

Neonatal capillary blood sampling

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Capillary blood sampling via a heel lance is the most common procedure performed in hospitalized neonates. Adequate training and supervision of the personnel performing the procedure is necessary to prevent/minimize inadequate sampling volumes, false laboratory results and complications such as pain. Efforts should be made to use simple pain-relieving interventions during the procedure.

Introduction

Capillary blood sampling (CBS) for laboratory testing is a standard procedure performed by various health professionals involved in the care of the neonate. In neonates it involves making an incision on the heel to obtain blood for sampling (heel lance) [1,2]. In general, laboratory specimens obtained from an artery or vein are regarded as the “gold standard” because they are perceived to reflect the body’s true values. However, sampling from arteries and veins is not always feasible and the risks associated with indwelling catheters such as thrombosis and infection limit the duration that they can be left in situ [2].

In addition, repeated venous sampling in hospitalized sick neonates may potentially limit the number of intravenous sites available for administration of total parenteral nutrition or medications.

Therefore, CBS remains the preferred method of obtaining small amounts of blood for laboratory analysis. As compared to venepuncture or arterial puncture, the advantages of heel lance (HL) include the ease and safety of the procedure, and results have shown to be comparable for most laboratory tests, with those from blood drawn from arterial catheters [3].

However, HL cannot be used to obtain large samples of volume or for specific testing such as a blood culture or coagulation profile.

Heel lance and pain

Preterm and term neonates undergoing HL cry and exhibit facial expression and body movements which are indicative of pain [4-11]. Several pharmacological and non-pharmacological interventions have been evaluated

to reduce HL pain and the evidence is summarized below.

Pharmacological interventions

Acetaminophen [12] and topical anesthetics [13-17] (lidocaine-prilocaine cream, amethocaine gel and 5 % lignocaine ointment) are ineffective in decreasing HL pain.

Several trials have evaluated the efficacy of different sweetening agents. Administration of sucrose (dose range 0.012-0.12 g) approximately two minutes prior to HL when compared to water, pacifier or positioning/containment was effective in reducing pain [18]. Similarly, administration of glucose solution (10-50 % concentration) and breast-feeding was found to be effective [19,23].

Non-pharmacological interventions

Warming of the heel does not reduce pain or facilitate blood collection by HL [24,25].

Using automated versus conventional lancets has been shown to reduce the duration of blood collection and indirectly the pain inflicted, degree of hemolysis of the blood sample obtained and bruising and inflammation of the heel [26-29]. As compared to HL, venepuncture is associated with less pain [30-33]. Comfort measures such as the use of pacifiers and rocking [34], non-nutritive sucking [35,36] and skin-to-skin contact (Kangaroo care) [37] are associated with reduction in HL pain.

Combinations of interventions

Several groups of investigators have shown that administration of glucose and multisensory stimulation [38,39], administration of sweet solutions followed by a pacifier [40] or the use of sugar-coated pacifier [41] is effective in reducing HL pain. Blass and Watt have shown that the combination of sucrose and non-nutritive sucking was effective in reducing HL pain [42]. Gormally et al [43] showed that providing a sweet-tasting solution and care-giving context (holding) may be a simple and practical method of reducing pain in neonates subjected to painful procedures.

In summary, the following recommendations can be made to reduce HL pain. Administration of a

sweetening agent (sucrose or glucose on a pacifier) is a simple and effective way to reduce pain from single events. Automated lancet should be used for blood sampling and the heel should not be warmed prior to lancing. If feasible, parents should be encouraged to hold their baby during the procedure and mothers should be encouraged to breast- or bottle-feed during the procedure. Venepuncture is the preferred method of sampling in term neonates.

