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Oxygen titration and compliance with targeting oxygen saturation in preterm infants

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Citation

Zanten, H. A. van. (2017, March 15). *Oxygen titration and compliance with targeting oxygen saturation in preterm infants*. Retrieved from <https://hdl.handle.net/1887/46692>

Version: Not Applicable (or Unknown)

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Issue Date: 2017-03-15

Chapter 1

General Introduction



This story is a reflection about a regular day at work for “Nikki”, an experienced nurse who has worked at a neonatal intensive care unit (NICU) for more than a decade. It is seven-thirty in the morning, and Nikki has just joined her colleagues for the handover from the night shift. It was apparently a busy night in the NICU – a preterm infant, born at the end of the previous shift had taken the last available space in the unit. The team leader asks Nikki if she can care for two patients today, including the new preterm baby who still requires umbilical lines. The team leader adds, “There are not many experienced nurses around today. But don’t worry, the other baby is doing fine; he only had a few desaturation events during the night.”

Nikki first takes care of the preterm infant who had had the desaturation events the previous night. The baby is doing well and shows no signs of infection. She checks the CPAP prongs, the ventilator settings, and the alarm settings. Just before she leaves, however, the baby has another apnoea event with desaturation. Nikki turns up the oxygen level to allow the baby to recover. She makes a mental note to have the registrar check on this baby, and – because this infant does not appear to be sick – she decides to first help the registrar with the umbilical line procedure in the new preterm infant. While they perform the procedure, the oxygen saturation alarm sounds for the seemingly stable other baby, indicating that the oxygen saturation is above the target range. *“That alarm can wait a moment,”* Nikki thinks. *“I cannot leave this patient now.”* A few minutes later, a colleague comes in, after preparing medication, and asks Nikki if she needs any help. “Could you please turn off that alarm? It’s constantly ringing because the oxygen saturation is too high. I just turned the oxygen up because he was desaturated, so could you turn down the oxygen a bit?” Nikki is relieved when the alarm is silenced, as it was getting on her nerves. However, the silence does not last long, as another alarm indicates that this infant is now experiencing another desaturation event. Thankfully, her colleague comes to the rescue again and increases the oxygen level. She also follows Nikki’s advice and adjusts the upper alarm limit to get rid of this “yo-yo” effect. However, the registrar overhears this and is a bit upset regarding this decision. He worries about how the consultant will react when she hears about this. Unfortunately, Nikki has had this kind of discussion more than once. The target values are difficult to track, and the noise created by the alarms cannot be good for the other patients. Nevertheless, the registrar insists upon changing the alarm’s settings to their previous settings. Nikki is a bit annoyed by this and replies, “If the neonatal consultant wants to keep this patient’s oxygen saturation level within the intended target range, she can come to the unit, sit next to the patient, and titrate the oxygen herself. We are too busy here!”

Thanks to advances in neonatal care in the past few decades, the percentage of extremely preterm infants who survive has increased considerably. Worldwide, approximately 15 million preterm infants (defined as a gestational age below 37 weeks of gestation) are born each year; thus, one in ten pregnant women gives birth to a preterm infant.¹ In the Netherlands, approximately 14,000 preterm infants are born each year, 30% of whom are born before 34 weeks of gestation.²

Despite significant improvements in the care of preterm infants, both morbidity and mortality remain high among these infants, and this group has an increased risk of long-term disabilities. At least 50% of all neonatal mortality is due to preterm birth, and preterm infants who survive have an increased risk of developing severe complications, including intracranial haemorrhage and cerebral white matter damage, which can lead to cerebral palsy and other severe motor and/or coordination problems, epilepsy, severe cognitive impairment, and developmental coordination disorder.³ Long-term complications include an increased risk of asthma and early-onset chronic obstructive pulmonary disease (COPD).³ Given that nearly half of all severely disabled children were born preterm, this is clearly not a healthy start to life.

