INTRAOPERATIVE REFLECTANCE OXIMETRY IN BURN PATIENTS

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INTRODUCTION

Transmission pulse oximetry is based on the absorption of light as it passes through pulsatile blood contained in skin and subcutaneous tissues. Reflectance pulse oximetry is based on the absorption of a similar signal scattered edgewise through vessels and tissue within 5 to 10 mm of the surface of the skin.

Transmission pulse oximetry is nearly universally used in the intensive care and intraoperative management of critically ill patients [1]. Appropriate monitoring sites can be difficult to find in burn patients, because standard transmission sites are often burned or contained within the operative field. In an effort to deal with the need for pulse oximetry in patients with a cold periphery, such as those on cardiopulmonary bypass, recent work has been reported with reflectance oximetry [2]. This study employed the 504 version 1.1 standard pulse oximeter (Critical Care Systems, Milwaukee, WI), and documented better signal detection with a forehead reflectance probe, compared to an earlobe transmission probe in patients with a cold periphery.

Nellcor Corporation (Hayward, CA) has recently developed a reflectance oximetry probe for use on the forehead or temple of patients weighing at least 40 kg. The light-emitting diodes and photodiodes of this probe, designated the Oxisensor II RS-10, are separated

ABSTRACT. Objective. Transmission oximetry sites for intraoperative monitoring are frequently difficult to find in burn patients, as standard transmission oximetry sites are often burned or contained within the operative field. The objective of this study was to determine if reflectance oximetry is of potential value in monitoring this group of patients. Methods. A total of 16 operative procedures in a group of acutely burned adult and pediatric patients with an average age of 9.7 years (range, 10 months to 37 years), average burn size of 42% of the body surface (range, 15% to 94%), and average weight of 34.2 kg (range, 9 to 100 kg) were done with simultaneous transmission and reflectance oximetry monitoring. Results. During these 16 procedures in a diverse group of acutely burned adult and pediatric patients, there was no significant difference in saturations derived from transmission and reflectance oximetry probes. In smaller children, adequate signal for reflectance probe monitoring was often detected in hyperemic sites, such as healed partial thickness burn. Conclusions. This is the first published report documenting both the clinical use of the reflectance oximetry in burn patients and the clinical use of the Nellcor Oxisensor II RS-10 reflectance oximetry probe (Nellcor Corporation, Hayward, CA). This technique can facilitate the intraoperative monitoring of acutely burned adult and pediatric patients in whom standard transmission oximetry sites are difficult to find.

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by 10 mm, and are designed to rest on the skin so there is essentially no air path, and no reflectance, from the surface itself. We evaluated the ability of this probe to facilitate the intraoperative management of adult and pediatric burn patients. This is the first published report documenting the clinical use of this probe and the first report describing the use of reflectance oximetry in burn patients.

**METHODS AND MATERIALS**

After approval of the study by the Institutional Review Board of the Massachusetts General Hospital and the Shriners Hospitals for Crippled Children, 13 patients were monitored with simultaneous reflectance (Nellcor RS-10 Oxisensor II) and transmission (Nellcor D-20, I-20, or D-25 Oxisensor II) oximetry probes during 16 operative procedures for acute burns. The average age of the subjects was 9.7 years (range, 10 months to 38 years), average weight was 34.2 kg (range, 9 to 100 kg), and average burn size was 42.1% of the body surface (range, 15% to 94%).

All procedures were done under general anesthesia with endotracheal intubation and positive pressure ventilation. Inspired oxygen fraction averaged 36% (range, 30% to 50%). Dual monitoring was done using the Nellcor N-100 oximeter for an average of 123 min (range, 20 to 375 min). The first 7 procedures were monitored by recording results of saturations manually every 10 min. The subsequent 9 procedures were monitored with dual strip recorders (Nellcor P-200 thermal printer) that documented saturations every 30 sec during the procedure. A total of 145 5-min averages of transmission and reflectance saturations were calculated and compared. Transmission probes were located in standard sites, such as the earlobe or digit, depending on availability. Reflectance probes were located and relocated until a reliable signal was detected. This commonly required placing the probe at 1 to 5 sites before reliable signal was detected; but, probes did not typically require subsequent relocation. Reflectance probes were secured in place with tape, as the adhesive on the probe was not adequate in the humid environment of the burn operating room. Probes were not shielded from ambient light. Electrocardiographic synchronization, where the electrically detected electrocardiographic signal is fed into the oximeter via a cable to facilitate signal acquisition, was not done.

**RESULTS**

We found that the strongest reflectance signals were obtained from the forehead, supraorbital area, healed donor sites, and healed superficial burns (Figs A and B). Detectable signals were obtained in all 13 patients, regardless of weight or age. During dual monitoring, there was only one transient desaturation event (to 82% in a 15-kg child); transmission and reflectance probes correlated well during the episode. When transmission and reflectance values for oxygen saturation were compared, an average error of 0.02% ± 1.7% was found between the two monitoring techniques, with no significant difference by paired t-test.

Based on unpublished data collected during clinical validation studies to support approval of the device by the Food and Drug Administration, the manufacturer recommends that patients requiring mechanical ventilation not be monitored using reflectance oximetry because positive pressure ventilation can cause enhanced venous pulsations, which may be interpreted by the sensor as a cardiac rate. However, we did not encounter this artifact in our mechanically ventilated patients.

**DISCUSSION**

Transmission pulse oximetry is based upon the difference in absorption of red light (around 660 nm) and infrared light (around 920 nm) by pulsatile blood [3-6]. Red light is better absorbed by reduced (deoxygenated) hemoglobin. Infrared light is better absorbed by oxyhemoglobin. Algorithms compare these absorptions and estimate the proportion of hemoglobin containing oxygen. Transmission pulse oximetry can be rendered inaccurate for many reasons, none of which were encountered in our study. Monitoring can be rendered inaccurate by motion artifact, which may be decreased by EKG synchronization; low perfusion states, such as shock or hypothermia; enhanced venous pulsations, such as seen in right ventricular failure; strong unshielded ambient light; optical shunting between two sensors in close proximity; subcutaneous edema; a hemoglobin less than 5 g/dl; carboxyhemoglobin; methemoglobin; fetal hemoglobin; or intravenous dyes [7].

In 1938, Herzman [8] documented that the forehead had extremely high superficial skin blood flow. This discovery led to attempts to develop reflectance oximetry in this area of very strong superficial signal. The reflectance oximetry probe (RS-10 Oxisensor II) has been developed by Nellcor for use in this area. Hypermetabolic, hyperdynamic burn patients have a generalized enhanced skin blood flow, particularly in areas of recently healed, erythematous donor site or superficial burn. These conditions make them ideal candidates for reflectance oximetry. Reflectance oximetry works in an identical fashion to transmission oximetry, except that the photosensor, which is on the same plane as the light-