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RESEARCH ARTICLE

Clinical Audit on Adherence to NICU Protocol for Safe Pulse Oximetry Application at a Tertiary Care Hospital.

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Abstract: ***Background***: Monitoring vital signs safely and efficiently in the neonatal intensive care unit is crucial to effective management. Pulse oximetry is a method applied for non-invasive measurement of oxygen saturation and heart rate. However, if pulse oximetry probes are left attached for extended periods without supervision, they may cause thermal and pressure injuries, specifically in neonates, whose skin is extremely delicate. ***Objective:*** This audit aimed to assess compliance with the NICU protocol for safe application and monitoring of pulse oximetry. It also aimed to evaluate whether probe rotations and skin checks were performed at recommended intervals. ***Methods:*** A prospective clinical audit was conducted in the neonatal intensive care unit at Pak Red Crescent Medical College, Dina Nath, Lahore. The initial audit included 30 neonates requiring continuous pulse oximetry monitoring from August 20 to September 30. Data was collected using a structured proforma. Following the initial audit, staff education and training were provided. A re-audit was conducted from October 22 to November 30 with 23 neonates.*Results:* In the initial audit, 30 neonates were observed. Of these, 21 were term neonates, 7 were preterm, and 2 had no documented gestational age. There were 16 females and 14 males; sixteen neonates (53.3%) sustained burn injuries. In the case of term neonates, 14 out of 21 (66.7%) had burn injuries. In the case of preterm neonates, only 1 out of 7 (14.3%) had burn injuries. As for skin cleaning before probe application, only 2 neonates (6.7%) had it. The average time for probe application was 8.7 hours. In the follow-up audit, 23 neonates were assessed. There were no burn injuries. All 23 neonates (100%) had skin cleaning before probe application. The mean duration of probe application was 4.9 hours.***Conclusion:*** The initial audit revealed significant gaps in adherence to pulse oximetry safety protocols. The re-audit demonstrated dramatic improvements after staff education and protocol implementation. Burn injuries were completely eradicated. Regular monitoring and further audits are suggested to maintain long-term compliance.

Keywords: Pulse oximetry, neonatal intensive care unit, burn injury, protocol adherence, clinical audit, quality improvement .

INTRODUCTION

The term "audit" is inferred from the Latin "audire," which means "to hear." It shows active listening and also the holding of an inquiry. If you refer to it in English, "audit" is the checking or examination of an organization's financial records. It is generally carried out by a different, independent entity, not by somebody assigned internally. Clinical audit in the healthcare sector is a quality improvement tool that involves a systematic review of care against explicit criteria to enhance patient care and outcomes [1].

Careful and secure monitoring of vital signs in the neonatal intensive care unit is essentially crucial for efficient overall management. Pulse oximetry offers a non-invasive method for checking oxygen saturation and heart rate. It matters greatly in the respiratory management of very sick newborns because it supports day-to-day care. It can also identify and stop hypoxia and apnea early; consequently, clinical outcomes improve, and mortality decreases [2].

Due to high sensitivity (44% to 76%) and specificity (85% to 90%), pulse oximeters are great tools providing instant feedback. Therefore, they are widely used for continuous monitoring in the ICU and operating theaters [3].

Neonatal skin, particularly preterm skin, is more fragile and vulnerable because of reduced subcutaneous fat and impaired thermoregulation. The skin is evolving functionally and structurally in the fetus. As early as week 4, the fetus has two layers of skin: the basal layer and the periderm, the outer one [4]. The preterm baby's skin is less functional, and therefore, the risk of it being injured is even higher. Indeed, the flexibility of skin maturation in neonates is one of the reasons for the unique properties of infant skin [5].

Despite its benefits, pulse oximetry has some drawbacks. Most of these drawbacks are preventable with proper monitoring. Pulse oximetry can cause superficial thermal and pressure injuries. Contributing factors include prolonged probe attachment, tightly attached probes, poor perfusion, and device malfunction [6]. Thermal and pressure injuries can increase the risk of infection, prolong hospital admission, and cause discomfort for both the patient and attendants [7].

