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Comparison of nasal and forehead oximetry accuracy and pressure injury in critically ill patients

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ABSTRACT

Background: In critically ill patients, clinicians can have difficulty obtaining accurate oximetry measurements.
Objective: To compare the accuracy of nasal alar and forehead sensor measurements and incidence of pressure injury.
Methods: 43 patients had forehead and nasal alar sensors applied. Arterial samples were obtained at 0, 24, and 120 hours. Oxygen saturations measured by co-oximetry were compared to sensor values. Skin was assessed every 8 hours.
Results: Oxygen saturations ranged from 69.8%-97.8%, with 18% of measures < 90%. Measurements were within 3% of co-oximetry values for 54% of nasal alar compared to 35% of forehead measurements. Measurement failures occurred in 6% for nasal alar and 22% for forehead. Three patients developed a pressure injury with the nasal alar sensor and 13 patients developed a pressure injury with the forehead sensor ($\chi 2 = 7.68$; $p = .006$).
Conclusions: In this group of patients with decreased perfusion, nasal alar sensors provided a potential alternative for continuous monitoring of oxygen saturation.

Introduction

Continuous pulse oximetry monitoring is a standard of care for critically ill patients in the intensive care unit (ICU). However, clinicians frequently have difficulty obtaining an accurate oximetry measurement in patients with decreased perfusion due to peripheral vascular disease, low body temperature, or shock with vasopressor use. Several studies have demonstrated the utility of forehead sensor measurements under these clinical conditions.[1–7] Forehead sensors use reflectance technology and measure oxygen saturation of blood from a branch of the supraorbital artery that arises from the carotid artery. Therefore, measurement of oxygen saturation at the forehead is considered to be a more central measurement than digit or ear sensor measurements. However use of this sensor requires a headband to prevent venous pulsation and obtain accurate measurements. The headband applies up to 20 mm Hg pressure over the forehead sensor to improve accuracy.[8] Forehead sensors with headbands have led to pressure injury at our institution despite following vendor recommendations for alternating placement from one side of the forehead to the other every 8 hours.

Two studies of newer technology oximetry sensors placed on the nasal ala, which are fed by branches of both the external and internal carotid arteries, have demonstrated rapid detection of induced desaturations and correlation with arterial oxygen saturation.[9,10] These two studies were conducted in healthy subjects or during routine anesthesia care over several hours. Several reasons have been cited for inaccuracy of non-invasive measurements of oxygen saturation in critically ill patients. Decreased perfusion and use of vasopressors are known to impair the accuracy of oximetry sensor measurements.[4,7] Additionally, sepsis can lead to overestimates of oxygen saturation by oximetry.[11] Forehead sensor measurements have also previously been reported to be higher than arterial samples in patients with chronic obstructive pulmonary disease.[12] Dark skin pigmentation was found by Feiner and colleagues to increase the bias of pulse oximetry saturation (SpO_2), as measured by digit sensors, compared to arterial oxyhemoglobin saturation (SaO_2) when SaO_2 measurements were

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less than 80%.[13] Positioning patients in head down positions, including prone and Trendelenburg positions, has been reported to impact the accuracy of forehead sensors[8,14]; however, impact of positioning on the nasal alar sensor is not known.

Research is needed to examine the accuracy of the alar sensor in the ICU patient population. During periods of low perfusion, patients are at risk for device related pressure injury.[15–17] The aims of this study were to compare the accuracy of nasal alar and forehead sensor measurements with SaO_2 measurements in patients at risk for decreased perfusion and to compare pressure injury incidence with each device.

Methods

Study design

This prospective observational study was conducted in a large university-affiliated medical center between October 2014 and April 2016. The study was approved by the Human Studies Committee. Written informed consent was obtained from the patient's legally authorized representative. No patients were able to provide their own consent.

Inclusion and exclusion criteria

A convenience sample of 43 patients were recruited from a 36-bed surgical/burn/trauma intensive care unit (ICU) and a 34-bed medical ICU. Included patients were 18 years of age or older, had an existing arterial catheter, and had evidence of hypoperfusion due to at least one of the following: 1) Difficulty obtaining a consistent signal from a digit or ear sensor; 2) Receiving ≥ 0 .10 mcg/kg/min of norepinephrine, or 3) Core temperature ≤ 35°C. Inclusion criteria for norepinephrine dosage and hypothermia were selected based on known circumstances for decreased peripheral perfusion. Patients were excluded if there were any anatomic impediments (burns, wounds, dressings, etc.) to placement of the sensor on the nasal ala, a hemoglobin value < 5 g/dL, a history of known dyshemoglobinemias evidenced by carboxyhemoglobin levels > 10% or methemoglobin level > 2%, inability to obtain consent from a surrogate, or a consideration for comfort care in discussions of the ICU team and the family. No patients with a craniotomy or frontal lobe injuries were included due to concerns with the forehead sensor headband application.

