Newborn Essential Solutions and Technologies-Education (NEST-ED) Clinical Modules provide educational support for each of the technologies included in the NEST360 bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre- and in-service settings and are not intended to be comprehensive clinical guidelines or targeted towards intensive care of the newborn.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVID-19</td>
<td>Coronavirus disease 2019, SARS-CoV-2</td>
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<tr>
<td>CRP</td>
<td>C-reactive protein</td>
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<tr>
<td>dl</td>
<td>Decilitre</td>
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<tr>
<td>g/l</td>
<td>Grams per litre</td>
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<tr>
<td>HAI</td>
<td>Hospital-acquired infection</td>
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<tr>
<td>HCWs</td>
<td>Healthcare workers</td>
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<tr>
<td>HIV</td>
<td>Human immunodeficiency virus</td>
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<tr>
<td>IPC</td>
<td>Infection prevention and control</td>
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<tr>
<td>IV</td>
<td>Intravenous</td>
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<tr>
<td>KMC</td>
<td>Kangaroo mother care</td>
</tr>
<tr>
<td>LBW</td>
<td>Low birth weight</td>
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<tr>
<td>LCD</td>
<td>Liquid crystal display</td>
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<tr>
<td>LED</td>
<td>Light emitting diode</td>
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<tr>
<td>mg/dl</td>
<td>Milligrammes per decilitre</td>
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<tr>
<td>mm</td>
<td>Millimetre</td>
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<tr>
<td>mm/dl</td>
<td>Millimetres per decilitre</td>
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<tr>
<td>mmol/l</td>
<td>Millimoles per litre</td>
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<td>NEST360</td>
<td>Newborn Essential Solutions and Technologies</td>
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<tr>
<td>NEST-ED</td>
<td>Newborn Essential Solutions and Technologies-Education</td>
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<tr>
<td>NGT</td>
<td>Nasogastric tube</td>
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<tr>
<td>PCR</td>
<td>Polymerase chain reaction</td>
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<tr>
<td>POC</td>
<td>Point-of-care</td>
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<tr>
<td>ppm</td>
<td>Parts per million</td>
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<tr>
<td>QC</td>
<td>Quality Control</td>
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<tr>
<td>µmol/l</td>
<td>Micromole per litre</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible power supply</td>
</tr>
<tr>
<td>µl</td>
<td>Microlitre</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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</tbody>
</table>

### NOMENCLATURE

- **Point-of-care testing**: Bedside testing
- **Cot**: Bassinet, infant crib
- **Hospital acquired infection**: Iatrogenic infection, nosocomial infection
- **Transfer tubes**: Capillary tubes, micropipettes
Introduction

This NEST-ED Clinical Module has been prepared to help healthcare staff and students understand when and how to use point-of-care devices in newborn care. This is one module in a series of NEST-ED Clinical and Technical modules available that may be used by teaching institutions to supplement current newborn care curricula. Hospitals, clinical departments and individuals may use them to update their knowledge and to better facilitate the effective and safe use of newborn care equipment.

Whilst reading this series on a digital device, download and open the document in Adobe Acrobat. On the toolbar, click View, Navigation Panes and then click Bookmarks. Use the Bookmarks pane to navigate between sections of the document.

Every module has a similar structure with sections and subsections. The sections have similar headings and subheadings to make it easy for the user to navigate them. However, words may have different meanings for the various cadres of staff reading them and so to reduce misinterpretation, the heading titles are explained below.

An exception to this structure is the Infection Prevention & Control: General Infection Prevention module. This module describes general infection prevention measures in relation to the use of equipment in the ward. There are also sections on reprocessing of single use items and a useful table of suitable disinfectants.

CLINICAL PROBLEM

This describes the situations in which a piece of equipment may be clinically useful. It does not include all the clinical background in making that decision, as this should be covered in country-specific neonatal care protocols and clinical training materials.

ASSESSMENT

This section explains how a piece of equipment works, as well as how it may be useful in certain patient care settings (e.g., why an overhead radiant heater is useful for short term warming in the labour ward while resuscitating a newborn).

MANAGEMENT

Step by step preparation for setting up, checking and using the equipment is described. This is followed by explanations of how to remove the equipment from an infant when it is no longer needed, how to clean it and how to store it safely until further need.
INFECTION PREVENTION

In this section infection prevention measures are described for the equipment when in use, followed by instructions on how to disinfect the equipment both during and after use.

COMPLICATIONS

The complications described in this section are those relating to the use of the equipment and do not include all clinical complications that may arise from underlying medical problems. These are beyond the scope of the modules and should be covered in clinical training materials.

CARE & MAINTENANCE

Advice is given on where to place equipment for use, how to safely handle such devices and their consumables and how to keep them functioning well by using preventive maintenance measures.

TROUBLESHOOTING & REPAIR

This section provides helpful advice on what to check if equipment is malfunctioning on the ward. It is intended to help healthcare staff deal with minor technical difficulties for which there are simple remedies. Detailed machine maintenance is beyond the scope of these modules and is covered in the technical modules that accompany these clinical ones.

ASSESSMENT QUESTIONS

A few questions are attached based on module content. These may be used, for example, during mentoring visits or to emphasise some of the points raised in teaching with the module.

REFERENCES & ALERTS

References and alert boxes are included within each module to provide clarity on areas where recommendations are governed by published standards, evidence and/or expert opinion. This is included for the dual purpose of facilitating (1) feedback and continuous improvement of NEST-ED Education Modules and (2) implementer review of content for incorporation in local trainings.

 QUERY ALERT BOXES appear where there may be controversy or disagreement. In these cases, alert boxes provide background to the recommendations that are made in the body of the document. Relevant documents are cited, and a brief explanation of reasoning for the current module content is provided.

 RECOMMENDATION ALERT BOXES appear where there are recommendations based largely on expert opinion or consensus or to emphasise an important element of care. Relevant documents are cited, and a brief explanation of reasoning for the current module content is provided.
Point-of-Care Testing

Point-of-Care Diagnostics
1 Clinical Problem

Point-of-care (POC) test devices can be extremely useful for increasing efficiency and quality of clinical care, especially in settings where infrastructure may limit the availability of timely, gold standard laboratory testing.

POC testing is useful when healthcare professionals require quick feedback on test results to help determine the next steps of patients’ clinical care. Healthcare professionals use POC testing for various conditions including malaria infection, hypoglycaemia and human immunodeficiency virus (HIV). POC tests corresponding to such conditions include rapid malaria tests, blood glucose tests and HIV antigen tests.

