Variation in Oxygen Saturation Measurements in Very Low Birth Weight Infants

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ABSTRACT

Low birth weight is heavily correlated with health issues. Very low birth weight (VLBW) infants, with a birth weight below 1500 g, are particularly at risk, and often subject to multiple developmental problems.

The Neonatal Intensive Care Unit (NICU) at Helsinki University Central Hospital has been collecting patient data in a database since 1999. We studied data collected from 2059 VLBW infants admitted between 1999 and 2013. Our aim was to study the variance of oxygen saturation measurements and compliance with guidelines as an example of using statistical means to assess quality of care from vital trend measurements. As an example of quality control, we have studied the discrepancy between automatic measurements and manual readings taken from the same sensor output.

Categories and Subject Descriptors

G.3 [**Probability and Statistics**]: Correlation and regression analysis; H.2.8 [**Database Management**]: Database Applications—*data mining*; J.3 [**Life and Medical Sciences**]: Medical information systems

Keywords

quality control; neonatology; oxygen saturation; very low birth weight infants

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1. INTRODUCTION

Preterm infants are babies born before the gestational age of 37 weeks [1]. While preterm infants represent roughly 10% of all births, they represent over two thirds of all infant deaths [4]. Preterm birth is associated with life long risks of medical and social disabilities [6]. Particularly at risk are Very Low Birth Weight (VLBW) infants (birth weight < 1500 g) [3].

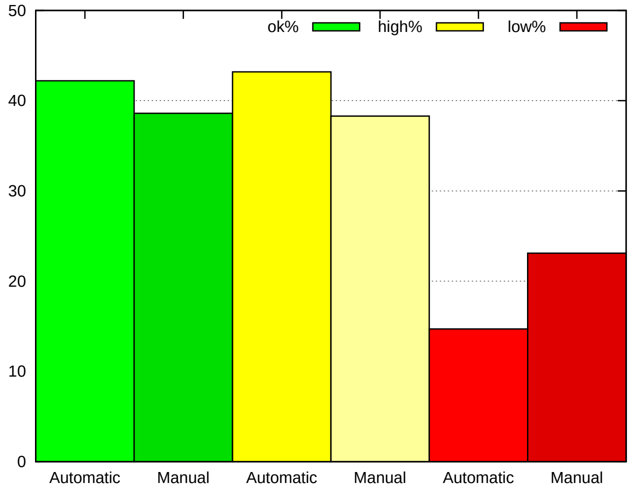
VLBW infants are vulnerable to both high and low oxygen (O_2) saturation. Blood O_2 saturation is monitored closely in order to prevent the adverse effects of inadequate or excessive oxygenation, such as bronchopulmonary dysplasia (BPD) [7] and retinopathy of prematurity (ROP) [2]. Even though O_2 therapy has been used in the treatment of preterm infants since the 1940s, there is considerable uncertainty associated with determining optimal O_2 saturation levels [8].

A variety of factors can lead to poor O_2 saturation in VLBW infants. These include clinical problems, such as respiratory distress syndrome (RDS) and bronchopulmonary dysplasia (BPD) [7], apneas, periodic breathing and infections. Moreover, invasive testing and procedures, such as taking blood samples, clinical examinations, suctioning of the airways and even changing the position of the baby can decrease saturation. In contrast, too high saturation is primarily caused by unnecessarily high levels of supplemental O_2. Saturation compliance data can help to identify the situations where O_2 saturation falls outside the target range.

2. BACKGROUND

The Neonatal Intensive Care Unit (NICU) at Children's Hospital, University of Helsinki is a Level III[1] NICU in Southern Finland covering 18000 deliveries per year. The NICU treats 400–500 patients per year, of whom 100–150 are VLBW infants.

[1]A neonatal intensive care unit that is capable of caring for the smallest and sickest of newborn babies.



