Do nursing textbooks accurately describe pulse oximetry? An audit of current literature

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ABSTRACT

Background: The assessment of a patient's vital signs is a critical nursing task. Despite this, research has found that many nurses have a poor understanding of pulse oximetry. Aim: As undergraduate students rely heavily on textbooks as an educational resource, an audit was conducted of nursing texts to determine the quality of pulse oximetry descriptions. Method: The audit was guided by questions based on the findings of research examining nurses' understanding of pulse oximetry. Two researchers used these questions to appraise textbook content. Findings: A convenience sample of 32 contemporary nursing textbooks was appraised. Text descriptions of pulse oximetry varied from brief to more extensive, with the content ranging from superficial to detailed. Conclusion: Superficial, inconsistent or misleading information within basic nursing textbooks may be one factor associated with nurses' knowledge deficits about pulse oximetry. Academics and nurse educators should appraise core content of textbooks carefully before recommending textbooks to nursing students.

Key words: Pulse oximetry ■ Audit ■ Nursing literature ■ Nurse education

The accurate assessment and interpretation of vital signs is essential for detecting clinical deterioration (Turkington et al, 2014). These vital signs include blood pressure, pulse, respiratory rate, temperature and oxygen saturation. Despite their importance, however, the clinical assessment of these signs is frequently neglected even though most deterioration is detectable in the hours before a serious adverse event (Ludikhuize et al, 2012). The failure to thoroughly assess vital signs may explain why many nurses are often unaware that their patients are deteriorating and why nurses tend to call for assistance relatively late in a crisis (Genardi et al, 2008; De Meester et al, 2013).

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Little research attention has been given to the neglect of vital signs assessment and interpretation (Rose and Clarke, 2010). Possible reasons may include perceived lack of time or education, staffing levels, and nurses' reliance on intuition (Hogan, 2006; Odell et al, 2009; Philip et al, 2013). In one study of 614 general ward nurses, attitudes towards vital signs monitoring were influenced by nurses' qualifications and years of clinical experience (Mok et al, 2015). Of concern is that these nurses had limited understanding of the key indicators of clinical deterioration and were also unaware of their knowledge deficits (Mok et al, 2015).

Peripheral oxygen saturation (SpO_2), one of the key vital signs, is measured via a pulse oximeter. It provides an estimate of arterial oxygen saturation (SaO_2). Oxygen saturation reflects the ratio between the oxygen content of haemoglobin and the potential oxygen-carrying capacity of haemoglobin (Van Leeuwin and Bladh, 2015). A pulse oximeter calculates SpO_2 by shining light of two wavelengths through a tissue bed and comparing the light absorbance of oxyhaemoglobin and deoxyhaemoglobin (Sebald, 1997). This technology has been widely available in clinical practice since the early 1980s and is used to inform patient care and improve outcomes (Milner and Mathews, 2012). As a form of patient monitoring, pulse oximetry has many benefits: it is continuous, non-invasive, gives early warning of hypoxic events, and is superior to clinical judgement (Dolenska, 2006). A recent systematic review therefore found that pulse oximetry significantly reduced the extent of perioperative hypoxaemia and enabled the detection and treatment of hypoxaemia and respiratory-related events (Pederson et al, 2014).

Despite the clinical benefits of pulse oximetry use, significant deficits in clinicians' (doctors, nurses and allied health professionals) understanding of pulse oximetry have been identified (Elliott et al, 2006). Knowledge deficits were related to the principles of pulse oximetry, what a pulse oximeter measures and is used for, factors influencing the accuracy of oximeter readings, and the oxyhaemoglobin dissociation curve. Experienced and inexperienced clinicians demonstrated limited understanding of pulse oximetry and many reported limited or no training in its use (Elliott et al, 2006). Of concern is that similar findings have been demonstrated in more recent research, suggesting that the understanding of pulse oximetry has not

improved over time (Çelik, 2014 et al 2014; Milutinovic et al, 2016). It has therefore been recommended that research focuses on the characteristics of undergraduate or pre-registration nursing education and how different models of theoretical and clinical education influence the transfer of oximetry knowledge to clinical practice (Seeley et al, 2015).