2 Assessment

Timely, accurate laboratory results may facilitate better adherence to evidence-based practices, prompt decision making and ultimately reduce morbidity and mortality when used effectively.

This clinical module will provide guidelines for the diagnostic tests used at the bedside. POC devices may be chosen over traditional laboratory testing when rapid results are critical or when logistics or infrastructure limit the timely availability of laboratory results. A careful understanding of appropriate application, sample collection, margin of error and when to seek confirmatory laboratory testing are critical when using POC devices.

POC testing can be performed using various samples (e.g., blood, saliva, urine) and devices. Examples include: (Figure 2.1)

- Portable and handheld instruments (e.g., glucometer, haemoglobinometer, bilirubinometer).
- Test kits (e.g., HIV rapid test, malaria rapid test, C-reactive protein test, lactate test).
- Small bench analysers or fixed equipment (e.g., COVID-19 or HIV benchtop polymerase chain reactions, blood gas analysers).

This clinical module will provide an overview of the principles of use of POC devices, which are portable, quantitative, require small volume capillary blood samples for analysis and are used in clinical settings.
POC tests use different methods depending on the particular substance to be analysed.

Many glucometers use a principle of electrochemical detection. A drop of blood is placed at the end of the glucose test strip. Glucose in the blood then reacts with an enzyme in the test strip. This reaction generates an electrical current proportional to the glucose in the blood that reacts with the glucose oxidase. This determines an estimated blood glucose level.

Haemoglobin and bilirubin measurements operate via spectroscopy. An optical reader shines light through a blood sample and measures how much light of a particular wavelength is absorbed. For bilirubin measurements, the device must separate serum from red blood cells so that the absorbance of haemoglobin does not mask the absorbance of bilirubin.

Lateral flow strips or immunochromatographic strips (e.g., rapid HIV, malaria, pregnancy tests) use antibody-antigen binding to detect particles of interest. For example, in a malaria test, antibodies bound to the strip at the test line capture proteins produced by the malaria parasite. A second set of antibodies binds to the “top” of the malaria protein and are visible as a coloured line. A second control line is visible whenever the test is run properly.

**Alert 2.0 POC Test Result Accuracy**

Users should always be aware of clinical and technical factors that might affect the accuracy of a POC test result. Clinical factors affecting the accuracy of test results can include haematocrit, impaired circulation and certain medications. Technical factors include failure to calibrate new test strips, expired test strips, strips stored at inappropriate temperatures and inadequate blood sample volumes. Always be aware of the accuracy of rapid diagnostic tests relative to laboratory testing results. This will allow for appropriate clinical judgments regarding patient management and awareness of when confirmatory laboratory testing may be needed.

POC devices can generally be used on any patient group. However, care should always be taken to ensure that the POC device used is accurate within the range of critical results for the patient population (e.g., when measuring glucose in neonates, glucometers must be accurate at higher haematocrit levels than are needed for child and adult populations).
3 Management

This section gives an overview of how to use POC test devices that require small capillary blood samples to be applied directly on a test strip or applied via a transfer tube to a device. This section also includes details of infant preparation, principles of sample application or transfer to the device and care of the patient during and after testing.

See the glucometer, bilirubinometer and haemoglobinometer modules that follow for device specific recommendations.

**SETTING UP FOR A PATIENT**

1 Collect:
   - Device
   - Unexpired Test strip or microcuvette
   - Transfer tube if required
   - Calibration strips or solutions
   - Quality control solutions where indicated

2 Turn on the device. For most devices this is completed by either pressing the power button or inserting a strip into the device strip port.

3 Perform a **calibration test where** indicated by the user manual. Calibration tests are required for most POC devices and may be indicated as:
   - **Routine manual calibration:** performed at a set time interval recommended by the manufacturer.
   - **Test strip calibration:** performed any time a new batch of test strips is opened and used.
   - **Automatic coding and calibration:** performed automatically by the device; in these cases the device may still need to be checked using a quality control test or control solution to verify device accuracy.

4 Perform a **quality control** test when:
   - Opening a new packet or container of test strip/microcuvette.
   - Test result do not accord consistently with clinical condition.
   - Recommended by user manual.
**PREPARING A PATIENT**

1. Assess the patient to determine if it is appropriate to use a particular POC device. Important considerations are:
   - **Clinical conditions**: where POC testing would be useful to direct treatment.
   - **Patient’s medications, conditions or previous treatments**: these may interfere with POC testing, making test results inaccurate or difficult to interpret.

2. **POC device accuracy**: ensure the device can provide accurate results in a range that is relevant for your patient population.

3. Always explain the purpose, benefits and risks of a procedure to guardians BEFORE performing the procedure.

4. Collect:
   - Gloves
   - 70% alcohol
   - Cotton wool or gauze

5. Follow handwashing protocol and put on gloves.

6. Make plans and preparations to manage the patient’s pain.

7. If appropriate, consider warming the sample site to improve blood flow before proceeding.

8. Disinfect the skin on the outer or inner edge of the heel using cotton wool or gauze soaked in 70% alcohol. ([Figure 3.1](#)) Allow to dry before testing. Capillary blood samples on newborns are taken from the outer or inner edge of the heel to protect the nerves and blood vessels. **Samples should never be taken from the finger or toe.** Avoid areas of skin which are poorly perfused, oedematous, inflamed or infected.

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**Figure 3.1** Disinfect the outer or inner edge of the patient’s heel using cotton wool or gauze soaked in 70% alcohol.
TESTING A PATIENT

1. Collect: (Figure 3.2)
   - New lancet
   - Calibrated device
   - Unexpired Test strip or microcuvette (Figures 3.4, 3.5)
   - Appropriate volume (usually 50 µl or 75 µl) transfer tube if required
   - Cotton wool or gauze
   - 70% alcohol
   - Gloves
   - A small tray to carry the items
   - Sharps container

2. Follow handwashing procedures and put on gloves if not already done.

3. Ensure device is turned on.

4. Using an appropriately sized lancet for your patient, prick the disinfected outer or inner edge of the heel. (Figure 3.3) WHO recommends that lancets for term infants should not penetrate further than 2.4 mm and that lancets for preterm infants should not penetrate further than 0.84 mm. A blood drop should form. If this does not occur, massage the sole of the foot or calf muscle to generate a blood drop.