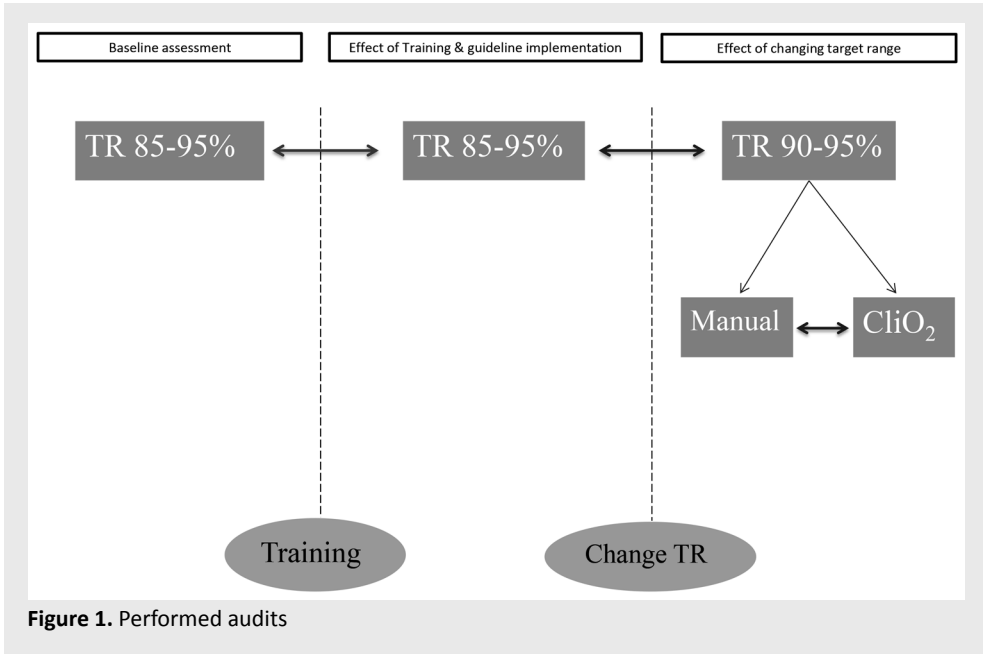
Approximately 75 years ago, the introduction of oxygen therapy greatly increased the survival of preterm infants. Today, oxygen is one of the most widely used therapeutic “drugs” in neonatal care.⁴⁻⁶ Second only to respiratory support, oxygen is the most commonly used intervention in preterm infants with respiratory insufficiency and/or apnoea, and preterm infants often receive supplemental oxygen for prolonged periods. The goal of oxygen therapy is to achieve adequate oxygenation levels using the lowest possible concentration of inspired oxygen.⁷ Unfortunately, however, supplemental oxygen therapy has an extremely narrow therapeutic range in preterm infants; as a result, these infants often develop either low blood oxygen levels (hypoxaemia) or high blood oxygen levels (hyperoxaemia), both of which can lead to increased morbidity and mortality.⁸ Preterm infants who experience hypoxaemia – defined as oxygen saturation (SpO_2) $<80\%$ – have an increased risk of cerebral palsy, patent ductus arteriosus, pulmonary vascular resistance, apnoea, and death. On the other hand, preterm infants who experience hyperoxaemia – defined as $\text{SpO}_2 >95\%$ – have an increased risk of developing complications that can include retinopathy of prematurity (ROP) and bronchopulmonary dysplasia.⁹⁻¹⁵

