REVIEW ARTICLE

Pulse oximetry: A reliable and cost effective screening tool in children with pneumonia for developing countries

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Abstract

The infant mortality rates are high in developing countries and, according to World Health Organisation (WHO), statistics show that the main contributors are acute respiratory infections and pneumonia. In children hypoxaemia is an ominous sign associated with respiratory tract infections. Hypoxia can be detected easily with pulse oximetry. It is a non-invasive, readily available and cost-effective way to identify hypoxaemia. If we identify hypoxaemia at the primary care level, especially in a low-income setting, we can make early referral to tertiary care settings. This will subsequently have a positive impact in saving lives. A detailed search of Medline database was conducted through PubMed from 1990 to date, to review the literature on the usefulness of pulse oximetry at primary care centres in developing countries. Such information will become vital in formulating guidelines for income-poor countries in order to stratify high-risk children with hypoxaemia.

Keywords: Pneumonia, Children, Pulse oximetry.

Introduction

Pneumonia is one of the major causes of morbidity and mortality among children under the age of 5 years.[1] Hypoxaemia is a well-recognised complication of acute lower respiratory tract infections (RTI) in children[2] and has been found to be associated with fatal outcomes.[3] Hypoxaemia can be diagnosed by measuring haemoglobin oxygen saturation either by invasive blood sampling or by pulse oximetry (PO), which is a non-invasive technique that measures oxygen saturation levels in arterial blood by attaching a sensor to the body surface of the patient.[4]

The sensitivity and/or specificity of PO in the preliminary assessment of young infants presenting to health settings with hypoxaemia has not been studied extensively.

However, clinical practices in developed countries highlight the potential benefit of PO as an ancillary triage and assessment tool. PO is commonly used in Canada and US as a triage system to detect hypoxaemia in paediatric patients presenting with symptoms suggestive of bronchiolitis, pneumonia and exacerbations of asthma. Choi et al. showed that the routine use of PO to screen children presenting to the emergency department (ED) at Children's Hospital Los Angeles with bronchiolitis enabled more efficient triage and reduced the overall average length of stay in the ED.[5] More recently, Neuman et al. incorporated PO into a clinical algorithm to enable risk stratification among children with suspected pneumonia in Boston.[6]

In developing countries, often there is no well-developed triage system as every patient is seen on first-come-first-served basis without any criteria for prioritisation. We believe that the utilisation of PO is an easy and inexpensive tool in resource-poor settings and can help stratify high-risk patients in primary care.

This review aimed at examining the literature for the utilisation of PO in the identification of hypoxaemia in acute respiratory infections (ARIs). This will enable us in the later stage to add PO to the algorithm for assessment of the sick child at the primary care level at low-cost settings.

Understanding Pulse Oximetry

PO is patient-friendly, as it is simple, non-invasive and a reasonably accurate measurement of arterial oxygenation. PO determines the oxygen saturation of haemoglobin (SpO_2) by spectrophotometry, which measures the amount of infrared and red light after crossing body tissue.

The sensor is attached to the patient's body and emits light of two wavelengths i.e. infrared 910-940 nm and red 650-660 nm. Oxygenated haemoglobin allows red light to pass through, but absorbs infrared light, whereas deoxygenated haemoglobin allows infrared light to pass

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through and absorbs more of the red light. The level of oxygen in the blood is calculated from the ratio of absorbed red to infrared light using the ratio of oxyhaemoglobin to the sum of all the functional haemoglobin.[4]

In conventional transmission PO (TPO), a red/infrared light emitter and photo-detector are placed on opposite sides of a narrow tissue segment (e.g. digit, earlobe); transmitted light is partially absorbed within the tissue, and the detector measures the residual transmission. To address the unique challenges of performing PO in young infants, a less commonly used approach, called reflectance PO (RPO), offers potential advantages. Although PO technology is fundamentally the same in both TPO and RPO, but the latter employs single-surface probes. Also, the light emitter and detector are adjacent to one another so that the probe can be placed on a flat, more centrally-located skin surface such as an infant's chest.[7,8] Instead of detecting transmitted residual light, the RPO sensor detects the residual light reflected back from the pulsating artery.

In a study of 18 infants in Israel, the Nellcor N395 (TPO) and Conmed PRO2 reflectance oximeters (Conmed, Ithaca, NY) yielded similar SpO2 and both were concordant with SaO2 measured in blood gases. However, the RPO method was superior at lower SpO2 (<85%).[7]

Uses of PO in Developing World

In most of the developing world, clinical indicators, such as compromised mental state, poor intake, cyanosis, respiratory rate >60, nasal flaring, head nodding, and chest in-drawing, are used to identify the severely ill child with pneumonia. A number of studies have shown that these are not sensitive predictors of severity unless complemented with measurement of oxygen saturation using PO.[8-11] A study in Papua New Guinea showed that introducing oxygen concentrators and pulse oximetres could curtail case fatality among children diagnosed with pneumonia by 35%.[12] Mawaniki et al. in a study from Kenya also concluded that diagnosis of hypoxaemia cannot be predicted by clinical signs alone, and in resource-poor health facilities where oxygen is expensive, using PO cuts down the cost.[13]