5. When collecting a capillary blood sample, wipe the first drop from the patient’s skin as it may contain alcohol or tissue fluids, which can cause the device to give an inaccurate measurement.

   **If a sample is collected directly onto a test strip:**
   - Put the second drop of blood onto the tip of the strip. (Figure 3.4) The device should automatically absorb the blood drop.
If a sample is collected using a microcuvette:

- Place the tip of the microcuvette in the drop of blood.
- Ensure that the drop of blood is large enough to completely fill the microcuvette. Fill the microcuvette in one continuous process. Do not refill a partially filled microcuvette. *(Figure 3.5)*

- Carefully wipe off any excess blood from outside the microcuvette. Avoid touching the open end.
- Visually inspect the microcuvette for any air bubbles near the optical eye. If bubbles are present the microcuvette should be discarded and a new sample should be taken.

If a sample is collected using a transfer tube:

- As the second drop of blood forms hold the transfer tube horizontally to collect the blood until the tube fills to the level recommended. *(Figure 3.6)*
- Touch the open end of the transfer tube to the test strip. *(Figure 3.7)*
- Squeeze the end of the transfer tube to expel the blood sample onto the test strip, being careful to avoid making bubbles or touching the strip with fingers. Confirm that the strip is adequately filled with blood.

**Transfer tubes are typically recommended by manufacturers to deliver an accurate volume of blood. Application of samples directly to test strips when transfer tubes are recommended may result in an inaccurate result.**

Figure 3.6 Collect blood into horizontally held transfer tube.  
Figure 3.7 Expel blood onto test strip.

6 Using dry cotton wool or gauze, apply pressure to the heel to stop the bleeding. *(Figure 3.8)*

Figure 3.8 Apply pressure to stop bleeding.

7 The test result is displayed as a number on the device screen. *(Figure 3.9)* Read and record this test result. If the measurement is not in accord with the patient’s clinical condition or an error code is displayed, repeat the test or consider confirmatory laboratory testing.
Figure 3.9 Read and record the result.

8 Compare test results to patient’s condition and clinical standards to determine the appropriate course of action.

CONCLUDING ASSESSMENT

The used lancet is disposed of in a sharps’ container. Dispose of the used test strip/microcuvette, transfer tube and gloves in a clinical waste container. Then wash your hands.

4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or disposed of promptly or adequately between patients, they may pose a significant infection risk.

GENERAL INFECTION PREVENTION

1 Clean hands with soap and water or 70% alcohol before and after assessing a patient using a POC device or handling any materials that will be used on a patient (e.g., a lancet). Gloves should be worn throughout the process of taking a blood sample and disposed of immediately after finishing the test.

2 Always thoroughly clean the infant’s skin before doing a test using a POC device. Inadequate cleaning of the skin may result in an infection. Do not take a sample from an infected skin site as this risks disseminating the infection.

3 Avoid pricking the same area multiple times.
4 **Never** prick different areas with the same lancet.

5 Ensure that all patient related consumables used for POC tests (e.g., lancets, test strips, microcuvettes, transfer tubes, alcohol wipes) **are not re-used. (Alert 4.1)**

6 Following universal precautions dispose of the used lancet in a sharps’ container. Dispose of the used test strip, microcuvette, transfer tube and gloves in a clinical waste container. Then wash your hands.

### Alert 4.1 Equipment Disinfection

Disinfection of equipment should always comply with manufacturer guidelines. General guidance on environmental cleaning and disinfection of equipment was taken from the *Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources, Jhpiego*, Module 6 which lists isopropyl alcohol (70-90%), sodium hypochlorite (0.05% or >100ppm available chlorine) quaternary ammonium and Iodophor germicidal detergent as appropriate for low level disinfection. Phenolic germicidal detergent is also listed in this category but should not be used in neonatal wards since affordable, effective alternatives are available. There are also concerns it may cause hyperbilirubinaemia and/or neurotoxicity in newborns.

### DISINFECTION AFTER USE

1 Wearing clean gloves wipe down the POC device with 70% alcohol or in accordance with ward policy. **(Figure 4.1)** Be careful not to submerge or drip alcohol onto the device, particularly in the POC strip reading slot.

*Figure 4.1 Wipe down the device with 70% alcohol.*
5 Complications

The introduction of equipment in newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximise patient safety.

**CLINICAL COMPLICATIONS**

- **Bruising:** inappropriate or repeated attempts to collect blood for testing may result in bruising to the heel.
- **Bleeding:** if pressure is not applied after taking blood, bleeding may persist for a short period of time. Continued bleeding may indicate an underlying bleeding disorder.
- **Artery, nerve or bone damage:** do not take samples from fingers, toes, the back or inner part of the heel. This may cause artery, nerve or bone damage.
- **Pain:** the skin prick can cause pain.
- **Infection:** this may occur if precautions are not adequate.

**DEVICE COMPLICATIONS**

- **False readings:** inaccurate and/or readings that are not consistent with the patient’s clinical condition may be caused by:
  - Expired test strips/microcuvettes.
  - Improper storage of test strips/microcuvettes (e.g., high humidity).
  - Using a test strip/microcuvette that is not device specific.
  - Improper collection and application of blood sample to the device.
  - Contamination of blood samples (e.g., alcohol on the skin that has not dried, dirt in the device).
  - Not following the recommended time frames for testing or reading the results.
  - Failure to calibrate the device.
6 Care & Maintenance

Power source, location and preventive maintenance will vary by POC device.

See the following modules on glucometer, bilirubinometer and haemoglobinometer for device specific recommendations relating to the power source, ward location and user preventive maintenance.

7 Troubleshooting & Repair

Typical failures and repair mechanisms will vary by POC device.

See the following modules on glucometer, bilirubinometer and haemoglobinometer for device specific recommendations.
Assessment Questions

1. On the image of the foot below, mark the area of the foot that is most safely used to collect blood:

2. Why is a transfer tube recommended for some tests?
   Answer: To get an accurate volume of blood.

3. What solution is used to disinfect a device?
   Answer: 70% alcohol solution

4. What actions should be taken when a POC result is not consistent with a patient’s clinical condition?
   Answer: Repeat the test in the correct manner. Verify the test result with laboratory testing. Perform a quality control check
Glucometer

Point-of-Care Diagnostics
1 Clinical Problem

Assessment of blood glucose with a glucometer should be conducted as part of a routine assessment for all infants on admission to a newborn unit.

