Oxygen Saturation Targeting in Preterm Infants Receiving Continuous Positive Airway Pressure

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Objective The precision of oxygen saturation (SpO_2) targeting in preterm infants on continuous positive airway pressure (CPAP) is incompletely characterized. We therefore evaluated SpO_2 targeting in infants solely receiving CPAP, aiming to describe their SpO_2 profile, to document the frequency of prolonged hyperoxia and hypoxia episodes and of fraction of inspired oxygen (FiO_2) adjustments, and to explore the relationships with neonatal intensive care unit operational factors.

Study design Preterm infants <37 weeks' gestation in 2 neonatal intensive care units were studied if they were receiving CPAP and in supplemental oxygen at the beginning of each 24-hour recording. SpO_2, heart rate, and FiO_2 were recorded (sampling interval 1-2 seconds). We measured the proportion of time spent in predefined SpO_2 ranges, the frequency of prolonged episodes (≥30 seconds) of SpO_2 deviation, and the effect of operational factors including nurse-patient ratio.

Results A total of 4034 usable hours of data were recorded from 45 infants of gestation 30 (27-32) weeks (median [IQR]). When requiring supplemental oxygen, infants were in the target SpO_2 range (88%-92%) for only 31% (19%-39%) of total recording time, with 48 (6.9-90) episodes per 24 hours of severe hyperoxia (SpO_2 ≥98%), and 9.0 (1.6-21) episodes per 24 hours of hypoxia (SpO_2 <80%). An increased frequency of prolonged hyperoxia in supplemental oxygen was noted when nurses were each caring for more patients. Adjustments to FiO_2 were made 25 (16-41) times per day.

Conclusion SpO_2 targeting is challenging in preterm infants receiving CPAP support, with a high proportion of time spent outside the target range and frequent prolonged hypoxic and hyperoxic episodes. *(J Pediatr 2014;164:730-6)*.

Supplemental oxygen therapy is an integral part of modern neonatal intensive care and improves survival of preterm infants with respiratory dysfunction.[1,2] However, excess oxygen delivery is associated with adverse outcomes, in particular retinopathy of prematurity,[3] and hence there is a need to continuously adjust the fraction of inspired oxygen (FiO_2) so as to avoid the extremes of oxygenation. Measurement of oxygen saturation (SpO_2) by pulse oximetry is now an indispensable tool for guiding oxygen therapy in the newborn.[4,5] Several randomized trials in extremely preterm infants have highlighted the importance of targeting an appropriate SpO_2 range, with a low target range (and resultant intermittent hypoxia) associated with increased mortality, and a high target range with an increase in the risk of retinopathy of prematurity,[6,7] and bronchopulmonary dysplasia.[8]

The recent randomized trials also highlight the difficulties of targeting a defined SpO_2 range in the preterm infant, with a wide range of SpO_2 values on histograms of pooled data.[7,9] These findings reinforce those of previous observational studies of SpO_2 targeting, in which preterm infants were noted to spend extended periods outside the target range when receiving supplemental oxygen.[10-18] These investigations have for the most part included both ventilated infants and those receiving continuous positive airway pressure (CPAP) or other less-invasive forms of support, with in one case the suggestion of increased difficulty in maintaining the target SpO_2 range in infants on CPAP.[17] The only study reporting data exclusively relating to CPAP support had a very wide acceptable SpO_2 range (87%-96%), which among the 12 study infants was successfully targeted around 80% of the time during 3 hours of recordings.[10] Further studies focusing on SpO_2 targeting in preterm infants on CPAP are required as uptake of this modality of respiratory support continues to increase.[19]

Beyond the overall proportion of time spent outside the target SpO_2 range, few studies have reported the frequency of discrete episodes of hypoxia and hyperoxia, the severity and extent of which is clearly important in the pathogenesis

CPAP	Continuous positive airway pressure
FiO_2	Fraction of inspired oxygen
HR	Heart rate
NICU	Neonatal intensive care unit
RHH	Royal Hobart Hospital
RWH	Royal Women's Hospital
SpO_2	Oxygen saturation

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of complications arising therefrom. Short-lived hypoxic episodes (SpO_2 <80% for ≥10 seconds) occurred relatively frequently in 2 cohorts of preterm infants on mixed modes of respiratory support.[15,16] The incidence of longer-lasting episodes of SpO_2 disturbance with potentially more impact are less well documented. Furthermore, the influence of operational factors in the neonatal intensive care unit (NICU), such as the nurse/patient ratio and NICU nursing experience, on SpO_2 targeting is incompletely understood, with a suggestion of poorer saturation targeting by nurses looking after more than one infant being a factor.[17]

We sought to better understand SpO_2 targeting in a robust sample of preterm infants solely receiving CPAP. We aimed to describe their SpO_2 profile and to document the frequency of prolonged hyperoxia and hypoxia episodes, the relationships with NICU operational factors, and the frequency of FiO_2 adjustments.