A range of clinical assessment tools based on historical (i.e. caregiver-reported) and physical examination features has been applied to the triage and referral of sick young infants (0 to 59 days of age) by community health workers (CHWs) at the community or first-level setting in developing countries.[14] Recently, the Young Infant Study (YIS) group devised a 7-sign algorithm (at least one of: history of difficulty in feeding, history of convulsions, movement only when stimulated, respiratory rate of 60 breaths per minute or more, severe chest in-drawing, or temperature of 37.5°C or more or below 35.5°C) to detect physician-diagnosed severe disease (i.e. illness requiring hospital admission) with a sensitivity of 85% and specificity of 75% in 0-6 day-old infants and sensitivity of 74% and specificity of 79% in 7-59 day-old infants.[15] The YIS 7-sign algorithm was adopted by the WHO in an updated young infant component of the 'integrated management of childhood illness' (IMCI) protocols,[16] and has become a standard clinical assessment tool in many young infant health care delivery programmes and community-based research studies in low-resource settings.

In developed countries, PO was found to be beneficial when used in children with bronchiolitis when introduced as a screening tool in emergency room triage in a study conducted by Choi and Claudius.[5] They found participants without PO at triage (pre-intervention group) had mean stay at hospital of 4 days and 59 minutes whereas the post- intervention group had mean stay of 4 days and 9 minutes. Therefore, they concluded that clinical examination alone cannot substitute the need of PO monitoring.

In winters and fall, Respiratory Syncytial Virus (RSV) bronchiolitis infection is also a frequent illness found in young children. Management involves utilisation of oxygen in most cases and targets keeping PO >94%.[17] Therefore, PO monitoring will help identify need of oxygen therapy in children. Regarding severity of bronchiolitis, Voets et al. conducted a study on patients with positive nasopharyngeal respiratory syncytial virus, and concluded saturation of oxygen less than 95%, respiratory rate of more than 45 breaths per minute and age less than 6 months in respiratory distressed children are important factors to anticipate need of hospitalisation and determining severity of bronchiolitis.[18] In another study from Malaysia on infants with RSV bronchiolitis, prematurity was the most significant factor for respiratory failure and compromised oxygen saturation level by logistic regression analysis (Odds ratio [OR] 1.17; 95% confidence interval [CI] 1.06-1.55; p<0.01 and OR 1.14; 95% CI 1.02-2.07; p=0.02 respectively, making PO monitoring a mandatory aspect for assessment of premature infants with RSV bronchiolitis.[19] Thus, in RSV bronchiolitis the determination of PO can assist doctors in predicting severity of disease and management of children.

High-risk patients requiring PO can include children with breathing obstruction, central cyanosis, respiratory distress, shock, coma, convulsions, and severe dehydration as emergency signs. For children less than two months of age, the parameters include a sick infant, restless, irritable, lethargic, temperature more than 38.5 degree centigrade, trauma, other surgery-requiring conditions, severe anaemia, poisoning, extreme pain, respiratory distress, major burns, malnutrition and oedema in feet as priority signs.[20]

Advantages of PO use

The need for the use of PO for the management of acute illnesses in young children in developing countries has been highlighted for more than a decade.[21] But there are a number of advantages observed in introducing PO to primary care settings at resource-poor health setups, including availability of low cost, easy-to-use devices, interpretability of readings by minimally trained personnel, rapidity with which a measurement can be obtained and the capacity of the technology to address motion artefacts.[12] Some studies also suggest that appropriate implementation of PO is a very cost-effective tool with estimates that suggest US $2.97-$52.92 per disability adjusted life year.

Limitation of PO use

Despite all the benefits, there are many reasons that inhibit its extensive utilisation. Firstly, training of the staff to recognise problems that can give erroneous SpO2 like irregular cardiac rhythms[22] and poor perfusion states such as low cardiac output, shock, hypothermia, vasoconstriction, arterial occlusion or during blood pressure cuff inflation.[23] Secondly, attachment of probes to little fingers of the babies can be technically challenging and gives erroneous readings if not appropriately done.[24] In the presence of warm sepsis, PO is not reliable and needs to be supplemented by venous/arterial oxygen measurement.[25] Therefore, regular technical support is required to monitor the functioning of POs to ascertain its reliability.

Conclusion

Literature review shows that PO can be a useful and cost-effective modality in the developing world for detecting hypoxaemia early, especially at the level of primary care. PO can identify high-risk children with respiratory tract infections. This can help in improving the management plan for sick children presenting with RTIs. This could lead to improved infant mortality rate. A well-devised randomised control trial in a sizeable population can give a more valid answer for its appropriate utilisation.

Limitation to the Review

Since not much research has been done on the use of PO in developing countries at primary care level, hence few references are from last five years. Infact this observation prompted us to highlight the utility to be analysed in future studies.

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