Glucometers should also be used during continuing management for all sick or at-risk infants. Hypoglycaemia may present as:

- Jitteriness
- Irritability
- Hypotonia
- Lethargy
- Reduced level of consciousness
- Failure to feed or poor feeding
- Seizures
- Hypothermia
- Apnoea or irregular breathing

Hypoglycaemia may also be asymptomatic or the signs may be very non-specific and identified incidentally as part of routine blood glucose testing. It is important to identify hypoglycaemia as it may lead to permanent brain damage or death. Prematurity, intrauterine growth retardation, birth asphyxia, having a diabetic mother and being sick are all risk factors for developing hypoglycaemia.

Whilst hypoglycaemia is more common, hyperglycaemia may also occur and requires careful monitoring, treatment and reassessment.

2 Assessment

Hypoglycaemia occurs in 10% of healthy newborns but can also directly contribute to both morbidity and mortality. It is one of the most common medical emergencies.

Glucometers (Figure 2.1) provide a rapid measurement of approximate whole blood glucose level to direct treatment for patients with mild to severe hypoglycaemia. Where available POC tests should be confirmed by laboratory analysis when hypoglycaemia is persistent, recurrent, the device displays only “HI” or “LOW” or there is concern about the accuracy of the POC device.

Many glucometers use test strips (Figure 2.2) with a glucose oxidase electrode. Glucose in the blood reacts with an enzyme in the test strip. This reaction generates an electrical current proportional to
the glucose in the blood, that reacts with the glucose oxidase. This determines an estimated blood glucose level.

**Clinical factors** which may affect the accuracy of a test result include:
- **Haematocrit**: many glucometers assume an average adult haematocrit and may not be accurate for newborns who typically have high haematocrits.
- **Poor peripheral circulation**: due to shock or hypothermia.
- **Metabolic factors**: e.g., high bilirubin, metabolic acidosis, hyperoxia.
- **Medications**: e.g., paracetamol.
- **Contaminated samples**: e.g., substances on the skin (70% alcohol that has not dried, dextrose containing fluids).

**Technical factors** which may affect the accuracy of the test result include:
- **Improper storage of test strips/microcuvettes**: these are affected by temperature and humidity if not stored according to manufacturer's recommendations.
- **Improper blood sample**: a sample that is contaminated, of inadequate volume, improperly applied to the test strip or there is an excessive time lag between sample collection and testing. In this last instance, glycolysis occurs in the sample and will cause a falsely low glucose reading.
- **Test strip factors**: e.g., using expired or incompatible strips, not calibrating the device.

The effect of these factors on the accuracy of a result will vary between devices. Therefore, always be sure to read the manufacturer's manual and be familiar with the types of clinical conditions that may affect the particular device being used.

Glucometers may be either portable or stationary (benchtop) devices. Glucose strips that change colour according to a visual scale are also available for measuring glucose levels. These are not recommended due to their higher inaccuracy and the subjective nature of measurement. Not all glucometers can measure hypoglycaemia accurately in newborns. All devices used for newborns should be validated for assessing hypoglycaemia in the infant age group.

Glucose levels in all infants should not fall below 2.5 mmol/l (45 mg/dl).
3 Management

Management of a glucometer includes how to set up and use the device, prepare the patient, conduct and conclude the assessment.

SETTING UP FOR A PATIENT

1 Collect: (Figure 3.1)
   - Glucometer
   - Unexpired Test strip/microcuvette
   - Control solution

2 Turn on the glucometer. This may be completed by pressing the power button or inserting a strip into the glucometer.

3 Fully insert a test strip into the glucometer. (Figure 3.2) The strip should click into place.

4 A quality control test should be conducted when changing strip containers or according to manufacturer recommendations.
**PREPARING A PATIENT**

1. Assess patient for clinical conditions associated with hypoglycaemia.
2. Always explain the purpose, benefits and risks of a procedure to guardians BEFORE performing the procedure.
3. Collect:
   - Gloves
   - 70% alcohol
   - Cotton wool or gauze
4. Follow handwashing protocol and put on gloves.
5. Make plans and preparations to manage the patient’s pain.
6. Consider warming the foot to improve blood flow before proceeding.
7. Disinfect the skin on the outer or inner edge of the heel using cotton wool or gauze soaked in 70% alcohol. *(Figure 3.3)* Allow to dry before testing. Capillary samples on newborns are taken from the outer or inner area of the heel to protect the nerves and blood vessels. **Samples should NEVER be taken from the finger or toe.** Avoid areas of skin that are poorly perfused, oedematous, inflamed or infected.

![Figure 3.3 Disinfect the outer or inner edge of the heel using cotton wool or gauze soaked in 70% alcohol.](image)

**TESTING A PATIENT**

1. Collect: *(Figure 3.4)*
   - New lancet
   - Glucometer
   - Unexpired Test strip/microcuvette
   - Cotton wool
   - 70% alcohol
   - Gloves
   - A small tray to carry the items
   - Sharps container
2. Follow handwashing procedures and put on gloves.
3. Insert glucometer strip or ensure glucometer is turned on.
4. Obtain a capillary blood sample *(Alert 3.1)* from the disinfected outer or inner edge of the heel and apply it to the test strip already inserted into the device. *(Figures 3.5, 3.6)* If using a microcuvette see **Point-of-Care Diagnostics – Point-of-Care Testing** section for further details.
Alert 3.1 Best practice for best results

Always wipe the first drop of blood from the patient's skin using dry cotton wool or gauze as it may contain alcohol or tissue fluids. This may give an inaccurate measurement.

5 Using dry cotton wool or gauze, apply pressure to the heel to stop the bleeding. (Figure 3.7)

6 Blood glucose level will be displayed as a number on the glucometer screen. (Figure 3.8) Read and record this result. Refer to departmental guidelines to determine what action is required. If the measurement is not in accord with the patient’s clinical condition, repeat the test.

7 Whenever hypoglycaemia is found and treated, the blood glucose should be rechecked 30 minutes after intervening.
**Alert 3.2 Variance in international standards for hypoglycaemia management**

American Academy of Paediatrics, Paediatric Endocrine Society and WHO are all in agreement that glucose levels below 2.5mmol/l (45mg/dl) signify hypoglycaemia in newborns. However, they differ on the specific actions that should be taken and how aggressively to manage glucose levels below 45mg/dL (2.5 mmol/l). For a full discussion of the management of hypoglycaemia in newborns, these documents should be referenced and local practices put into place.