Indications for CBS

a) Any test where small volumes (< 1cc) of blood are required. These include:

1. Hematological analysis (e.g. complete blood cell count)
2. Biochemical analysis (e.g. electrolyte, glucose and bilirubin levels, therapeutic drug monitoring)
3. Bedside accucheck/glucose estimation
4. Metabolic screening (phenylketonuria and hypothyroidism).

b) Blood gas sampling [44] when:

1. Arterial blood gas analysis is indicated but arterial access is not available
2. Correlation with non-invasive monitor readings (e.g. transcutaneous values, end-tidal CO₂)
3. Assessment of initiation of therapeutic modalities (i.e. mechanical ventilation) and monitoring progression of the disease

Heel-lance procedure

a) Site selection

In neonates, the recommended site for sampling is on the plantar surface laterally beyond an imaginary line drawn posteriorly from between the 4th and 5th toes to the heel and medially from the middle of the great toe to the heel (FIGURE 1). This is based on the study by Blumenfeld et al [45] who evaluated the heels of 40 children weighing between 0.56 and 13.15 kg, 35 of whom were newborns at necropsy.

They measured the distance between the skin surface and the perichondrium of the calcaneus and in the smallest infant, the skin-perichondrium distance was documented to be 2.38 mm. In addition, they showed that the calcaneus rarely extended the recommended area of sampling. Thus, they recommended the maximum lancet depth of 2.4 mm to be used on the lateral or medial edges of the plantar surface to avoid damage to the calcaneus.

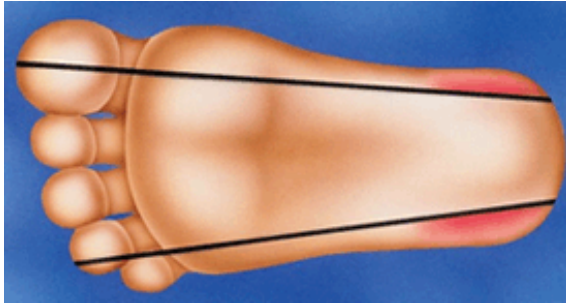


FIGURE 1: Appropriate puncture sites on the heel in neonates (darkened areas)

Based on the above guidelines only a limited area of the heel is available for sampling. With increasing survival of low-birth-weight infants, concerns have been raised regarding the effects of repeated HL in these infants with small feet. In addition, Fitzgerald *et al* [46] have shown that repeated HL leads to tissue injury and inflammation, making the heel more tender and hypersensitive to further lances.

Therefore to investigate whether it would be safe to extend the currently recommended area of sampling, Jain and Rutter [47] studied 80 infants weighing between 0.56 and 4.34 kg and with gestational age between 24 and 42 weeks. Using ultrasound they measured the shortest distance between the skin and the perichondrium of the calcaneus.

They showed that the shortest depth of perichondrium was in the center of the heel and ranged from 3 to 8 mm. In fact, in all but two of the infants the shortest skin-perichondrium distance was 4 mm or more, suggesting that a standard automated lancet that punctures to a depth of 2.4 mm can be safely used on any part of the plantar surface except the posterior aspect of the heel. Despite the findings of this study, the

recommendations from the study by Blumenfeld *et al* are being used in clinical practice [45].

b) Equipment

The supplies needed to perform the procedure are listed in TABLE I. At our institution we are currently using an automated lancet to perform the procedure. They are available in two sizes, one for full-term neonate (incision depth of 1 mm and length of 2.5 mm) and one for preterm neonate (incision depth of 0.85 mm and length of 1.75 mm). Preheparinized capillary tubes are used for blood gas analysis.

Non-sterile gloves
Institution approved antiseptic swabs (alcohol/ chlorhexidine swabs)
Sterile gauze/cotton ball
Sterile lancet (based on the institutional preference)
Collection device depending on the type of test:
Microtainers
Capillary tubes (preheparinized), metal flea and magnet, caps for tubes at both ends
Test strip
Filter paper collection device

TABLE I: Equipment for heel-lance procedure

c) Technique/steps involved in the procedure

1. The individual performing the procedure should wash his/her hands, wear gloves prior to the procedure and assemble the appropriate equipment.
2. Warming the heel is NOT performed as it does not facilitate blood collection (volume and duration), does not reduce the infant's response to pain or the number of repeat punctures.
3. Pain-relieving interventions are administered based on institutional preference.
4. The infant's heel is held with a moderately firm grip. The forefinger is placed at the arch of the foot and the thumb below the puncture site at the ankle.
5. After selection of the puncture site, the area is cleaned with an antiseptic swab and allowed to dry for maximum antiseptic action (approximately 30

seconds) and to prevent the mixture of blood and antiseptic solution.