Pulse oximeters are commonly used to measure peripheral SpO_2 , providing a continuous measure of oxygenation.¹⁶ To prevent hypoxaemia and hyperoxaemia, the nurse routinely titrates the oxygen level manually in order to maintain SpO_2 within a prescribed target range. Strict control of SpO_2 – measured indirectly using pulse oximetry – can reduce both mortality and morbidity in preterm infants.¹⁶ However, it can be extremely difficult to implement SpO_2 policies in daily clinical practice, particularly in a neonatal intensive care setting. Titrating the oxygen level in order to maintain a narrow target range of SpO_2 can be challenging for the

nurse, particularly during and/or following an apnoea event accompanied with bradycardia and/or oxygen desaturation. Several factors can influence the nurse's compliance, which is generally defined as the extent to which the nurse adopts behaviours that are consistent with the prescribed clinical intervention.¹⁷ Several studies have reported poor compliance among nurses with respect to targeting SpO₂ levels and in SpO₂ alarms settings.¹⁸⁻²⁰ Improving compliance – which would reduce the prevalence of both hypoxaemia and hyperoxaemia – would considerably improve the outcome of preterm infants.

Auditing is an effective way to improve compliance and is widely used and recommended in nursing practice in order to improve quality of care.²¹⁻²² With auditing, the caregiver is prompted to modify their clinical practice when necessary. A clear benefit of clinical auditing is that it can be used to monitor the effectiveness of daily practice and can lead to improvements. The ability of auditing to improve effectiveness can be influenced by the caregivers themselves, particularly when they believe that the audit is relevant to their practice, when the auditing process fits within their daily routine, and when other factors apply, such as the caregiver's willingness to change.²³

In 2012, our neonatal intensive care unit audited both oxygen titration practices and compliance regarding the targeting of SpO₂. We first measured baseline performance in order to determine how oxygen was handled during oxygen titration in response to hypoxaemic events. Alarmed by the findings, we initiated a quality improvement project. To increase awareness among the staff in the NICU with respect to oxygen use, we created and implemented a guideline regarding oxygen titration. We then performed a second audit in order to evaluate the effectiveness of this new guideline. Based on the results of recent trials to study oxygen targeting, the target range for SpO₂ was narrowed towards the higher end of the target range. We then performed another audit in order to assess how this change affected the nurses' compliance with respect to targeting SpO₂ values. A final audit was performed after we implemented automated oxygen control in order to further improve targeting (Figure 1).



OUTLINE OF THIS THESIS

The general aim of this thesis project was to assess the effect of changing practices with respect to oxygen titration and compliance in preterm infants born before 30 weeks of gestation, admitted to the NICU at Leiden University Medical Centre (LUMC) in Leiden, the Netherlands. All of the preterm infants included in the study required either non-invasive or invasive respiratory support, and all infants received supplemental oxygen.

In **Chapter 2**, we discuss the literature regarding compliance with respect to targeting SpO₂ in very preterm infants within the NICU. Here, we did not limit the search criteria with respect to study design or methodology; this approach led to a variety of different aspects regarding compliance, which required a narrative-style review.

In **Chapter 3**, we report the occurrence and duration of hyperoxaemia following the administration of additional oxygen by manual titration following ABC (apnoea combined with bradycardia and cyanosis) in very preterm infants in our NICU.

Chapter 4 reports the results of an audit to assess the effect of introducing an oxygen titration guideline for SpO₂ distribution and compliance with respect to targeting SpO₂ in very preterm infants, as well as how oxygen was titrated during and following ABC.

In accordance with both European and Dutch guidelines, the SpO₂ target ranges were adjusted. Specifically, the target range for SpO₂ in preterm infants was narrowed from 85-

95% to 90-95%. In **Chapter 5**, we describe the effect of this smaller target range on SpO₂ distribution, compliance regarding the targeting of SpO₂, and how ABC is treated in preterm infants.

In **Chapter 6**, we describe the effect of implementing automated oxygen control in preterm infants with respect to SpO₂ distribution, compliance regarding the targeting of SpO₂, and the way in which oxygen is titrated in response to ABC. In **Chapter 7**, we provide a follow-up on **Chapter 6** by reporting the effect of implementing automated oxygen control on ABC in preterm infants.

In **Chapter 8**, we discuss the main findings of this thesis, and we provide future perspectives. English and Dutch summaries are presented in **Chapter 9**, and the references are provided in **Chapter 10**.