	OK	High	Low
Automatic	42.2%	43.2%	14.7%
Manual	38.6%	38.3%	23.1%

Figure 1: O_2 saturation target compliance.

Throughout the care period in the NICU, vital statistics such as blood pressure and O_2 saturation are monitored with various sensors. Some statistics, such as weight and head circumference, are measured periodically by NICU staff. Since 1999, the sensor and measurement data has been stored in a database for research use. We have started to study the documented vital trends by looking at O_2 saturation and analyzing its variance and compliance with existing guidelines. Our aim is to identify factors affecting O_2 saturation compliance by statistical means and thereby to improve quality of care.

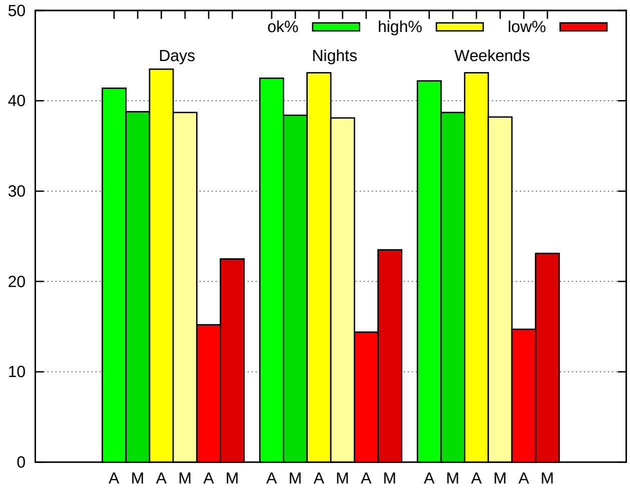
3. METHODS

We studied O_2 saturation data collected from 2059 VLBW infants treated in the Helsinki Children's Hospital NICU between 1999 and 2013. Median gestational age at birth was 202 days (H28+6) and median birth weight was 1102 g. O_2 saturation was measured by pulse oximetry [10].

A total of 463180 manual readings and 31347035 automatic measurements were taken. Both manual readings and automatic measurements came from the same pulse oximeters. Automatic measurements are 2 minute averages of median oxygen saturations for 10 second intervals. Manual readings were entered in the database by staff and represent the instantaneous oximeter value at the time of reading. The patient-specific target range for O_2 saturation was likewise entered in the database, along with any changes to the target range that occurred during the patient's stay in the NICU.

Patient data was anonymized by removing all fields with personal information on export of the database, leaving only the patient ID (an integer with no relevance outside the database) to distinguish between patients. The study was approved by the Helsinki University Central Hospital Ethics Committee, decision number 115/13/03/00/14 dated 8 April 2014.

4. RESULTS



		OK	High	Low
Automatic	Weekday	41.4%	43.5%	15.2%
	Weeknight	42.5%	43.1%	14.4%
	Weekend	42.2%	43.1%	14.7%
Manual	Weekday	38.8%	38.7%	22.5%
	Weeknight	38.4%	38.1%	23.5%
	Weekend	38.7%	38.2%	23.1%

Figure 2: O_2 saturation target compliance divided by time period.

Fig. 1 shows O_2 saturation target compliance for automatic measurements and manual readings for all VLBW patients.

The readings and measurements were divided into three time periods: weekdays (Mon–Fri 08–15h), weeknights (Mon–Fri 00–08h, 15–24h) and weekends (Sat–Sun). Fig. 2 shows O_2 saturation target compliance divided by time period.

In order to assess whether the proportion of O_2 saturation measurements which are within bounds are equal in the three time periods, we marked values inside the target range with 0 and values outside the target range with 1 and ran a one-way ANOVA test [5] for the three groups of data. The p-values were $p = 0.0177$ for manual readings and $p = 3.0278 * 10^{-202}$ for automatic measurements, indicating that the three groups do not share the same proportion of within bounds O_2 saturation values.