Graduating nursing students represent the workforce of the immediate future. Their clinical knowledge and skills after recent years of intense study should demonstrate the ability to safely deliver high-quality nursing care. Despite this, an Australian study of more than 300 novice nurses identified significant knowledge deficits about pulse oximetry (Seeley et al, 2015). Less than half of these nurses knew that oxygen saturation is not an indicator of adequate ventilation and most incorrectly thought that pulse oximetry is used for the rapid detection of tissue hypoxia (Seeley et al, 2015).

Aim

The factors contributing to graduate nurses' pulse oximetry knowledge deficits are not clear but inadequate education may be an associated factor. It has been suggested that the origin of these knowledge deficits can be identified in deficiencies in undergraduate curricula (Kiekkas et al, 2013). Because undergraduate students rely heavily on textbooks as a key resource for their learning and professional development, an audit was conducted of basic nursing texts to determine the quality of pulse oximetry descriptions. The purpose of the audit was to determine whether these texts are a reliable resource for understanding and using pulse oximetry in the clinical setting.

Method

In order to identify relevant textbooks a search was conducted of the websites of key publishers of nursing texts (Cengage, Elsevier, FA Davis, Lippincott, Pearson, Sage), Google Books, Book Depository and Amazon. The search focused on fundamentals of nursing or clinical nursing skills textbooks. Texts on clinical specialties such as critical care nursing were excluded because they are targeted at experienced nurses who therefore have a level of assumed knowledge. To ensure the search identified contemporary textbooks available to nursing students, it was limited to texts published from 2013 onwards. Once relevant texts were identified, hard copies were requested via inter-library loan or from the publisher. Where possible, the most current edition of texts was reviewed.

The index of texts was scanned to identify content on pulse oximetry, oxygen saturation and the oxyhaemoglobin dissociation curve. The relevant text section was then audited for key content using guiding questions. The questions reflected the findings of research highlighting clinicians' poor understanding of pulse oximetry (for example, Çelik et al, 2014; Seeley et al, 2015; Milutinovic et al, 2016). These studies identified knowledge deficits regarding what a pulse oximeter measures and is used for, factors influencing the accuracy of readings, and the oxyhaemoglobin dissociation curve. Six questions guided the audit:

- How does the text describe what a pulse oximeter measures?
- Is a description of how an oximeter works included?
- How is oxygen saturation defined?
- What information is provided about what an oximeter is used for?
- Does the text include a description of the oxyhaemoglobin dissociation curve?
- Does the text include information about factors affecting the accuracy of readings?

Results

Thirty-two contemporary textbooks on fundamentals of nursing or clinical nursing skills were identified for an audit of content relating to pulse oximetry (see *Table 1*). Textbooks with no pulse oximetry content listed in the index were discarded. The descriptions of pulse oximetry in the audited texts varied from brief to more extensive, with the content ranging from superficial to detailed. There was considerable variation in the descriptions and in the amount of text dedicated to pulse oximetry. Nursing skills texts tended to have briefer descriptions of relevant theory (such as of the oxyhaemoglobin dissociation curve) than theoretically focused books.

What does a pulse oximeter measure?

Based on international guidelines, the expected answer to this question is peripheral oxygen saturation of haemoglobin in arterial blood (World Health Organization (WHO), 2011; Pretto et al, 2014). All texts provided an answer to this question with some common themes. Most commonly, a pulse oximeter was said to measure 'O_2 saturation'; many texts also emphasised arterial blood. However, some texts that mentioned O_2 saturation did not provide a definition of this. Another common answer to this question was merely 'SpO_2', as was 'SaO_2'. A more superficial answer to this question in two texts was 'the amount of O_2 in the blood'.

How does an oximeter work?

Oxygen saturation is estimated by 'measuring the transmission of light through a pulsatile vascular tissue bed' (Al-Shaikh and Stacey, 2019:154). The expected answer to how an oximeter works should refer to a pulse oximeter containing two light-emitting diodes (red and infrared) and a photodetector (Aston et al, 2014). Just over half the reviewed texts provided a relevant description. These descriptions typically stated that a probe emits two light wavelengths that are absorbed by oxygenated and deoxygenated blood (DeLaune et al, 2016). One quarter of the texts provided no information about how an oximeter works; the remainder provided a brief description only.

