35]	1994	UK	Structured questionnaire	30 nurses and 30 junior doctors from general medical or surgical wards	• 30% of doctors and 93% of nurses thought an oximeter measured partial pressure of O_2 • 10% of doctors and 7% of nurses thought an oximeter measured respiratory rate or tidal volume • 1 doctor and 1 nurse (3%) knew than an oximeter required pulsatile blood flow

Knowledge about specific factors that can influence the accuracy of a pulse oximeter was examined in a number of studies. Howell [18] reported a mere 14% of doctors and nurses knew that an oximeter alarms when pulsatile flow is lost. Only 17% of the nurses and 27% of the doctors in Popovich *et al.*'s [24] study were aware of this. Stoneham *et al.*'s [35] study had similar findings. Howell [18] found that only 40% of nurses and 50% of doctors knew that arrhythmias may affect the quality of a reading. This was understood by 30% of the doctors and 54% of the nurses in Faponle & Erhabor's [29] research. Rodriguez *et al.* [34] found that only 39% of paediatric doctors knew that shock may affect the accuracy of an oximeter's readings, whilst 45% of the participants in Alshehri's [31] study knew this. The influence of factors such as nail polish [3, 18, 24, 27], patient movement [3, 27], shivering [18] and ambient light [28] were also poorly understood. Interestingly, the majority (86%) of the experienced critical care nurses in Giuliano & Liu's [23] study knew that poor perfusion affected the reading, that readings are less accurate during movement (63%) and that oximetry should not replace arterial blood gas analysis (70%).

Significant knowledge deficits were also found in relation to the oxyhaemoglobin dissociation curve. In Popovich *et al.*'s [24] study, the physiology represented by the curve was understood by only 5% of nurses and 47% of doctors. Teoh *et al.* [27] also found that medical staff had a poor understanding of the curve, particularly the correlation between SpO_2 and PaO_2. Similarly, only 45% of the doctors and less than 2% of the nurses in Kruger & Longden's [33] study understood this relationship. Rodriguez *et al.* [34] found that only 17% of paediatric house officers could answer three questions correctly about the curve, whilst in Alshehiri's [31] study only 22% of doctors and nurses could do so.

There was a widespread belief (43-72%) among clinicians that they had not received adequate training in pulse oximetry [29, 31, 34]. When evaluating knowledge levels of registered nurses, doctors and respiratory therapists, Attin *et al.* [28] were able to demonstrate an improvement in knowledge levels after the implementation of an educational programme on pulse oximetry. Before receiving targeted education, 66% of participants correctly answered knowledge-based questions. Following implementation of an educational programme on pulse oximetry, the number of correct responses increased to 82% for the whole group ($p=0.01$).

Discussion

Fourteen studies which examined clinicians' knowledge of pulse oximetry were reviewed. All of these studies used convenience sampling and a wide range of sample sizes; the findings of this review need to be interpreted with this in mind. All but one of the 14 studies suggested that regardless of their role, years of experience or the clinical area of employment, many clinicians have a poor understanding of pulse oximetry. This could be primarily attributed to a lack of training on the use of oximetry reported by many of the clinicians studied [29, 31, 34].

Despite the availability of oximetry, physicians frequently failed to appreciate the significance of decreased SpO_2 values in many patients [36]. This is consistent with the main findings of this review. Schroeder *et al.* [37] concluded that some infants have a prolonged period of hospitalisation due to a perceived need for supplemental oxygen based on oximetry readings. Further to this, Mallory *et al.* [38] suggested that the increased reliance upon oximetry has contributed to the increase in bronchiolitis hospitalisation rates seen in the last 2 decades, where a more thorough assessment may reveal that hospitalisation is actually not necessary. These findings obviously have significant implications not just for the patient, but also the health care budget.

It is worth exploring the results of one particular study in depth, as the results are inconsistent with the findings of all the other studies reviewed. The study conducted by Guiliano & Liu [23] suggested that critical care nurses have an increased level of knowledge of pulse oximetry compared with other samples. There were, however, some significant differences in their sample which may provide some reasons for this.