**CONCLUDING ASSESSMENT**

The used lancet is disposed of in a sharps’ container. Dispose of the used test strip or microcuvette and gloves in a clinical waste container. Then wash your hands.

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### 4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or disposed of promptly or adequately between patients, they may pose a significant infection risk.

**GENERAL INFECTION PREVENTION**

1. Clean hands with soap and water or 70% alcohol before and after assessing a patient using a glucometer or handling any materials that will be used on a patient (e.g., a lancet). **Gloves should be worn throughout the process of taking a blood glucose measurement and disposed of immediately after concluding the test.**

2. Always thoroughly clean the infant’s skin before doing a test using a glucometer. Inadequate cleaning of the skin may result in an infection. Do not take a sample from an infected skin site as this risks dissemination of the infection.

3. Avoid pricking the same area multiple times.

4. Never prick different areas with the same lancet and do not re-use lancets.

5. The used lancet is disposed of in a sharps’ container. Dispose of the used test strip or microcuvette and gloves in a clinical waste container. Then wash your hands.

6. See **Point-of-Care Diagnostics | IPC** section for further precautions.
**5 Complications**

Introduction of equipment into newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximise patient safety.

**DEVICE COMPLICATIONS**

**Technical factors leading to inaccurate readings:** These can be caused by:

- **Substances on the skin:** if you record a very high reading in an infant that is otherwise showing symptoms of hypoglycaemia, consider recleaning their skin and retake a sample.
- **Expired test strips:** out of date test strips can produce inaccurate readings. Unopened test strips or microcuvettes may have a limited shelf life.
- **Improper storage of test strips/microcuvettes:** the container lid should be tightly closed to protect from humidity. Keep away from any direct heat source.
- **Failure to perform quality control checks** as recommended.

**Clinical factors leading to inaccurate readings:** these can be caused by:

- High patient haematocrit
- Poor peripheral circulation

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1. Wearing clean gloves wipe down the glucometer with 70% alcohol. *(Figure 4.1)* Be careful not to submerge or drip alcohol onto the glucometer, particularly avoid dripping alcohol into the reading slot.

*Figure 4.1 Wipe down the glucometer with 70% alcohol.*
6 Care & Maintenance

Users are responsible for basic first-line care and maintenance to ensure equipment lasts for their potential lifetime.

**POWER SOURCE**

A glucometer is powered by replaceable or rechargeable batteries. (Figure 6.1) If using a rechargeable glucometer it should be placed on the charging dock when it is not in use to ensure power in the event of a power outage. (Figures 6.2a, 6.2b)

![Figure 6.1 Glucometer with replaceable batteries.](image)

![Figure 6.2a Low battery warning.](image)

![Figure 6.2b Glucometer on its charging dock.](image)

**WARD LOCATION**

The glucometer and associated testing strips or microcuvettes should be stored in a clean, dry and secure area. As glucometers are fairly small, care should be taken to ensure that they remain on the ward and accessible for use when required.
USER PREVENTIVE MAINTENANCE

Glucometers require little preventive maintenance beyond recharging or replacing batteries and ensuring that the device is cleaned appropriately when indicated.

**Quality control (QC) tests** (Figure 6.3) are recommended for most glucometers on a regular basis. This may range from daily to biweekly or monthly. Manufacturer recommendations on the frequency of quality control tests should be followed.

A quality control test using the control solutions provided with the glucometer are used. Most glucometers with this functionality will have a specific quality control testing mode to switch to within the device menu. The control solution should be placed on the strip as with a normal sample. The results should appear within seconds as a ‘pass’. If the device is not set up to provide a pass/fail response, check that the measurement provided is in range of that estimated on the quality control solution bottle. (Figure 6.4) If the device does not pass the quality control test, contact the manufacturer who may recommend steps to repair, calibrate or replace as needed.

If control solutions are not available, a solution of known glucose content may also be used to check the glucometer. This can be performed as a normal patient test. Compare the result with the known glucose content of the sample. For example, a 10% dextrose solution contains 10g/l which equals 10mg/dl. Therefore 1 drop of 10% dextrose solution should give you a reading between 8-12mg/dl. If the device shows results inconsistent with the known glucose content, contact the manufacturer or your maintenance department to recommend steps to repair, calibrate or replace as needed.

![Figure 6.3](image1.png) **Figure 6.3** Allow the strip to absorb a drop of the control solution.

![Figure 6.4](image2.png) **Figure 6.4** Compare result to quality control reference values.
Troubleshooting & Repair

Although users are not responsible for repairing their devices there are steps that should be taken to troubleshoot first-line errors that may occur before contacting maintenance or engineering support.

1. **The glucometer is not turning on:**
   - Some glucometer models require a strip to be inserted to power on and will automatically turn on once this is completed. Try inserting a glucometer strip.
   - Charge the device or replace the batteries.
   - If the glucometer still does not turn on contact your maintenance department.

2. **The glucometer is providing results consistently incompatible with patient condition:**
   - Ensure that the test strips or microcuvettes are not out of date.
   - Confirm that you are using the appropriate test strips or microcuvettes compatible with the glucometer.
   - If the results are still inconsistent, complete a quality control test as described in *Glucometer: Care & Maintenance | User Preventive*. If the results are still inconsistent, contact your maintenance department.

Assessment Questions

1. How often should quality control tests be performed on glucometers?
   **Answer:** When a new container of glucometer strips is opened or according to manufacturer recommendations.

2. List three factors that might cause a glucometer to give an inaccurate reading.
   **Answer:** Poor peripheral circulation, metabolic factors, high haematocrit, medications, contaminated blood samples, improper storage of strips, improper blood samples, sampling the first drop of blood.
Bilirubinometer

Point-of-Care Diagnostics
1 Clinical Problem

Serum bilirubin testing is the gold standard test for measuring degree of jaundice. Jaundice is common in newborns and low levels are normally harmless. High levels of bilirubin are potentially toxic. All jaundiced newborns should be monitored to identify those who need phototherapy or exchange transfusion.