How is SpO_2 defined?

According to the British Thoracic Society, SpO_2 is the arterial oxygen saturation measured by pulse oximetry (O'Driscoll et al, 2017). Despite this concise definition, there was considerable variation in definitions of SpO_2. The most common, found in one third of texts, was simply 'O_2 saturation' but, again, many did not define what O_2 saturation actually is. The second most common definition, which was in one quarter of texts and the most accurate, referred to the percentage or ratio of

Table 1. Audited texts

	What does a pulse oximeter measure?	Includes description of how an oximeter works?	How is SpO_2 defined?	What is pulse oximetry used for?	Includes description of oxy-Hb dissociation curve?	List of factors affecting the accuracy of readings?	Other
Burton et al (2019)	O_2 saturation of capillary blood (SaO_2)	Yes	Pulse saturation	Not described	No	Yes	
Cooper and Gosnell (2019)	Arterial O_2 saturation (SaO_2)	No	Not defined	Not described	No	No	
Potter et al (2019)	O_2 saturation, an estimate of the amount of O_2 in the blood	Yes	Peripheral capillary O_2 saturation; the % of oxygenated Hb compared with the total amount of Hb	The indirect measurement of O_2 saturation	No	Yes	
Taylor et al (2019)	Arterial oxyhaemoglobin saturation of arterial blood	No	Not defined	Monitoring patients receiving O_2 therapy, monitoring those at risk of hypoxia, and postoperative patients	No	Yes	
Tollefson and Hillman (2019)	O_2 saturation in peripheral arterial blood flow (Urden et al, 2017)	No	A comparison between the amount of O_2 being carried by Hb and the amount of O_2 it can carry (Lizarondo, 2016)	To identify deterioration in physiologic function… allowing the person to receive rapid treatment and avoid associated complications (Khanh-Dao Le, 2016; Urden et al, 2017)	No	Yes	
Vaughan and Keogh (2019)	O_2 level in the blood (SpO_2)	No	O_2 level in the blood	Part of the respiratory evaluation when the patient is at risk for or actually experiencing respiratory distress	No	Yes	
Berman et al (2018)	Arterial blood O_2 saturation (SaO_2)	Yes	Not defined	Detecting hypoxia before clinical symptoms develop	Brief comment	Yes	
Delves-Yates et al (2018)	SpO_2	No	Not defined	Measuring O_2 levels	No	Yes	
Lynn (2018)	O_2 saturation of arterial blood	Yes	A ratio between O_2 content of the Hb and the potential O_2 carrying capacity of Hb (Van Leeuwin and Bladh, 2015)	Monitoring patients receiving O_2 therapy, titrating O_2 therapy, monitoring those at risk of hypoxia or hypoventilation, and postoperative patients	No	Yes	
Treas et al (2018)	O_2 saturation (an indication of the O_2 being carried by Hb in the blood)	Brief description	Pulse saturation, a good estimate of arterial O_2 saturation (SaO_2)	Monitoring oxygenation	No	Yes	States that because it is 'simple to perform' the task can be delegated to a lesser qualified though trained nurse
Williams (2018)	Arterial O_2 saturation	Yes	Pulse O_2 saturation level and the % of Hb that is bound with O_2	Tracking changes in arterial O_2 saturation	No	Yes	States: 'Pulse oximetry is a reliable indicator of oxygenation'
Berman et al (2017)	Arterial blood O_2 saturation (SaO_2) displayed as SpO_2	Yes	Not clearly defined	Detecting hypoxaemia before clinical signs and symptoms develop	No	Yes	
Bloomfield et al (2017)	The % of O_2 saturation	Yes	The ratio of oxyhaemoglobin to deoxyhaemoglobin (Jubran, 2015)	For short- and long-term monitoring of oxygenation	No	Yes	States that O_2 saturation 'tells … the extent to which the Hb molecule is bound to O_2'
Craven et al (2017)	Gas exchange in the circulatory system	Brief comment	Arterial O_2 saturation	Approximating oxygenation or the patient's need for O_2	No	Yes	States that oximetry does not assess the quality and efficacy of ventilation
Crisp et al (2017)	Arterial oxygenation; the % of Hb bound with O_2 in the arteries (SaO_2)	Yes	Peripheral O_2 saturation	Non-invasive measurement of arterial oxygenation	No	Yes	Notes that oximetry is not a replacement for assessment of respirations