Finger injuries caused by the use of a pulse oximeter included chemical burns, thermal burns, sunburn, pressure erosion, sensory loss, and gangrene. The exact pathophysiological mechanisms of these complications have not been conclusively elucidated. However, pressure ischemia, prolonged usage, probe overheating, misuse, and short-circuiting are thought to be the major factors [8].

Conducting an audit of pulse oximetry-related burns in the NICU can provide insight into whether standard recommendations and protocols are being followed. This can contribute to improved patient care. The conclusions can help identify interventions to reduce the incidence of burn injuries in the NICU [9].

Adherence to established international guidelines for pulse oximetry attachment in the NICU will improve patient care and management. It will also reinforce the confidence of the overseeing staff and parents' trust in the treatment provided [10].

MATERIALS AND METHODS

Study Design

This prospective clinical audit used a pre-post intervention design. It aimed to assess compliance with the NICU protocol for safe application and monitoring of pulse oximetry. The audit also aimed to reduce the incidence of thermal and pressure injuries in neonates.

Study Setting

The study was conducted in the neonatal intensive care unit at Pak Red Crescent Medical College, Dina Nath, Lahore. This is a tertiary care hospital.

Study Population

The audit included neonates requiring continuous pulse oximetry monitoring. The initial audit included 30 neonates. The re-audit included 23 neonates.

Inclusion Criteria

- Neonates admitted to the NICU
- Neonates requiring continuous pulse oximetry monitoring
- Neonates whose parents provided informed consent

Exclusion Criteria

- Neonates with pre-existing skin conditions at the probe site
- Neonates with congenital skin abnormalities
- Neonates transferred out of the NICU before completion of monitoring

Data Collection

Data was collected using a structured proforma. The following information was recorded for each patient: medical record number, patient name, gender, age, date and time of admission, gestational age (preterm or term), diagnosis, site of probe application, cleaning of the site before application, and duration of probe application.

Protocol Standards

The audit used the following international guidelines:

- The Royal Children's Hospital recommends rotation of the pulse oximeter probe every two hours [11].
- BioMed Central UK recommends covering the skin under the probe with micropore surgical tape or gauze to prevent skin injury without affecting the accuracy of readings [12].
- The Ministry of Health recommends cleaning the skin before probe application and ensuring proper alignment of the emitter and detector [13].

Infants naturally acquire precise heart rate data faster when the sensor is applied to their right hand or wrist before connecting it to the pulse oximeter, compared with other techniques. This is ordinarily applied in the intensive and special care settings. The stated method must be used during resuscitation [14]. Most of the few thermal skin injuries related to pulse oximetry so far were the result of increased probe temperature due to inappropriate combinations of incompatible units of technical equipment or internal malfunctions within the probe [15].

Intervention

Following the initial audit, the results were shared with the head of the department and all NICU faculty and nurses. The pediatrics department and staff nurses attended a training workshop. For the re-education, protocol leaflets were handed out. The training emphasized that the pulse oximetry probe should be rotated every two hours and that skin integrity should be inspected, especially in preterm neonates. This was performed to reduce the frequency of thermal and pressure-related burns and to maintain skin integrity. A re-audit was conducted to evaluate compliance with the established guidelines. The results of the initial audit and the re-audit were compared.

Statistical Analysis

MS Excel was employed to store and statistically analyze the collected data. For categorical variables, frequencies and percentages were computed. For continuous variables, means and standard deviations were computed. The chi-square test or Fisher's exact test was applied to measure differences in group proportions between the first audit and the re-audit. The outcomes

were considered statistically significant when the p-value fell below 0.05.

Ethical Concerns

The Institutional Ethics Committee properly ratified the research. Parents or guardians of the neonates imparted their written consent.

RESULTS

Demographic Characteristics

During the initial audit, a total of 30 infants were examined. In that group, 16 were female (53.3%), and 14 were male (46.7%). Then, regarding gestational timing, 21 infants were full-term (70.0%), 7 were premature (23.3%), and 2 had gestational age not been recorded (6.7%). For the re-audit, 23 babies were also evaluated. At this suitable time, 10 females (43.5%) and 13 males (56.5%) were counted. About gestational age, 18 infants (78.3%) were full term, and 3 (13.0%) were premature. And 2 (8.7%) had gestational age unknown, essentially not documented. Table 1 presents the demographic characteristics of babies across both audit phases.