Where timely and accurate results are available, serum bilirubin testing should be considered in all newborns at risk for significant hyperbilirubinaemia. This would include newborns with any of the following:

- Visible jaundice on the day of birth within 24 hours of birth
- Jaundice extending below the umbilicus
- Prematurity
- Sepsis
- Significant bruising or bleeding (e.g., cephalohaematoma)
- Maternal-infant blood incompatibility (e.g., ABO or Rhesus incompatibility)
- Glucose-6-phosphate dehydrogenase (G6PD) deficiency
- History of a sibling with significant hyperbilirubinaemia

Repeat testing of the same infant is often necessary as bilirubin levels will rise during the first week of life before they plateau and then decline. See NEST-ED Clinical Module: Jaundice Management – Phototherapy for further details on the identification and treatment of neonatal jaundice. It is important to identify significant hyperbilirubinaemia as, if left untreated it may lead to permanent brain damage.

2 Assessment

Where available, serum bilirubin testing should be conducted as part of the routine assessment of all sick, preterm, jaundiced and at-risk newborns. Additionally, repeat serum bilirubin testing should be done as part of continuing jaundice management of those undergoing phototherapy, exchange transfusion or at continuing risk of significant jaundice in the first weeks of life.

Serum bilirubin measurements can be obtained using POC serum bilirubinometers (Figure 2.1), transcutaneous devices (Figure 2.2) and the gold standard laboratory serum bilirubin measurement. (Figure 2.3) Ideally serum bilirubin is assessed before starting phototherapy if timely results are available and then during ongoing management to determine when phototherapy can
be stopped. See NEST-ED Clinical Module Jaundice Management – Phototherapy for serum bilirubin treatment thresholds and actions.

**Transcutaneous bilirubin results are less** accurate once phototherapy has commenced; therefore, POC serum bilirubinometers are preferable during and after the initiation of phototherapy treatment. This module will cover the function and use of a POC bilirubinometer to obtain total serum bilirubin results.

![Figure 2.1 Point-of-care bilirubinometers.](image1)

![Figure 2.2 Transcutaneous bilirubinometer.](image2)

![Figure 2.3 Serum bilirubin measured in a medical laboratory is the gold standard test.](image3)

Some serum bilirubinometers are lateral flow devices that employ membrane technology to separate serum from whole blood. When the whole blood sample is added to the test strip, the sample flows along the strip by capillary action. The membrane captures the blood cells, and the serum flows into a window on the test strip where spectrophotometry determines the total serum bilirubin concentration of the newborn.

If results do not match the infant’s clinical condition or there is concern about the accuracy of the POC results, then confirmatory laboratory testing should be performed, if available.

**Clinical factors** which may affect the accuracy of a test result include:

- **Large amounts of conjugated bilirubin:** most POC serum bilirubinometers report total bilirubin. If a sample contains large amounts of conjugated bilirubin accuracy of the test result can be affected.

- **High haematocrit:** samples with high haematocrit may take longer or need more blood in order for a sample to progress to the reading window.

**Technical factors** which may affect the accuracy of the test result include:

- **Device factors:**
  - Expired strips.
  - Failure to calibrate the device at recommended interval.
  - Contamination of the blood application point.
  - Any visible dirt or blood in the reading window of the test strip will cause an inaccurate result.

- **Blood sample factors:**
  - Failure to use the transfer tube when recommended.
  - Improper blood sample volumes.
  - Very high haematocrit.
  - Direct exposure of a blood sample to phototherapy, sunlight or bright indoor light.

- **Timing factors:**
  - Failure to wait for the reading window to fill prior to initiating a test.
  - Too much time passing between obtaining a blood sample and running a bilirubin POC test.
Management of a bilirubinometer includes how to set up and use the device, prepare the patient, conduct and conclude the assessment.

### SETTING UP FOR A PATIENT

1. **Collect: (Figure 3.1)**
   - Bilirubinometer
   - Test strip (Figure 3.2)
   - Calibration strip: some bilirubinometers include a calibration strip, others may require use of an unused test strip.

![Figure 3.1 Bilirubinometer and test strip.](image-url)
Clinical Education Modules

Point-of-Care Diagnostics – Bilirubinometer

1. Assess patient for clinical conditions associated with jaundice.
2. Always explain the purpose, benefits and risks of a procedure to guardians BEFORE performing the procedure.
3. Collect:
   - Gloves
   - 70% alcohol
   - Cotton wool or gauze
4. Follow handwashing protocol and put on gloves.
5. Make plans and preparations to manage the patient’s pain.
6. Consider warming the foot to improve blood flow.
7. Disinfect the skin on the outer or inner edge of the heel using cotton wool or gauze soaked in 70% alcohol. (Figure 3.4) Allow to dry before testing. Capillary samples on newborns are taken from the outer or inner area of the heel to protect the nerves and blood vessels. Samples should never be taken from the finger or toe. Avoid areas of skin that are poorly perfused, oedematous, inflamed or infected.

Figure 3.2 Bilirubinometer test strip.

Figure 3.3 Turn on bilirubinometer.

Figure 3.4 Disinfect the outer or inner edge of the heel using cotton wool or gauze soaked in 70% alcohol.
TESTING A PATIENT

1 Collect: (Figure 3.5)
   - New lancet
   - Transfer tube if required
   - Bilirubinometer
   - Test strip
   - Cotton wool or gauze
   - 70% alcohol
   - Gloves
   - A small tray to carry the items
   - Sharps container

   ![Figure 3.5 Collect test materials.](image)

2 Open a new test strip for the patient you intend to test.

⚠️ Alert 3.1 Reminders about lateral flow test strips

Remember the following in order to avoid test result inaccuracy when using bilirubinometers:

- Do not remove a new test strip until you are ready to perform the test on a patient. Unused strips that are exposed to air for long periods of time can give less accurate results.
- Do not touch the test strip blood application point or serum window (Figure 3.6) with your hands; this can also lead to inaccurate results.
- Turn off phototherapy lights prior to collecting blood samples.
- Calibrate device according to manufacturer recommendations and/or when prompted to do so by the device.
- When transfer tubes are recommended, use them to transfer the sample from patient to device to ensure proper volume of blood is tested.
- Wait for the manufacturer’s recommended time for blood to flow from the blood application well to the reading window prior to testing.
3 Turn off the phototherapy light. If the phototherapy light remains on during the collection of a blood sample, the result will be artificially low.