Table 1 (continued). Audited texts

	What does a pulse oximeter measure?	Includes description of how an oximeter works?	How is SpO2 defined?	What is pulse oximetry used for?	Includes description of oxy-Hb dissociation curve?	List of factors affecting the accuracy of readings?	Other
Hill et al (2017)	O_2 saturation (SpO_2): an estimate of arterial oxygen saturation (SaO_2)	No	O_2 saturation; the % of Hb that is saturated with O_2	Monitoring people receiving O_2 therapy, those at risk of hypoxaemia, and those with respiratory conditions	No	Yes	States: 'Pulse oximetry is a reliable indicator of oxygenation'
Hogan (2017)	O_2 saturation (SaO_2)	No	Not defined	No comment	No	No	
Koutoukidis et al (2017)	Pulse O_2 saturation (SpO_2)	Yes	The extent to which Hb is loaded with O_2	Estimating arterial O_2 saturation	Yes	Yes	Encourages the user to ask whether they are educated, authorised and competent
Rosdahl and Kowalski (2017)	O_2 saturation of functional Hb in the blood	Yes	Not clearly defined	Used during the admission process or when a patient is receiving supplemental O_2	No	Yes	
Smith et al (2017)	Arterial O_2 saturation (SaO_2)	Yes	Hb O_2 saturation (SpO_2)	Cost and time efficient monitoring of arterial oxygen saturation (SaO_2)	No	Yes	
Timby (2017)	O_2 saturation of blood	Yes	O_2 saturation obtained by pulse oximetry	For monitoring the O_2 saturation	Yes	Yes	
DeLaune et al (2016)	Arterial O_2 saturation	Yes	Peripheral O_2 saturation	To measure SpO_2, which is a reliable estimate of SaO_2	Yes	Yes	
Moore and Cunningham (2016)	O2 saturation or O_2 status of the patient	Yes	Peripheral O_2 saturation	Monitoring conditions affecting respiratory status, monitoring for potential hypoxaemia, evaluating effectiveness of O_2 therapy and weaning respiratory support	No	Yes	Provides detailed description of ventilation and respiration
Shaw et al (2016)	Pulse rate and O_2 saturation	No	Not defined	Rapid identification of the client becoming more hypoxic	No	Brief	
Delves-Yates (2015)	Peripheral arterial blood O_2 saturation	Yes	The levels of peripheral arterial O_2 obtained via a pulse oximeter	To detect hypoxia, giving a non-invasive indication of a patient's cardiorespiratory status		Yes	Emphasises that good O_2 levels do not provide evidence of ability to expire CO_2
Dougherty and Lister (2015)	O_2 saturation from Hb in arterial blood	Yes	The amount of Hb saturation in the tissue capillaries	Monitoring for hypoxaemia	Yes	Yes	
Taylor (2015)	Arterial O_2 saturation (SaO_2)	Yes	Arterial saturation	To determine how well the lungs are delivering O_2 to the blood	No	Yes	Inconsistent use of SaO_2 and SpO_2
Baillie (2014)	How saturated with O_2 are the Hb molecules	Brief comment	O_2 saturation of Hb in arterial blood	Acute and chronic illness, investigations and surgery, and respiratory and circulatory problems	No	Yes	
Dempsey et al (2014)	O_2 saturation (SpO_2), an estimate of SaO_2	No	The % of Hb that is saturated with O_2	Monitoring people receiving O_2 therapy and people at risk of hypoxaemia	No	Yes	
Perry et al (2014)	Arterial blood O_2 saturation	Brief comment	The % to which Hb is filled with O_2	For patients with unstable O_2 status or are at risk of impaired gas exchange	No	Yes	Includes delegation considerations
Boyd (2013)	O_2 saturation	Brief comment	O_2 saturation	To determine if the O_2 saturation is within the acceptable range	No	Yes	States O_2 saturation is measured with a pulse oximeter after training and assessment in its use
Brooker and Waugh (2013)	Arterial O_2 saturation	Brief comment	The % of saturated Hb in arterial blood	Indication of the amount of O_2 in peripheral blood	No	Brief comment	

