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Near Infrared Spectroscopy Detects Hypoxemia Before Pulse Oximetry

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Introduction: Routine intraoperative monitoring includes the use of continuous pulse oximetry. Despite its efficacy in identifying hypoxemia, clinical practice has demonstrated a lag time from the onset of hypoxemia until its detection by routine pulse oximetry. Recently, there has been a growing interest in the use of near infrared spectroscopy (NIRS) as a means of monitoring global cerebral oxygenation. NIRS relies on the same technology as pulse oximetry, using infrared light to calculate cerebral oxygenation. When using both NIRS and pulse oximetry in the same patient, we have noticed that NIRS declines prior to pulse oximetry during periods of hypoxemia. The current study compares the time for decreases in oxygen saturation as measured by pulse oximetry versus cerebral oxygenation measured NIRS.

Methods: The study was approved by the institutional IRB. Patients undergoing airway procedures in which apneic oxygen was needed were included. The patients were monitored with standard pulse oximetry placed on the finger and with a unilateral NIRS probe (INVOS 5100B, Somanetics, Troy, Michigan) placed on the right side of the patient's forehead. Prior to the start of apnea, the patient was ventilated with 100% oxygen for 3-5 minutes to ensure an oxygen saturation of 100% by pulse oximetry and a cerebral oximeter (rSO_2) value $\geq$ 90%. Once apnea was started, the time until the rSO_2 and the pulse oximeter decreased by 5% and 10% were noted. Once the oxygen saturation decreased by 10%, the endotracheal tube was replaced in the trachea and ventilation started again. The time to desaturation by 5% and 10% as measured by the cerebral oximetry and pulse oximeter were compared using a non-paired t-test. The decrease in the rSO_2 value that occurred when there was a 5% decrease in the pulse oximetry value was recorded. All data are presented as the mean ± SD.

Results: The cohort for the study included 7 patients ranging in age from 1 month to 7 years (1.8 ± 2.4 years) and in weight from 3.8 to 44 kgs (12.9 ± 14.1 kgs). All patients were undergoing airway surgery with use of a laser so that apneic oxygenation was used to limit the potential for airway fire. There were a total of 27 episodes of apnea used in the 7 patients (3 to 5 per patient). The time required for a 5% decrease of the rSO_2 was 97 ± 9 seconds compared to 160 ± 53 seconds required for a 5% decrease of the pulse oximeter ($p<0.0001$). In all 27 instances, the rSO_2 decreased by 5% before the pulse oximeter decreased by 5%. The time required for a 10% decrease of the rSO_2 was 142 ± 46 seconds compared to 204 ± 70 seconds required for a 10% decrease of the pulse oximeter ($p=0.0003$). In all 27 instances, the rSO_2 decreased by 10% before the pulse oximeter decreased by 10%. When the pulse oximetry reading had decreased by 5%, the rSO_2 had decreased by 17 ± 4%.

Conclusions: The use of NIRS is continuing to increase as a means of monitoring cerebral oxygenation in both the operating and the ICU setting. The current study demonstrates that a decrease in cerebral oxygenation as reflected by the rSO_2 value measured by cerebral oximetry occurs prior to decreases in oxygen saturation measured using pulse oximetry placed on the finger. Although no clinical sequelae were noted in our patients, it is worrisome to note that significant decreases in the rSO_2 values were noted when there was only a 5% decrease in the pulse oximeter value. The significant lag time of conventional pulse oximetry may limit the ability of pulse oximetry to provide an early warning of changes in oxygenation.