Fig. 3 shows a histogram of all O_2 saturation readings and measurements. O_2 saturation percentage is shown on the X axis, number of readings and measurements on the Y axis. As can be seen from the figure, there are peaks at every 10% (and lesser peaks at every 5%); this suggests that the manually recorded readings have to some extent been rounded to the nearest 10% (5%) before entering them in the database. Since the main interest in O_2 saturation readings is adherence to target range, the exact value of the reading is clinically less interesting. There are only 7 patients in the data set for whom the lower limit of the target range was at any time below 80%. The lower limit was never less than 60%.

5. CONCLUSIONS

The analysis of O_2 saturation data showed a difference in target compliance when comparing automatic measurements

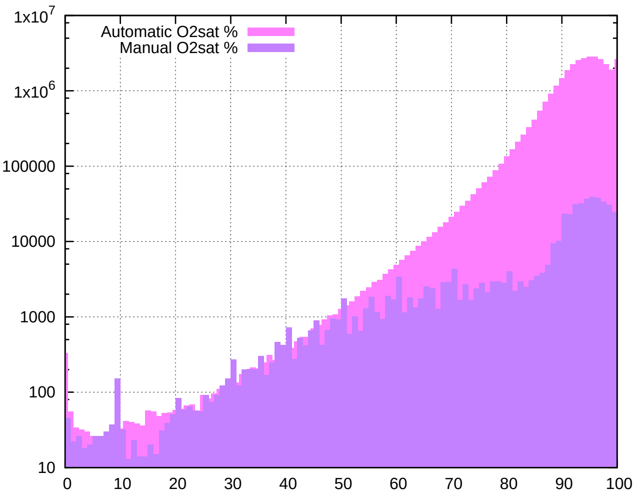


Figure 3: O_2 saturation measurements 1999–2013.

and manually entered readings. The difference was greatest in measurements below the target range, 14.7% vs 23.1%. Part of the difference is due to manual readings representing instantaneous oximeter value at the time of reading and automatic measurements average over longer period of time. However, manual readings are also prone to observer bias, as shown in Fig. 3.

Manual readings are taken during routine care, when nurses chart various parameters, such as pulse, temperature and O_2 saturation. Manual readings are also entered when there is a problem with the patient, such as apnea. This may lead to manual readings overrepresenting too low and to a lesser extent too high saturation values. Discrepancy between manual recordings of O_2 saturation and continuous automated sampling was recently reported in adult surgical and medical patients in a 16-patient study [9]. Understanding the limitations of both methods is crucial if O_2 saturation is used in calculating clinical risk scores or other prognostic tools.

In our study target compliance also differed when comparing fully staffed normal working hours with periods of lower staff presence. Interestingly, automatic measurements showed worst compliance during weekdays, and manual readings during weeknights. Weekdays in the NICU are filled with examinations, laboratory testing and other invasive procedures, which disturb the baby and cause changes in O_2 saturation. Weeknights and weekends are more peaceful, but staff presence is lower. This may be reflected in fewer routine manual readings and overrepresentation of readings entered during problems.

6. FUTURE WORK

Poor O_2 saturation compliance can be a symptom of a serious clinical problem. We plan to combine the saturation data to adverse patient outcomes to analyze if it could be used as a prognostic tool or as an early warning sign of threatening preventable problems, such as infections.

We have studied manual O_2 saturation readings and compared them with automatic measurements as an example of using physiological sensor data in assessing quality of care in a NICU. In future work we shall assess how adherence to oxygen targets affects treatment time and complications, such as BPD, necrotizing enterocolitis (NEC), and ROP, and ultimately patient mortality. Combining this data to quantification of out-of-bounds saturation measurements would give more insight whether depth or duration of desaturation or oversaturation is clinically most relevant. The challenges lie in combining information from multiple channels and isolating the effect of varying circumstances in the presence of a number of complications, as is the case with many VLBW infants.

The authors declare no competing financial interests.

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