Methods

We conducted a prospective observational study in preterm infants receiving CPAP and supplemental oxygen at 2 Australian tertiary neonatal centers, Royal Hobart Hospital (RHH), Hobart and Royal Women's Hospital, Melbourne (RWH). Both units use CPAP for initial and step-down respiratory support in preterm infants. CPAP is generated with either a bubble CPAP system (Fisher and Paykel HealthCare, East Tamaki, New Zealand) or a mechanical ventilator (Babylog 8000 plus, Dräger Medical Systems Inc, Notting Hill, Australia) and delivered via Hudson binasal prongs (Hudson Respiratory Care, Temecula, California), or a midline CPAP delivery system (Flexitrunk; Fisher and Paykel HealthCare) with alternating mask and prong interfaces. At the time of the study, the target range for SpO_2 was 88%-92% (inclusive) in both centers, with the lower SpO_2 alarm limit set at 85% and the upper limit set at 94% when in supplemental oxygen, and at 100% when in room air. The study period was February to November 2012. Data collection was approved by our institutional ethics committees as an audit of clinical practice.

Preterm infants <37 weeks' gestation were studied if they were younger than 4 months' corrected gestational age and receiving CPAP support. At RHH, consecutive data recordings each of 24 hours' duration were made on all such infants during the study period so long as a study investigator was available. A new recording was commenced each day if the infant remained in supplemental oxygen. At RWH, data recordings were made on selected infants receiving CPAP and supplemental oxygen. The maximum number of 24-hour recordings for any one infant was set at 25. Recording of data continued during periods of instability and deterioration, unless intubation was required. During the data recordings, all aspects of clinical management were undertaken as per usual, including nursing allocation, infant handling and care episodes, and parental contact.

Physiological data were recorded from standard bedside monitors at a sampling frequency of 1 Hz (RHH) or 0.5 Hz (RWH). SpO_2 and heart rate (HR) were sourced from either a Dräger Infinity Monitor (Dräger Medical Systems Inc, Notting Hill, Australia) or a Masimo Radical v4 oximeter (Masimo Corp, Irvine, California). SpO_2 averaging time was set at its minimum,[20] which was 2-4 seconds (Dräger Infinity monitor) or 2 seconds (Masimo). FiO_2 was continuously measured with an inline oxygen analyzer (MX300-I; Teledyne Analytical Instruments, Industry, California), sampling from the inspiratory limb of the CPAP circuit. SpO_2 and HR data were digital signals extracted via X5 (Dräger) or 9-pin RS232 (Masimo) cables; FiO_2 was an analog signal digitized via an analog-digital converter (model USB-6008; National Instruments, Austin, Texas). Data were input to a laptop computer with custom software written using LabVIEW (National Instruments). Bedside staff was not specifically informed of the recording and did not have access to the recording system. Demographic and clinical details of the study infants were collected from the patient records and charts. For patients at the RHH site, data were collected for each nursing shift on nurse/patient ratio and the bedside nurses' level of NICU nursing experience (years).

Statistical Analyses

Data were processed using purpose-built software, with all recorded data used for the analysis. Periods during which there was SpO_2 signal dropout were excluded from the analysis. The proportion of time spent in hypoxia (SpO_2 <88%), normoxia (ie, target range, SpO_2 88%-92%), hyperoxia (SpO_2 >92%), and eupoxia (normoxia or hyperoxia in air) was determined. As an indicator of severity, periods of hypoxia were further divided into level I: 85%-87%; level II: 80%-84%; and level III: <80%. Similarly, hyperoxic periods were subcategorized as level I: 93%-95%; level II: 96%-97%; or level III: ≥98%. Periods of hypoxic bradycardia (SpO_2 <80% and HR ≤100 bpm) were also identified. Frequency of prolonged episodes (≥30 seconds) of each level of hyperoxia and hypoxia, and of hypoxic bradycardia, was documented. Frequency of FiO_2 adjustments (defined as at least ±0.01 change in FiO_2) was determined from the FiO_2 signal.

To gain an overall snapshot of SpO_2 targeting in the study population, data from all recordings in all individuals were pooled and presented as SpO_2 histograms and proportions. Further, summary statistics were derived for the study infants by pooling all data from each individual. Proportions of time in the predetermined SpO_2 levels were determined, along with the frequency of prolonged hypoxic and hyperoxic episodes, and of FiO_2 adjustments, in each case reported as median and IQR. The effects of NICU operational factors on SpO_2 targeting were assessed using regression analysis of data from each nursing shift, extracted from the 24-hour recordings at RHH. Input variables were nurse/patient (1:1 vs 1:2 or greater, input as ordinal variable 0, 1), number of years of NICU nursing experience (<5 years, 5-15 years, >15 years, input as ordinal variable 0, 1, 2), and time of shift (comparing evening shift 3 p.m. to 11 p.m. with day shift 7 a.m. to 3 p.m., and night shift 11 p.m. to 7 a.m. with day shift, in both cases input as a dichotomous variable). Outcome variables were