Neonatal Capillary Blood Sampling: Techniques, Challenges, and Clinical Significance

1Ghdir Abduleah Khalil, 2Ruba Mohammed Alhawsawi, 3Nouf Hamed Altalhi, 4Wafa Moslim Al-Fahmi, 5Maha Ayed Al-Sohaimi

[1]*Phlebotomist, Alhada Armed Forces Hospital, Taif, Saudi Arabia*
[2]*Phlebotomist, Alhada Armed Forces Hospital, Taif, Saudi Arabia*
[3]*Phlebotomist, Alhada Armed Forces Hospital, Taif, Saudi Arabia*
[4]*Phlebotomist, Alhada Armed Forces Hospital, Taif, Saudi Arabia*
[5]*Phlebotomist, Alhada Armed Forces Hospital, Taif, Saudi Arabia*

Abstract

Neonatal capillary blood sampling is a common and invasive test performed to diagnose and screen newborns. This paper is a detailed discussion of the means, major difficulties, and role of capillary blood sampling in the neonatal population. It refers to recently updated articles to examine the differences between two blood collection methods (i.e. heel lance and venipuncture), employing efficacy and pain response as criteria. As a result of special attention being paid to the accuracy of capillary bilirubin measurements against venous samples, the authors highlight the differences and put forward potential solutions for clinical interpretation. The text also describes the procedures that help prevent pain during sample collection, while maintaining the quality of the sample. These procedures, together with the study results, are presented through visual aids. The purpose is to bring together the existing literature in order to develop a safe, effective, and reliable neonatal capillary blood sampling technique that will lead to better neonatal care outcomes.

Keywords: Neonatal capillary blood sampling, heel lance technique, venipuncture in neonates, bilirubin measurement accuracy, phlebotomy best practices, pain management in neonatal procedures

1. Introduction

Neonatal blood sampling is one of the most basic and yet most critical procedures in the diagnosis, monitoring, and screening of various medical conditions in newborns. Out of all the available methods, capillary blood sampling (CBS), primarily performed using a heel lance, is the most common method of implementation. It's preferred due to its relative simplicity and wide availability, as well as the small blood volume it requires [1, 5]. This method is necessary for the performance of some laboratory tests, including complete blood counts, blood biochemical analyses (e.g., electrolytes, glucose, bilirubin levels), and essential metabolic screening for phenylketonuria, hypothyroidism, and other conditions [5]. However, using the capillary blood sampling method in neonates is also problematic in several ways. Neonates, especially premature and sick infants, are fragile and require very gentle handling at all times, particularly during medical procedures. Although the heel lance is less invasive than a vein puncture, the stress and pain of the procedure can cause strong reactions indicating pain and discomfort. More specifically, infants may cry, change their facial expressions to express their discomfort, and move their bodies in a manner indicative of pain [3, 5]. Thus, measures to reduce pain and distress during CBS are fundamental to protecting the welfare and well-being of the baby while simultaneously enabling successful collection of the required sample.

Another key consideration when evaluating and conducting neonatal capillary blood sampling is the accuracy and quality of the results obtained during the procedure. For example, several studies have examined the issue of differentiation between results obtained from capillary and venous blood, particularly for substances such as bilirubin [1, 2]. Accurately determining the level of bilirubin is crucial during the treatment of neonatal hyperbilirubinemia, a common condition with the potential to cause kernicterus and affect brain function [1]. As a result, understanding the differences between sampling methods, including when they agree and their potential biases, is key to sound clinical decision-making.

2. Objectives

The primary goal of this scientific article is to outline the methods of capillary blood sampling in neonates, focusing on the techniques, related difficulties, and clinical significance of the procedure. A detailed examination will be made of comparative effectiveness and pain reactions of heel lance versus venipuncture, the concordance between capillary and venous bilirubin measurements based on the latest studies, and recommendations for optimizing the procedure. By bringing together the information in these sources and related literature, the paper intends to serve as a valuable resource for medical staff working in neonatal care, ultimately assisting in the implementation of safer and more efficient blood sampling methods for this vulnerable patient population.