Firstly, the sample in this study [23] were specialist nurses with an average of 15 years of experience in critical care. It could be argued that they were more likely to have a thorough understanding of pulse oximetry than a nurse who has just commenced employment in critical care, particularly because pulse oximetry is one of the tools critical care nurses rely heavily upon to assess their patients. This is however, directly contradicted by Harper's [25] survey of nurses working in post-anaesthesia care units where there is also a heavy reliance on pulse oximetry. The nurses in his study had an average of 9.5 years of experience in the discipline and 44% had a bachelor's degree, yet they still demonstrated a significant knowledge deficit.

Secondly, the nurses in Guiliano & Liu's [23] study were attending a conference at the American Association of Critical Care Nurses National Teaching Institute. This indicates that these nurses were interested in educating themselves and being 'professionally active'. Whilst this assumption could not be generalised to all critical care nurses, it could be suggested that the nurses in the sample were more likely to seek out new knowledge or educational opportunities. This theory is supported by the fact that more than half of the nurses reported reading one to two professional critical care journals each month. Furthermore, nearly half of the nurses had a bachelor's degree, a significant number (20%) had a Master's degree and half of the nurses in the sample held a critical care registered nurse certificate. The sample is therefore biased towards experienced, qualified critical care nurses, making it difficult to generalise the findings to all nurses who work in a critical care setting. Finally, this study had the largest sample size of those reviewed (n=551), which could suggest that, with larger sample sizes, the other studies may have yielded different results.

The findings of this review challenge the commonly held belief that 'experience is everything'. Many of the participants in these studies were very experienced, yet had significant knowledge deficits. The nurses in Harper's [25] study for example, had an average of 13 years' experience using pulse oximetry, whilst the studies of Faponle & Erhabor [29] and Davies *et al.* [26] included consultant medical staff. If regular use of, or 'exposure' to equipment does not result in competency in its use, then the question must be asked – do undergraduate and postgraduate courses provide adequate education for clinicians to safely use pulse oximetry?

Kenward *et al.* [39] argued that there is a need for greater emphasis in pre-registration courses on the significance of changes in vital signs. Harrison *et al.* [40] supported this argument based on their study of 101 final year medical undergraduates. The majority of these students felt competent in providing basic life support, but lacked confidence in their ability to manage many clinical conditions such as acute hypoxia. Smith & Poplett [41] found similar results amongst a group of trainee doctors. Only 51% of pre-registration house officers and 69% of senior house officers in their study identified the normal range of oxygen saturation. Furthermore, 41 of the 108 trainees provided ranges or values for oxygen saturation which bore no relation to any recognisable normal range.

If a lack of formal training is the reason for clinicians' lack of knowledge of oximetry, it should not be regarded as 'justification' for it, as clinicians are expected to be accountable for the care they provide in order to uphold a duty of care. Wichowski & Kubsch [42] found that many nurses felt embarrassed, scared and unprofessional if they could not operate equipment in an expert manner. Whether these feelings prompted them to seek out knowledge is not known. If clinicians lack knowledge about the equipment or tools they are using, they should seek information from colleagues or other recognised resources. This is particularly important in view of the demonstrated benefit of education in at least one sample [28].

Limitations

The studies in this review have a number of limitations and their findings need to be interpreted in light of these. Firstly, the studies had varying sample sizes, the smallest being 17 [32] and 19 [25] participants. In general, the larger the sample, the better the accuracy of results, as larger samples tend to produce less error [43]. If the studies had larger sample sizes, their findings may have been different.

All of the studies in this review used convenience samples. Convenience sampling is arguably the most frequently used sampling method in nursing research [44] and, while there may be pragmatic reasons for this, the risk of sample bias cannot be ignored. Caution is needed when interpreting findings and generalising results derived from convenience samples [22].

A questionnaire was used to obtain data in all of the studies reviewed. Questionnaires have the benefit of being quick to administer and less expensive than other methods [22], but they need to be tested for reliability and validity to ensure the quality and credibility of the data. Reliable instruments enhance the power of a study to detect significant differences or relationships actually occurring in the population under study [20]. If the data are suspect, then the results are also suspect [45]. Fewer than half of the published studies commented on the reliability or content validity of the questionnaire used or whether it was pilot tested.