Procedures

Current practice at our institution is to place a forehead sensor when no signal can be obtained from digit sensors or if the digit sensor is inaccurate compared to SaO_2 measurements. Forehead reflectance oximetry sensors (Nellcor, Max-Fast) were in place in 40 of the patients at the time of enrollment; one patient had the forehead sensor placed at the time of enrollment, and forehead sensors could not be applied to two patients (one patient was proned and one with a helmet). Estimated placement time of the forehead sensor was determined based on patient ICU admission time, documentation in chart by RN regarding placement, or time of hypotension and change in oxygen saturation noted in the chart. A Velcro headband was used with all forehead sensors. Nasal alar oximetry sensors (Xhale Assurance) were placed upon patient enrollment. After a 10–15 minute stabilization period and validation that pulse rate signals from the sensors matched electrocardiographic heart rate, an arterial blood sample for hemoglobin saturation battery with SaO_2 measurement was obtained. An advanced practice registered nurse (APRN) member of the research team collected all of the data from sensor measurements and arterial blood samples. Nasal and forehead sensor measurements were recorded simultaneously. Poor plethysmograph was noted. Data collectors also noted if a question mark was displayed despite adjustment attempts of a sensor. When a question mark is displayed, no sensor pulse oximetry number is displayed and was considered a sensor measurement failure. The three measurements were again obtained 24 hours after initial sensor placement and 4–5 days (96–120 hours) after placement. The first two measurements were obtained in the first 24 hours during the period of highest acuity of critical illness and patients' highest risk for decreased perfusion. The third measurement was obtained 96–120 hours later to measure accuracy of the sensor when patients were expected to be less acutely ill and to assess for pressure injury risk with extended wear.

Forehead and nasal ala skin was assessed at time of enrollment. To reduce the risk of pressure injury and following our current hospital practice based on vendor recommendations, we moved location of the sensor from one side of the forehead to the other side and nasal ala to opposite ala every 8 hours. At that time, the skin underlying the sensor was inspected for pressure injury. A bedside data collection sheet for documentation of skin assessment was utilized. Education was provided to all nurses prior to start of the study and in real time upon patient enrollment. An APRN member of the research team performed the assessment on day shift and the bedside registered nurse (RN) performed the assessment between 1500-0700. Pressure injury staging guidelines from the National Pressure Ulcer Advisory Panel (NPUAP) were utilized.[13] All nurses in the institution assess skin regularly and document using descriptive wording based on the NPUAP pressure injury staging criteria. A second APRN member of the research team assessed the skin if any pressure injury was suspected; all determinations of pressure injury were validated. Prior to this study, forehead sensors were continued if patients developed a pressure injury and peripheral site measurements were inaccurate. Due to the high incidence of pressure injury associated with forehead sensors in our institution, the research protocol included removal of the forehead sensor if the first 2 nasal alar measurements were within 3% of the SaO_2 (clinical definition of accuracy) or when a pressure injury related to the forehead sensor occurred. If a pressure injury was identified related to the nasal alar sensor, the sensor was removed. If pressure injury developed at both sensor sites, the patient was removed from the study.

Measures

At each measurement (initial, at 24 hours and at 4–5 days), mean arterial pressure from the arterial catheter and temperature (obtained from bedside monitor), fraction of inspired oxygen (FiO_2, obtained from ventilator), and vasopressor medication and dose infusing (obtained from infusion pumps) were recorded. SaO_2 was measured with a calibrated Radiometer ABL800 Flex Series blood gas instrument in the clinical laboratory. Demographic and clinical data retrieved from the electronic medical record included age, gender, race, admitting diagnosis, hemoglobin level on enrollment and at 96–120 hours, and body mass index (BMI). APACHE II score was calculated by one member of the research team from data extracted from the electronic medical record at time of ICU admission.

Sensor devices

The Nellcor™ OxiMax™ Forehead SpO_2 sensor has reported accuracy in the range of 70% to 100% during low perfusion and a heart rate range of 25 to 250 beats/minute.[18] Xhale Assurance® nasal alar sensor also has reported accuracy with a SpO_2 range of 70–100% and a heart rate range of 30–240 beats/minute.[19]