3. Techniques and Procedures in Neonatal Blood Sampling

Blood sampling from infants is a very sensitive procedure that requires absolute accuracy and thorough knowledge of the physiological variations in this group of patients. The main ways to collect blood samples from babies are capillary blood sampling (usually via a heel lance) and venipuncture. Each method has unique indications, steps, benefits, and drawbacks.

3.1 Capillary Blood Sampling (Heel Lance)

Capillary blood sampling, which is usually completed through a heel lance, is the most frequent invasive procedure in hospitalized neonates [5]. A small cut is made on the heel to draw blood for different lab analyses. The perceived simplicity and safety of the procedure, together with the small sample volume it involves, make it a preferred method for a variety of routine tests [5].

3.1.1 Procedure

When performing a heel lance, proper procedure is essential to minimizing the patient's discomfort and the risk of complications. Using the correct technique also ensures the sample is adequate. The necessary steps in this procedure include:

• **Site Selection**: The sole is the recommended area for puncturing the heel. More specifically, lancing the lateral or medial parts of the heel helps prevent damage to the calcaneus bone. Figure 1 demonstrates the appropriate puncture sites [5].

Appropriate Areas for Capillary Blood Sampling

• **Warming the Heel:** In the past, it was a common practice to heat the heel before puncture to enhance blood flow and enable sample collection. However, some studies show that warming may not have a significant impact on reducing pain or the ease of blood collection [5].

• **Antisepsis:** The area of the puncture must be cleaned with a suitable antiseptic solution, such as 70% isopropyl alcohol. The site should be allowed to completely air dry to prevent hemolysis and infection.

• **Puncture:** The use of a sterile, automated lancet is advised when making the incision. Automated lancets are preferrable since they provide a specific, controlled puncture depth, which has been proven to result in less pain, shorter blood collection time, and less hemolysis compared to conventional lancets [5]. To avoid injury to the bone, the highest recommended depth of the puncture with the use of a lancet is 2.4 mm [5].

• **Blood Collection:** The first drop of blood is usually rubbed away to avoid contamination from tissue fluid. Depending on the test, the proceeding drops are taken into capillary tubes or on filter paper. In this case, the use of gentle pressure on the surrounding tissue may be allowed, but one should be careful not to apply excessive pressure as it can cause hemolysis and dilute the sample with tissue fluid.

• **Post-Procedure Care:** After collection, pressure is applied to the puncture site to stop the bleeding. A bandage may be put on if there is a need.

3.1.2 Advantages of Heel Lances

• **Accessibility:** The heel is considered the most easily accessible part of a newborn’s body.

• **Small Sample Volume:** The heel is a good choice for tests that require only a small amount of blood.

• **Perceived Ease:** This method is widely seen as less painful and quicker than venipuncture and thus requires less skilled training [5].

3.1.3 Disadvantages of Heel Lances

• **Pain:** Even though a heel lance is less invasive than a venipuncture, it is a painful procedure for newborns. Babies show different pain symptoms, such as crying and facial grimacing [3, 5].

• **Sample Quality:** If the procedure is performed incorrectly, there is a risk clotting, hemolysis, and contamination with tissue fluid.

• **Repeated Punctures:** Repeated heel lancing can cause the affected area to become inflamed and damaged, increasing local sensitivity in the heel [5].

• **Limited Volume:** A heel lance is not appropriate for large volume samples or certain tests, such as blood cultures or coagulation profiles [5].

3.2 Venipuncture

Venipuncture refers to the process of collecting blood directly from a vein, usually in the hand, foot, or antecubital fossa. Historically, it has been viewed as more technically complicated than a heel lance. However, recent research shows that, when performed by a competent phlebotomist, venipuncture can be less painful and more successful when collecting adequate blood samples for term neonates [3,4].

3.2.1 Procedure

• **Site Selection:** Venipuncture is typically performed on veins on the back of the hand or foot or the antecubital fossa. In the case of a newborn baby, the dorsal hand veins are usually chosen because they are most visible.

• **Preparation:** As with a heel lance, the site is cleaned with an antiseptic solution. A tourniquet can be placed gently above the selected spot to enlarge the vein for easier collection.

• **Puncture:** A thin needle is inserted directly into the vein. A butterfly needle, which is a 23 or 25 gauge winged steel needle, is a common choice.