Implications

The research available has clearly established that there is a significant knowledge deficit regarding the accurate use and interpretation of pulse oximetry among clinicians, many of whom reported receiving little education regarding its use. If clinicians' understanding of oximetry is poor, they may be unable to determine false high or low oxygen saturation readings. Whilst treating a false low reading may have relatively insignificant consequences for the patient, failing to recognise and thus treat a false high reading may dramatically affect the patient's outcome and, at worst, cause direct harm. A number of the cited studies recommended that clinicians be given comprehensive training before using an oximeter. It is also vital that clinicians are taught and understand the relevant physiological principles that relate to pulse oximetry.

Particular attention should also be paid to the outcomes of educational courses. If a clinician has a tertiary qualification, they are deemed to have a certain level of knowledge and competence. They are also likely to be a resource for their less-experienced colleagues. Assessment procedures in educational courses need to be rigorous enough to ensure that those who obtain a qualification have the knowledge and skills to practise safely. For example, a nurse who has completed a critical care course should have a thorough comprehension of the principles governing the use and limitations of pulse oximetry. The authors acknowledge that it is virtually impossible to assess each and every learning outcome or content area of an educational course. However, the widespread reliance upon pulse oximetry to measure a basic vital sign surely warrants comprehensive training and assessment.

Understanding the relevant physiological principles that influence pulse oximetry is particularly crucial in the ICU setting where critically ill patients often have derangements such as abnormal pH or body temperature that can alter SpO_2 readings. It is essential that ICU nurses, who rely upon oximetry as a continuous monitor of their patients' oxygenation, can distinguish between false high and low readings. Failure to do so could seriously compromise patient management and safety.

The results of this review also point to a need for clinicians to be more vigilant in assessing their own knowledge deficits and learning needs. Bergman [46] stated that medical students and residents have come to believe that if information is expressed in digits or a bell rings or lights blink, then the truth is revealed. The same could be said of many nurses who may be 'seduced' by the technology available to them and use it to supplement deficits in their clinical knowledge, skills or confidence. To do so is obviously fraught with danger. Nurses must consider the accuracy and reliability of all technological devices they are using for patient assessment.

Further research which is more rigorous in nature is needed to provide an accurate indication of clinicians' knowledge of pulse oximetry and areas of knowledge deficit. Larger sample sizes using stratified, random sampling and a reliable and valid survey tool would help to provide more useful results than those currently available. Future research needs to examine if or how the concepts of pulse oximetry are taught in professional courses such as nursing and medical degrees. Both the undergraduate and postgraduate areas should be examined, as well as specialist training courses such as those required to become a clinical specialist. Professional bodies which accredit tertiary courses for health professionals (i.e. registration boards) should critically examine how or whether acute care skills and knowledge are addressed in curricula. Aitken *et al.* [47] recently found little consistency in the structure of critical care nursing courses in Australia with regard to the proportion of each course devoted to core, specialty and generic subjects.

Finally, and most importantly, there is a need for research that examines the impact of clinicians' knowledge deficits on patient outcomes. No studies were identified by this review which examined the relationship between clinicians' knowledge of oximetry and patient outcomes. In their review of 281 critical incidents in ICU, however, Buckley *et al.* [48] found that 13% were due to lack of knowledge or using unfamiliar equipment. While there is clearly a risk of compromised patient outcomes if clinicians fail to thoroughly understand pulse oximetry, it has yet to be measured.

Conclusion

Research indicates that clinicians' understanding of pulse oximetry is poor. Knowledge deficits have been found in many areas such as what an oximeter measures, the oxyhaemoglobin dissociation curve and factors affecting the accuracy of readings. The studies reviewed point to a widespread lack of competence in the use of pulse oximetry among nurses, doctors and allied health professionals working in both critical care and acute hospital wards. They also indicate that years of experience or regular exposure to pulse oximetry do not guarantee a sound understanding of its safe application or limitations, although there is limited evidence suggesting knowledge may be improved through education.

Clinicians using pulse oximetry must have a thorough understanding of the technology and relevant physiological principles to ensure that false or erroneous SpO_2 measurements do not incorrectly inform patient management and cause harm. This review highlights a need for more thorough education at the undergraduate and postgraduate level to better equip health care professionals with the knowledge they require to use pulse oximetry competently. It urges clinicians to self-assess their knowledge deficits related to pulse oximetry in order to fulfil professional responsibilities and uphold a duty of care to their patients. It also argues for further, more rigorous research to be conducted so that we may better understand the full extent of this problem. "The first step towards knowledge is to know that we are ignorant"[49].

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