Table 1: Demographic Characteristics of Neonates

Characteristic	Initial Audit (n=30)	Re-Audit (n=23)
Gender		
Female	16 (53.3%)	10 (43.5%)
Male	14 (46.7%)	13 (56.5%)
Gestational Age		
Term	21 (70.0%)	18 (78.3%)
Preterm	7 (23.3%)	3 (13.0%)
Not documented	2 (6.7%)	2 (8.7%)

Burn Incidence

In that first audit, burn injuries happened in 16 neonates (53.3%). For term babies, 14 out of 21 (66.7%) ended up with burn injuries. For preterm neonates, only 1 out of 7 (14.3%) had burn injuries, and in the group where gestational age was not recorded properly, 1 out of 2 (50.0%) showed burn injuries. In the re-audit, apparently, there were no burn injuries at all among neonates (0%). Table 2 also shows the frequency of burn injuries by gestational age across both audit phases.

Table 2: Incidence of Burn Injuries by Gestational Age

Gestational Age	Initial Audit		Re-Audit	
	Number of Patients	Burn Incidence	Number of Patients	Burn Incidence
Preterm	7	1 (14.3%)	3	0 (0%)
Term	21	14 (66.7%)	18	0 (0%)
Not documented	2	1 (50.0%)	2	0 (0%)

Site Cleaning Compliance

During the initial audit, only 2 neonates (6.7%) had their skin cleaned before probe application, despite our expectation that more would. 26 neonates (86.7%) did not have skin cleaning. For 2 neonates (6.7%), the details were not documented properly. In the re-audit, all 23 neonates (100%) had skin cleaning before probe application. Table 3 shows compliance with site cleaning in both audit phases.

Table 3: Compliance with Site Cleaning Before Probe Application

Site Cleaning	Initial Audit (n=30)	Re-Audit (n=23)
Yes	2 (6.7%)	23 (100%)
No	26 (86.7%)	0 (0%)
Not documented	2 (6.7%)	0 (0%)

Duration of Probe Application

The first review exhibited that the average time for using the probe was about 8.7 hours (standard deviation: 6.1 hours; range: 1 to 24 hours). Only 5 newborns (16.7%) had the probe used for 4 hours or less. 14 newborns (46.7%) had the probe used for 4 to 8 hours. And 11 newborns (36.7%) had the probe in for over 8 hours. The second review indicated a revised estimate. On average, the probe was applied for approximately 4.9 hours (standard deviation: 1.1 hours; range: 2 to 7 hours). Only 2 newborns (8.7%) had the probe last for 4 hours or comparatively less. 21 newborns (91.3%) had the probe

used for 4 to 8 hours. None of the newborns had the probe employed for more than 8 hours. Table 4 presents the duration of probe use in the two audit phases.

Table 4: Duration of Probe Application

Duration	Initial Audit (n=30)	Re-Audit (n=23)
4 hours or less	5 (16.7%)	2 (8.7%)
4 to 8 hours	14 (46.7%)	21 (91.3%)
More than 8 hours	11 (36.7%)	0 (0%)
Mean duration (hours)	8.7	4.9
Standard deviation	6.1	1.1

Site of Probe Application

In the first audit, the probe was most commonly attached to the right foot (53.3%). The other locations were the left foot, both feet, and the right arm, combined with the right foot. In the second audit, the right foot was still the most common site (60.9%). However, multiple-site usage was more frequent (26.1%) than during the first audit. Table 5 presents the locations of probe applications across the two audit phases.

Table 5: Site of Probe Application

Site of Application	Initial Audit (n=30)	Re-Audit (n=23)
Right foot	16 (53.3%)	14 (60.9%)
Left foot	6 (20.0%)	4 (17.4%)
Both feet	5 (16.7%)	4 (17.4%)
Right arm + Right foot	2 (6.7%)	1 (4.3%)
Not documented	1 (3.3%)	0 (0%)

Details from Clinical Notes

The key points from the clinical notes in the first audit were that the probe was tethered too firmly. It remained in place for an extended period and was not moved. It was noted that preterm infants are very vulnerable. The second audit noted that the probe was changed every 4 hours and properly cleaned, and that there was better compliance with the protocol.