4 Make sure the bilirubinometer is switched on. (Figure 3.7)

5 Follow handwashing procedures and put on gloves.

6 Obtain a capillary blood sample (Alert 3.2) from the disinfected outer or inner edge of the heel. (Figure 3.8) If using a test strip see Point-of-Care Diagnostics | Point-of-Care Testing section for further details. If a sample is collected using a transfer tube:

   - As the second drop of blood forms hold the transfer tube horizontally to collect the blood until the tube fills to the level recommended. (Figure 3.9)
   - Touch the open end of the transfer tube to the test strip.
   - Squeeze the end of the transfer tube to expel the blood sample onto the test strip (Figure 3.10), being careful to avoid making bubbles or touching the strip with fingers. Confirm that the strip is adequately filled with blood.

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**Alert 3.2 Best practice for best results**

Always wipe the first drop of blood from the patient's skin using dry cotton wool or gauze as it may contain alcohol or tissue fluids. This may give an inaccurate measurement.

Transfer tubes are typically recommended by manufacturers to deliver an accurate volume of blood. Application of samples directly to test strips when transfer tubes are recommended may result in an inaccurate result.
Figure 3.8 Prick the disinfected inner or outer edge of heel using a lancet.

Figure 3.9 Fill the transfer tube to the ‘fill line’.

Figure 3.10a Use the transfer tube to squeeze capillary blood sample onto test strip.

Figure 3.10b Make sure to fully empty transfer tube of sample.

7 Place the prepared test strip into the device (Figure 3.11) to begin testing after waiting for the recommended time. Always protect the blood sample and test strip from direct exposure to phototherapy or sunlight.

Figure 3.11 Insert prepared test strip.

Figure 3.12 Screen displaying test result.
8 Wait for serum bilirubin result to be displayed on the screen. \((\text{Figure 3.12})\) If results appear in mg/dl and your facility prefers measurements to be recorded in mmol/dl (or vice versa), refer to conversion chart. \((\text{Figure 3.13})\) Read and record the serum bilirubin levels and the time of the test result. If the measurement is not consistent with the clinical condition or indicates the infant may require an invasive procedure (such as exchange transfusion), repeat the test or, ideally perform a laboratory test to confirm the result.

<table>
<thead>
<tr>
<th>mg/dl</th>
<th>µmol/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>86</td>
</tr>
<tr>
<td>10</td>
<td>171</td>
</tr>
<tr>
<td>15</td>
<td>257</td>
</tr>
<tr>
<td>20</td>
<td>342</td>
</tr>
<tr>
<td>25</td>
<td>428</td>
</tr>
<tr>
<td>30</td>
<td>513</td>
</tr>
</tbody>
</table>

1 mg/dl = 17.1 µmol/l

\(\text{Figure 3.13 Conversion chart.}\)

9 Compare serum jaundice levels to normal standards pertaining to initiation or discontinuation of jaundice treatment \((\text{see NEST-ED Clinical Module: Jaundice Management – Phototherapy for further details on clinical standards of treatment.})\)

10 If the POC test result indicates that an infant requires an exchange transfusion, the patient should be given intensive phototherapy and other appropriate supportive clinical interventions while a confirmatory serum bilirubin level from a laboratory is pursued. If laboratory testing is NOT available, the bilirubinometer should be recalibrated and the test repeated to confirm the result. Ideally, whenever a POC test result indicates the need for an invasive procedure, such as an exchange transfusion, confirmatory laboratory testing should be done prior to these procedures being carried out. \(\text{(Alert 3.3)}\)

\[\text{Alert 3.3}\]

In general, whenever test results do not correlate to a patient's clinical condition, healthcare staff are encouraged to repeat or pursue confirmatory testing for that result. However, this can be challenging when assessing an infant with jaundice as the physical exam following initiation of phototherapy is unreliable. Thus, an infant's physical exam and serial bilirubin measurements may not be congruent during phototherapy treatment.

\[\text{CONCLUDING ASSESSMENT}\]

The used lancet is disposed of in a sharps' container. Dispose of the used test strip or microcuvette and gloves in a clinical waste container. Then wash your hands. Switch off the device or return it to the charging station.
4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or disposed of promptly or adequately between patients, they may pose a significant infection risk.

**GENERAL INFECTION PREVENTION**

1. Clean hands with soap and water or 70% alcohol before and after assessing a patient using a bilirubinometer or handling any materials that will be used on a patient (e.g., a lancet). **Gloves should be worn throughout the process of taking a serum bilirubin measurement and disposed of immediately after concluding the test.**

2. Always thoroughly clean the infant’s skin before taking a measurement using a bilirubinometer. Inadequate cleaning of the skin may result in an infection. Do not take a sample from an infected skin site as this risks dissemination of the infection.

3. Avoid pricking the same area multiple times.

4. **Never** prick different areas with the same lancet and do not re-use lancets.

5. The used lancet is disposed of in a sharps’ container. Dispose of the used test strip and gloves in a clinical waste container. Then wash your hands.

6. See **Point-of-Care Diagnostics | IPC** section for further precautions.

**DISINFECTION AFTER USE**

1. Wearing clean gloves wipe down the bilirubinometer with 70% alcohol. **(Figure 4.1)** Be careful not to submerge or drip alcohol onto the bilirubinometer, particularly avoid dripping alcohol into the test strip reading slot.

---

(Figure 4.1) Wipe down the bilirubinometer with 70% alcohol.
5 Complications

Introduction of equipment in newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximise patient safety.

DEVICE COMPLICATIONS

Readings that are false or less accurate than expected can be caused by:

- **Device factors:**
  - Expired/damaged strips.
  - Failure to calibrate device per manufacturer recommendations.
  - Contamination of the blood application point or serum window.

- **Blood sample factors:**
  - Failure to use a transfer tube when indicated.
  - Inadequate blood sample volumes.
  - Very high haematocrit, blood samples contaminated by substances on the skin
  - Direct exposure of a blood sample to phototherapy or sunlight.

- **Timing factors:**
  - Failure to wait an adequate amount of time for test strip to process blood sample prior to initiating a test.
  - Greater than permitted amount of time to pass between obtaining a blood sample and doing a bilirubin POC test.

6 Care & Maintenance

Users are responsible for basic first-line care and maintenance to ensure equipment lasts for its potential lifetime.