• **Blood Collection:** Blood is drawn into a syringe or evacuated tube. Using gentle suction to prevent vein collapse is essential, particularly for smaller veins [4].

• **Post-Procedure Care:** After collection is complete, pressure is applied at the insertion point until bleeding stops and a bandage is put in place.

3.2.2 Advantages of Venipuncture

• **Less Pain:** Scientific publications show that venipuncture leads to less suffering if it is carried out by a skilled specialist, as compared to the cutting of the heel in term neonates [3, 4].

• **Better Sample Quality:** In general, venous blood samples are less prone to hemolysis and contamination than capillary samples, which is the main reason why venous blood samples allow for performing a wider range of tests, including blood culture and coagulability studies [4, 5].

• **Adequate Volume:** It is much easier to collect a sufficient amount of blood for multiple tests during a single venipuncture procedure.

3.2.3 Disadvantages of Venipuncture

• **Skill Requirement:** Phlebotomists need to be very skilled and experienced to be able to perform venipuncture successfully every time [3, 4].

• **Vein Access:** The procedure is difficult in some neonates, including dehydrated or very small infants, as well as those who have undergone repeated collections and consequently have limited venous access.

• **Potential Complications:** While unlikely, particularly when proper care is taken, patients can develop complications, including hematoma, infection, or nerve damage [5].

3.3 Pain Management During Blood Sampling

The painful nature of both venipuncture and heel lance procedures makes the use of effective pain relief methods vital during neonatal blood sampling. Non-pharmacological methods of intervention, such as giving the infant sweet-tasting solutions (glucose and sucrose) and non-nutritive sucking (using a pacifier), have been found to be very effective in the reduction of pain during heel lances and venipunctures [3, 5]. In addition, skin-to-skin contact (Kangaroo care) and parental holding can be sources of comfort and contribute to reduced levels of distress [5]. The practice of using automated lancets is confirmed as one of the most important pain reduction methods as it allows the procedure to be completed more quickly and thus lessens tissue trauma [5].

4. Bilirubin Measurement and Discrepancies

The accurate measurement of bilirubin in neonates is vital for the early diagnosis and treatment of hyperbilirubinemia, a common condition that can lead to severe neurological sequelae if not properly treated. Even though venous blood sampling is usually the method of reference for bilirubin measurement, capillary blood sampling is commonly performed because of its easier accessibility. However, a number of differences between capillary and venous bilirubin levels have been found over time, and as a result, the values must be interpreted with great caution.

4.1 Comparison of Capillary and Venous Bilirubin Measurements

The question of how well measurements of bilirubin in capillary blood agree with those in venous blood has been the subject of several investigations. Most of these studies unveil some inconsistencies that might alter the clinician's choice of therapy. We have summarized the main differences in our review of the relevant literature as follows:

• **Leite et al. (2022) [1]:** The study by Leite et al. compared the total bilirubin measurement that was done by the laboratory colorimetric method (venous blood) and direct spectrophotometry of capillary blood. The result showed that the mean serum was 11.9 mg/dL, while the mean capillary measurement was 9.2 mg/dL. The mean difference between the two methods was -2.73 mg/dL, which suggests that capillary values were consistently lower than serum values. The study also indicated that to make laboratory and capillary values comparable, multiplying capillary values by 1.3 mg/dL was proposed, with a high correlation (R^2 = 0.88) between the two methods.

• **Leslie et al. (1987) [2]:** In the earlier research paper by Leslie et al., it was reported that capillary samples were usually lower than venous bilirubin results, with underestimations being the highest when venous levels were above 170 μmol/L (10 mg/dL). For untreated jaundiced infants (Group 1), the mean difference was -0.9 mg/dL, and for infants receiving phototherapy (Group 2), it was -0.6 mg/dL. The underestimation became more apparent at higher bilirubin levels. In those cases, capillary samples were found to be lower than venous levels by more than 1 mg/dL in a significant number of patients when venous bilirubin was over 10 mg/dL.