Key: Hb=haemoglobin; CO_2=carbon dioxide; O_2=oxygen; OxyHb=oxyhaemoglobin; SaO_2=oxygen saturation in arterial blood; SpO_2=peripheral oxygen saturation measured by a pulse oximeter

KEY POINTS

- Pulse oximetry is used to measure one of the key vital signs
- Research has shown that nurses' understanding of pulse oximetry is poor
- An audit found considerable variation in core textbook descriptions of pulse oximetry
- Inadequate textbook descriptions of pulse oximetry might contribute to nurses' poor understanding of this technology

oxygenated haemoglobin compared with the total amount of haemoglobin. Less common definitions included: the percentage of haemoglobin saturated with O_2, pulse saturation, or the O_2 level in the blood. Nearly 20% of texts provided no definition of SpO_2.

What is a pulse oximeter used for?

There was variety in the descriptions of what an oximeter is used for. The most common answers, found in 65% of texts, were either for monitoring O_2 saturation, patients receiving O_2 therapy, or patients at risk of hypoxia. Less common answers were for monitoring oxygenation, postoperative patients, cardiorespiratory status, patients at risk of respiratory distress, detecting deterioration, and weaning patients from respiratory support. Simplistic descriptions included monitoring patients with unstable O_2 status and monitoring how well the lungs are delivering O_2. Two texts did not indicate what an oximeter is used for.

Oxyhaemoglobin dissociation curve

To make sense of how oxygen gets into the tissues, an understanding is needed of the oxyhaemoglobin dissociation curve (Hatfield, 2014).

The majority of textbooks audited (80%) did not explain nor refer to the oxyhaemoglobin dissociation curve at all. Only 16% of the textbooks provided an explanation of the curve and 4% made a brief comment.

Factors affecting the accuracy of oximetry readings

Most texts (87%) included a list of factors or commented on factors affecting the accuracy of pulse oximetry readings. Examples of these included carboxyhaemoglobin, low perfusion states and nail polish. Of the remainder, half made only a brief comment on these factors or none at all.

CPD reflective questions

- Reflect on your knowledge of pulse oximetry and that of your team's knowledge
- Are you confident that you know what a pulse oximeter measures?
- What is SpO_2? What does it reflect?
- Think about how a pulse oximeter should be used to guide clinical practice

Other comments

Some texts indicated that pulse oximetry monitoring can be delegated to less qualified staff, but that such a decision to do so must be carefully considered. Two texts stated that pulse oximetry is a reliable indicator of oxygenation. One text emphasised that oximetry does not assess the quality and efficacy of ventilation. Another noted that oximetry is not a replacement for assessment of respirations.

Discussion

This audit examined pulse oximetry descriptions in current nursing textbooks. Considerable variation was found in the accuracy of these descriptions; some were very basic or simplistic and inaccurate. Although the audit was based on a convenience sample of textbooks, the findings are a concern given the variation in quality of descriptions. The findings are not surprising, though, given the considerable gaps that have been found in clinicians' understanding of pulse oximetry and that many report receiving little or no education about oximetry use (Mok et al, 2015; Milutinovic et al, 2016).

Understanding the principles behind oximetry and the significance of SpO_2 readings has an impact on interpretation of measurements that may affect the provision of high-quality care (Pretto et al, 2014). The British Thoracic Society therefore recommends that all staff who use oximeters be trained in their use and be aware of the limitations of oximetry (O'Driscoll et al, 2017). However, the British Thoracic Society does not give specific recommendations about what oximetry training should include. The WHO pulse oximetry training manual (2011) covers the physiology of oxygen transport, knowing the pulse oximeter (for example, what it measures, what the alarms indicate), and how oxygen desaturation occurs.