DISCUSSION

The first audit exposed serious lapses in compliance with standardized protocols for pulse oximetry application in the NICU. A mere 6.7% of neonates had their skin cleaned before probe application. More than a third of neonates had the probe on for over 8 hours. Burn injuries occurred in 53.3% of neonates, and the entire episode needed immediate action to boost patient safety.

The re-audit results show great progress across the board. The skin cleansing rate went up from 6.7% to 100%. It is quite striking. The average probe duration was reduced from 8.7 hours to 4.9 hours. It seems substantial. Most importantly, burn injuries were totally removed. The changes likely result from the staff education and training program conducted between the two audit phases.

The ratio of burn injuries was higher in term neonates (66.7%) than in preterm neonates (14.3%) in the first audit. One might expect this result to be unexpected, as preterm neonates have thinner skin. However, it may indicate that the term neonates in this paper refers to those with longer probe application times and more tightly attached probes. Besides, the limited number of preterm neonates (n=7) may also make this finding less representative. Larger sample-size studies are required to confirm and clarify this relationship.

According to the protocols set by the American Academy of Pediatrics, the pulse oximeter probe should be applied on the right arm (pre-ductal) or right foot (post-ductal). It should be rotated every two hours. The skin should be cleaned and dried before application. Skin integrity should be checked regularly. The probe should not be applied too tightly [16].

The Royal Children's Hospital recommends rotating the pulse oximeter probe every 2 hours to prevent pressure and thermal injuries [11]. BioMed Central UK recommends covering the skin beneath the probe with micropore surgical tape or gauze to prevent skin injury without affecting reading accuracy [12]. The Ministry of Health recommends cleaning the skin before applying the probe and ensuring proper alignment of the emitter and detector [13].

The findings of this audit are consistent with previous studies. Desai reported a case of second-degree burn in a neonate due to pulse oximetry probe injury [17]. Broom et al. emphasized the need to predict neonatal skin injury as the first step toward reducing it [18]. Ceran et al. reported management of pulse oximeter probe-induced

finger injuries in children and reviewed the literature [19].

O'Donnell et al. found that applying the sensor to the right hand or wrist before connecting it to the pulse oximeter results in faster acquisition of accurate heart rate data in infants [14]. Mills and G.H. reported a burn caused by pulse oximetry and emphasized the importance of proper probe use [15].

The introduction of educational pamphlets and staff training led to a remarkable reduction in the frequency of burn injuries. This supports the effectiveness of audits and feedback as quality improvement tools in healthcare [20].

Limitations

This audit had several limitations. They were small sample sizes (n=30 and n=23). It was a single-center study. Some data fields had incomplete documentation. The re-audit sample size was smaller than the initial audit. The duration standardization required interpreting hourly entries. These limitations should be prudently considered when interpreting and analyzing the findings.

CONCLUSION

Overall, the audit findings reveal a clear need to focus on and improve compliance with standard guidelines for pulse oximetry in the NICU. If the Pak Red Crescent Hospital NICU consistently follows those standards, it helps the unit prevent burn injuries and deliver the best possible care for patients.

The re-audit report shows a drastic drop in burn and skin injury rates. The site cleaning compliance was 100%. The duration of probe application was kept within safe limits. Burn injuries were entirely eradicated in this audit cycle.

It is advisable to conduct regular audits and follow-up sessions to ensure that the laid-down rules are being adhered to. When these policies are strictly observed, they usually lead to continued improvements in safety and patient care, particularly in the NICU.

RECOMMENDATIONS

The audit findings have been used as a basis for these recommendations:

1. Continue mandatory site cleaning before every probe application.
2. Maintain a regular probe rotation schedule every 2 to 4 hours.
3. Monitor attachment tightness, especially in preterm infants.
4. Document site rotation in patient records.
5. Continuously conduct re-audits to determine whether the staff compliance level has been maintained.
6. Provide continuing education, learning, and training opportunities for staff.
7. Use protective barriers while you probe, such as micropore tape or gauze.
8. Keep ensuring proper alignment of the emitter and detector.

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CONFLICTS OF INTEREST

The authors affirm that there are no conflicts of interest associated with this research endeavor.

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