• **Rallis et al. (2024) [6]:** The aim of this recent study was to compare the point-of-care (POC) capillary and venous bilirubin measurements with laboratory standard venous measurements. The researchers found that both POC capillary and POC venous measurements were slightly elevated compared with the reference venous measurement. The mean difference between POC capillary and reference venous was 0.865 mg/dL, and between POC venous and reference venous was 0.771 mg/dL. The difference between these two POC (capillary and venous) was small, with an average of 0.094 mg/dL in favor of the capillary sample. The study further proposed that the POC analyzers are in optimal agreement with the reference venous sample and do provide the correct diagnosis (bilirubin > phototherapy threshold) of neonates. The studies underscore the differences in how well measurements of bilirubin in capillary blood agree with those taken in venous blood across various research works and methods. Some research shows that the value obtained from small capillaries is lower, while others indicate that it can be a little higher or that there is good compatibility, depending on the POC device and reference method.

4.2 Data Visualization of Bilirubin Discrepancies

We have generated two graphs to illustrate the discrepancies visually based on the data extracted from the literature. Figure 2 depicts the mean differences across the studies between capillary and venous/serum

bilirubin measurements by Leite et al. and Leslie et al. Figure 3 shows the correlation between the first values as reported by Leite et al. of capillary and laboratory serum bilirubin.

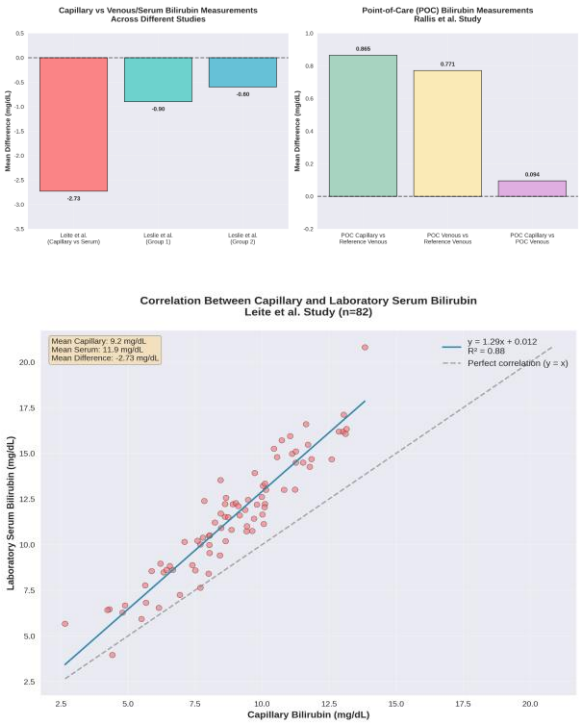

Figure 2 gives an explicit example of the studies by Leite et al. and Leslie et al., in which it is reported that capillary measurements are below venous or serum bilirubin levels. As this figure shows, Leite et al. is the study with the largest mean difference between methods. On the other hand, *Figure 3* depicts the association between the capillary and the laboratory blood sample in the study by Leite et al. The continuous underestimation of the capillary samples does not exclude a close relationship between the two methods. Such a relationship allows a clinician to make practical use of capillary measurements as long as the bias is ascertained and adjusted for.

4.3 Clinical Implications of Discrepancies

The differences seen between the two methods of bilirubin measurement, i.e., capillary and venous, have potential clinical implications of great magnitude. If the true bilirubin levels were to be underrepresented by capillary values in a consistent manner, then the situation might develop into a delayed or inadequate treatment of the hyperbilirubinemia, which can cause severe complications. In contrast, there could be a situation where the patient is overestimated and hence unnecessarily intervened. As a result, clinicians must be very conscious of the specific biases corresponding with the methods measuring bilirubin in the place where they work. Leite et al. offers a suggestion for how these biases can be handled to achieve better decision-making in clinics using capillary samples. They recommend using a correction factor (multiplying the capillary values by 1.3 mg/dL). In different clinical situations, the development of accurate point-of-care (POC) devices, as emphasized by Rallis et al., is a promising strategy for achieving a fast and dependable bilirubin evaluation, thereby eliminating or minimizing the need to repeatedly puncture the vein for the same test.