Some of the reviewed texts stated that assessment of SpO_2 can be delegated to less qualified staff. This is a concern, given the theoretical understanding needed to perform this task correctly. Although these texts advised that any person using a pulse oximeter must be qualified to do so, they did not indicate how a clinician can become qualified.

Nursing clinical skills texts tended to focus mostly on the clinical use of pulse oximetry and gave less attention to relevant theory, such as the diminished accuracy of oximetry in patients with poor peripheral perfusion (O'Driscoll et al, 2017). This may simply reflect the nature or focus of these texts, their limited scope, or even word limits allocated by publishers. However, it raises a question about what these texts are trying to achieve. If these texts do not recommend further reading on the topic, the novice nurse or undergraduate student may be left ignorant of relevant theory and incorrectly assume they understand all important principles about oximetry use. This is a trap for the novice, given that a pulse oximeter appears to be easy use; simplistic text descriptions may contribute to graduate nurses incorrectly thinking that they are competent in this skill.

Few, if any, of the audited texts cited international oximetry guidelines such as those of the British Thoracic Society, the Thoracic Society of Australia and New Zealand, and the WHO (WHO, 2011; Pretto et al, 2014; O'Driscoll et al, 2017). This may reflect the limited research conducted by the authors writing the

textbook content. It could also be that measuring oxygenation saturation is incorrectly assumed to be a simple procedure (Milutinovic et al, 2016). Perhaps the greatest limitation of pulse oximetry is its deceptive ease of use, which obscures the complexity of the critical analysis needed to interpret the oximeter readings (Seeley et al, 2015).

Costanzo (2009) found that success in an undergraduate nursing programme is determined by having the skills to transfer textbook concepts into clinical situations and examinations. Knowledge gaps about pulse oximetry principles cannot simply be filled through experience (et al, 2013). This is evident in studies highlighting the oximetry knowledge gaps of experienced clinicians (Çelik, et al, 2014; Fouzas et al, 2010). Unsurprisingly, some clinicians reported receiving inadequate education in the use of pulse oximetry (Faponle and Erhabor, 2002; Çelik et al, 2014). It is therefore essential that textbook descriptions, particularly those aimed at undergraduate students, are accurate and comprehensive. According to the WHO (2011), pulse oximetry is effective only if the user understands how the technology works. If oximetry is not explained adequately in the textbooks, nursing students may be left with knowledge deficits and thus not be competent at assessing this vital sign.

Although there were differences in the quality of pulse oximetry descriptions in the audited texts, it cannot be concluded that this is the sole cause of knowledge deficits. However, the varying quality of the descriptions may be one factor associated with nurses' poor understanding. Many factors influence the learning outcomes of undergraduate students and thus the competence of graduate nurses. Such factors include the student's intrinsic desire to learn, each student's unique learning style, the ways in which educational content is delivered (for example online, face to face, by video), and how theory or clinical skills are assessed by clinical educators and nursing curricula. Undergraduate students are often not aware of their knowledge deficits. It is therefore incumbent on the resources and teaching material provided to comprehensively cover all critical aspects of what students need to know. These factors must be considered when interpreting the audit's findings.

Limitations

The total number of fundamentals of nursing or nursing skills texts currently available worldwide is not known. It is therefore impossible to determine what portion of current textbooks were audited. However a systematic attempt was made to access and review as many current texts as possible. A second limitation is that nursing students may use other resources for their learning such as journal articles and web-based videos. These types of resources were not audited. The findings of this audit therefore only apply to textbooks.

Conclusion

The measurement and interpretation of vital signs is a critical nursing task. Despite this, research has found that many nurses' understanding of pulse oximetry is poor. Some of these nurses report no education or training about pulse oximetry use. Superficial, inconsistent or misleading information within basic nursing textbooks may be one factor associated with these knowledge deficits. Academics and nurse educators should appraise core content of textbooks carefully before recommending textbooks to nursing students. If gaps are identified in key learning material, additional educational resources should be provided. **BJN**

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