6. The base of the automated lancet is then placed flat against the heel, which is punctured using a quick controlled stroke.
7. The first drop of blood is wiped off with a cotton ball or gauze and discarded as it may be contaminated with skin cells, alcohol or excess tissue fluid, which may distort test results.
8. The desired specimen is then obtained in an appropriate container. The heel is held in a dependent position and gentle pressure applied to facilitate blood flow. Excessive squeezing of the heel may cause hemolysis or contamination of the specimen from interstitial fluid leakage and bruising. In addition, the infant should be observed for any indication of pain such as behavioral (facial grimacing/crying/gross motor movements) and physiological responses (changes in heart rate, respiratory rate, blood pressure). If any of these are observed, the procedure should be discontinued to allow the baby to become calm or to provide additional comfort measures such as a pacifier, rocking or containment.
9. Once the blood volume has been collected, the heel is cleansed of any residual blood. Gentle pressure with a cotton ball or gauze is then applied until the bleeding stops.
10. Seal the specimen container and mix contents, if required.
11. Blood gas testing: Once the capillary tube is filled with blood, place a finger over one end and cap the other end with commercially available covers. A metal flea is then placed in the capillary tube and the open end is capped. Holding the tube gently, the blood is mixed using a magnet back and forth along the outside of the tube.

d) Contraindications to HL [45,48]

1. Presence of local edema or congestion as the accumulated fluid in the tissues will lead to contamination of the blood specimen.
2. Presence of cyanosis or impaired perfusion as they will lead to distortion of the results or to inadequate sampling.

3. Infection at the site as it can lead to local osteomyelitis or systemic infection.
4. Puncturing previously traumatized skin can lead to increased pain and impaired blood coagulation.

e) Complications of HL include

1. Infection including cellulitis, perichondritis, calcaneal osteomyelitis [49] and abscess are the major complications of this procedure. They can be prevented by using the recommended puncture areas, avoiding the tip of the heel and with the use of proper antiseptic techniques, using a sterile lancet for each puncture and by selecting a new site for each puncture. Neonates undergoing repeated heel pricks should be monitored for signs of infection such as redness, swelling and tenderness.
2. Bruising can occur easily in the preterm neonates and is avoided by not using excessive or prolonged squeezing to obtain the specimen and correct positioning of the hand.
3. Scarring and occurrence of calcified nodules in neonates subjected to repetitive punctures [50].

Comparison between arterial and capillary blood laboratory results

Several studies have been published in the literature comparing blood gas results obtained from arterial and capillary sample with conflicting results. In 1990, Courtney *et al* [51] performed a study comparing postductal arterial and capillary blood gas measurements and reviewed the literature. The authors concluded that capillary blood gas measurements did not accurately predict arterial values in neonates.

However, Johnson *et al* [52] in 2000 compared laboratory results obtained from CBS using an automated incision device with those drawn from arterial catheters. There were no differences in pH, $p\text{CO}_2$, lactate or sodium levels between the two methods of sampling. Levels for potassium, ionized calcium and lactate were noted to be significantly higher from the capillary sample but were within the acceptable CLIA performance criteria.

The levels for pO_2 and glucose were markedly lower in the blood sample obtained via CBS. No differences were noted in the blood obtained from unwarmed versus warmed heels. In conditions where problems of oxygenation need to be delineated, arterial blood sampling should be obtained.

Conclusions

Heel lance remains the conventional method of blood sampling in neonates for screening tests (phenylketonuria and hypothyroidism) or obtaining blood for other laboratory investigations. Appropriate education and training of individuals performing the procedure is a necessary step in preventing complications. Warming of the heel has no effect on the outcome of sampling and therefore is an unnecessary step in the procedure. Pain-relieving interventions should be used to minimize the stress associated with HL.

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