5. Challenges and Best Practices in Neonatal Capillary Blood Sampling

Over the years, neonatal capillary blood sampling has been the main source of discomfort in child patients, and this has led to several problems. In order to ensure patient safety, reduce pain, and obtain consistently accurate results, it is necessary to follow best practices in addressing these obstacles. These issues are mainly related to how the patient is handled and managed, whether treatment involves using the proper technique, and the selection of the appropriate equipment.

5.1. Minimizing Pain and Distress

In neonates, blood sampling procedures are painful, and the neonates' discomfort due to the procedure is major concern. Though necessary, heel lance and venipuncture are invasive methods, which makes them naturally distressing to the infant. The literature is unanimous in its view on the importance of the application of effective pain management strategies:

- **Pharmacological Interventions:** A few pharmacological agents, such as acetaminophen and topical anesthetics, have been reported to show minimal efficiency in pain relief during a heel lance; however, pain relieving agents like sucrose or glucose solutions are the most effective. The administration of these solutions, which is usually done about two minutes before the procedure, and often together with offering the infant a pacifier, results in a significant reduction of pain responses [5].

• **Non-Pharmacological Interventions:** In addition to sweet solutions, a few non-pharmacological methods that help reduce pain have been found. These are non-nutritive sucking (pacifier use), skin-to-skin contact (Kangaroo care), and parental holding during the procedure. These sources of comfort not only distract but also provide security, alleviate the infant's pain perception, and reduce distress at the same time [5].

• **Automated Lancets:** The manner in which a lancet is used is a major factor in pain relief. Automated lancets that deliver a stable and a controllable incision depth (e.g. 1 mm for full-term neonates and 0.85 mm for preterm neonates) have been reported to shorten the duration of blood collection, reduce tissue trauma, and thus alleviate pain and decrease hemolysis and bruising [5].

5.2. Optimizing Technique and Site Selection

Using the correct technique and choosing the right site are the most basic requirements for obtaining a capillary blood sample in a successful and safe manner. Following guidelines and recommendations is a way to ensure high-quality samples are collected and complications are avoided:

• **Heel Puncture Site:** The recommended sites for heel puncture are the lateral or medial aspects of the plantar surface. In order to avoid injury to the calcaneus bone, the central portion of the heel should be avoided. This is very important, as the skin-to-perichondrium distance can be as small as 2.38 mm in some infants [5].

• **Lancet Depth:** The highest lancet depth allowed for bone injury prevention is 2.4 mm. The use of neonate lancets with suitable depths is critical [5].

• **Avoiding Excessive Squeezing:** The heel should not be excessively squeezed, but gentle pressure may be applied to facilitate blood flow. Hemolysis, dilution of the sample with tissue fluid, and inaccurate results can result from exerting too much pressure during collection [5].

• **First Drop Discard:** The very first drop of blood should always be removed, as it may contain tissue fluid and cellular debris that can contaminate the sample and affect test results.

5.3. Comparative Analysis of Sampling Methods

The decision between capillary blood sampling (heel lance) and venipuncture depends on several factors, such as the sample volume required, the type of test, and the skill of the healthcare professional. Although heel lance is the most popular method of sampling, venipuncture performed by a trained phlebotomist can result in less pain and a higher sample quality, making it a better option than heel lance.

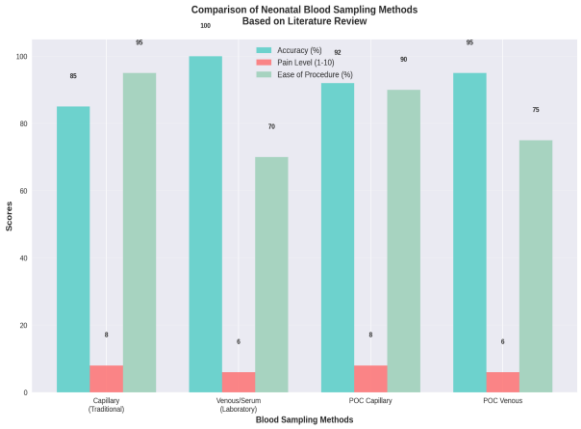

Figure 4 depicts a comparative overview of different neonatal blood sampling methods based on their perceived accuracy, pain level, and ease of procedure, thus providing a summary of the studies found in the literature.

Figure 4 illustrates that while traditional capillary sampling (heel lance) is usually regarded as easy to perform, venipuncture often results in a lower level of pain and higher accuracy because of the reduction of hemolysis and contamination. Point-of-Care (POC) capillary and venous methods are a compromise, offering both strong accuracy and relatively high ease of use, with POC capillary being marginally easier than POC venous. This signifies the changing understanding of neonatal blood sampling, where POC technology improvements are forming the bridge between old and new methods.

5.4. Optimizing Technique and Site Selection

Phlebotomy in neonates will be safe if healthcare professionals are trained properly and their skills are continuously evaluated regardless of the method used. One of the most important aspects in reducing pain, increasing success, and, at the same time, limiting the

occurrence of side effects in both a heel incision and venipuncture, is the presence of a professionally trained phlebotomist [3, 4]. Providing ongoing education on how to manage pain, correctly use the collection device, and use best practices are essential to guaranteeing high-quality neonatal care.

6. Conclusion

Unquestionably, neonatal capillary blood sampling is an essential procedure in healthcare for infants, serving as the foundation for many diagnostic, monitoring, and screening processes. It has many advantages, including low blood volume requirements, high accessibility, and rapid speed. However, it remains a challenging procedure in need of improvements, especially in terms of neonatal pain management and accuracy in the measurements such as bilirubin.

This paper has primarily emphasized the necessity of pain management and correctly carrying out the selected method. In addition, accurate site selection is crucial to delivering safety and comfort to neonates during blood sampling. Performing a comparative analysis of heel lance and venipuncture shows that, even if the heel incision is the most common method, it isn't always the most effective. When venipuncture is performed by a skilled specialist, it proves to be less painful and more likely to produce high-quality samples. Furthermore, the differences in the measurements of bilirubin between capillary and venous samples highlight how essential it is to recognize these biases and, whenever possible, using correction factors or relying on advanced point-of-care technologies to facilitate an accurate diagnosis.

Healthcare professionals who are engaged in blood sampling in neonates must undergo continuous education and training, while also maintaining steadfast commitment to using best practices. The quality of care that can be given to the youngest and most vulnerable patient population largely depends on the implementation of evidence-based approaches for pain management, the optimization of collection procedures, and the critical interpretation of laboratory results. The improvement of methods for blood sampling, the invention of minimally invasive devices for measurements, and the establishment of protocols that will assure the efficiency and comfort of patients in neonatal capillary blood sampling deserve additional research and discussion.

Refrences

[1] Leite, M. d. G. C., & Moura, R. S. A. (2022). Comparison of laboratory and capillary bilirubin measurement. *Residência Pediátrica*, *12*(1), 257. Available from: https://www.residenciapediatrica.com.br/detalhes/3971/comparison-of laboratory-and-capillary-bilirubin-measurement

[2] Leslie, G. I., Philips, J. B., 3rd, & Cassady, G. (1987). Capillary and venous bilirubin values. Are they really different? *American Journal of Diseases of Children (1960)*, *141*(11), 1199–1200. Available from: https://pubmed.ncbi.nlm.nih.gov/3673971/

[3] Shah, V. S., & Ohlsson, A. (2011). Venepuncture versus heel lance for blood sampling in term neonates. *Cochrane Database of Systematic Reviews*, (10). Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6984677/

[4] World Health Organization. (2010). *WHO Guidelines on Drawing Blood: Best Practices in Phlebotomy*. World Health Organization. Available from: https://www.ncbi.nlm.nih.gov/books/NBK138647/

[5] Shah, V., & Taddio, A. (2005). Neonatal capillary blood sampling. *Acute Care Testing*. Available from: https://acutecaretesting.org/en/articles/neonatal capillary-blood-sampling

[6] Rallis, D., Baltogianni, M., Maragoudaki, E., Tseklazi, P., Kapetaniou, K., & Giapros, V. (2024). Point-of-Care Capillary Compared to Venous Bilirubin Measurement in Neonates. *Indian Journal of Clinical Biochemistry*, *40*(3), 488– 495. Available from: https://link.springer.com/article/10.1007/s12291-024-01194-z