POWER SOURCE

Bilirubinometers may be powered by replaceable or rechargeable batteries. (Figure 6.1a) If using a rechargeable device, regularly charge the bilirubinometer when not in use to ensure power in the event of a power outage. (Figures 6.1b, 6.1c)
WARD LOCATION

The bilirubinometer and associated test strips should be stored in a clean, dry and secure area. As most bilirubinometers are small, care should be taken to ensure that the device remains on the ward and is accessible for use when required.

USER PREVENTIVE MAINTENANCE

Bilirubinometers require minimal preventive maintenance, including charging batteries and performing routine device calibration. **Calibration** should be conducted at the frequency recommended by the manufacturer to ensure consistent results. If the device reports an error, it may mean that calibration has not been completed successfully. Refer to manufacturer recommendations for troubleshooting error messages and re-attempt calibration.
7 Troubleshooting & Repair

Although users are not responsible for repairing their devices, there are steps that may be taken to troubleshoot first-line errors that may occur before contacting maintenance or engineering support.

1 The bilirubinometer is not turning on:

- Charge the device or replace the batteries.
- If the bilirubinometer still does not turn on, try inspecting and/or replacing the charging cable.
- If the bilirubinometer still does not turn on, contact your maintenance department.

2 The bilirubinometer is providing results consistently incompatible with patient condition:

- Check to make sure there are no blood sample factors which may be contributing to inaccurate results.
- Check that you have waited the recommended time between applying blood to the test strip and running the test.
- Check the expiration date of the test strips. If expired use non-expired strips.
- If the results are still inconsistent, complete calibration as described Bilirubinometer: Care & Maintenance | User Preventive Maintenance.
- If the results are still inconsistent, contact your maintenance department.

3 The bilirubinometer is displaying an error:

- Consult user manual to determine error cause. If the user manual is not available, repeat calibration.
- If the bilirubinometer fails to read a measurement, there may have been a serious internal error. Contact your maintenance department or the manufacturer.
Assessment Questions

1. How often should calibration be performed on a bilirubinometer?
   
   Answer: As often as recommended according to manufacturer specifications.

2. Give one example of each of the following factors that could cause a bilirubinometer to give an inaccurate result

   a. Device factor:
   b. Blood sample factor:
   c. Timing factor:

   Answer:

   **Device factors:** expired strips, failure to calibrate device and contamination of blood application point or serum window.

   **Blood sample factors:** failure to use a transfer tube, inadequate blood sample volumes, very high haematocrit, blood samples contaminated by substances on the skin and direct exposure of a blood sample to phototherapy or sunlight.

   **Timing factors:** failure to wait a sufficient amount of time for the test strip to process the blood sample prior to initiating test or waiting more than the allowed amount of time between obtaining a blood sample and running the test.

3. Label the image below:

4. If the test result does not correlate with the patient's condition, what would you do?

   Answer: Confirm no contributing blood sample factors, make sure phototherapy lights are switched off, check the recommended time was waited for blood application check expiry date of test strips, repeat the test, consider laboratory testing.
Haemoglobinometer

Point-of-Care Diagnostics
Clinical Problem

Anaemia, which can increase the risk of morbidity and mortality in a sick newborn, requires rapid testing and may need urgent treatment. Assessment of haemoglobin level with a Point-of-Care (POC) haemoglobinometer should be considered for all sick and small infants with signs of anaemia when laboratory testing is not readily available.

POC haemoglobinometers are a valuable tool to rapidly assess haemoglobin levels in infants who have or are at risk of having anaemia, including those with:

- Prematurity
- Pallor
- Sepsis
- Potential Rhesus or ABO incompatibility
- Evidence of bleeding, severe bruising, cephalohaematoma or trauma
- Twin birth
- Congenital infections (e.g., HIV, Malaria, TORCH.)

Signs of anaemia can be non-specific and may be progressive, so repeated testing is often necessary. Preterm infants are more likely to become anaemic than term infants.

Assessment

Where available, assessment of haemoglobin should be performed on all infants showing signs of anaemia.

Haemoglobinometers are either portable or stationary (benchtop) devices. Some readerless methods require a user to compare the colour of blood on paper to a reference colour scale. **These are not recommended due to their inaccuracy, poor ability to ‘read’ low levels of haemoglobin and the subjective nature of measurement.** Point of Care (POC) haemoglobinometers provide a rapid quantitative measurement of a haemoglobin level that can then be used to direct care for patients with suspected anaemia. **(Figure 2.1)** When patients have anaemia that is severe, recurrent or non-responsive to treatment, or when a test result does not seem compatible with a patient’s clinical condition, the POC test result should be confirmed by laboratory analysis. This module will cover the function and use of quantitative POC haemoglobinometers to assess haemoglobin from capillary blood samples in sick and small infants.
Quantitative POC haemoglobinometers usually require 1-2 drops of blood to be applied to a microcuvette or test strip to determine the haemoglobin level. (Figure 2.2) The POC device allows the blood sample to react with reagents that lyse red blood cells or convert the haemoglobin to a stable form. The device reader then quantifies the red colour of the haemoglobin to determine the haemoglobin level.

Clinical factors that may affect the accuracy of POC haemoglobinometer test results include:

- **Poor peripheral circulation** e.g., due to shock or hypothermia
- **Clinical factors:** e.g., metabolic acidosis, high haematocrit, hyperoxia, leukocytosis
- **Contaminated samples:** e.g., substances on the skin (alcohol that has not dried and dilutes the sample, dirt on optic reader that can impair photodetection)
- **Other rare causes**
Technical factors that may affect the accuracy of the test result include:

- **Improper storage**: temperature and humidity will affect result accuracy if test strips are not stored according to the manufacturer’s directions.
- **Improper blood sampling**: inadequate volume, sample contamination, improper application to the test strip or cuvette, air bubbles in a sample or if there is a long delay between sample collection and testing. (Alert 2.1)
- **Improper collection**: when a sample is very difficult to obtain, squeezing the site results in interstitial fluid diluting the blood and may lead to a falsely low result.
- **Test strip/microcuvette factors**: using strips or microcuvettes that are expired, incompatible with a device or failing to input the correct batch code may all give inaccurate results.

### Alert 2.1

Delays between taking a sample and placing it in the haemoglobinometer can give inaccurate readings. Be sure to keep within the time range that the manufacturer’s recommend.

Haemoglobin levels in newborns vary widely depending upon gestational and chronological age. See the table below:

<table>
<thead>
<tr>
<th>Above 34 weeks (g/dl)</th>
<th>29–34 weeks (g/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Birth</strong></td>
<td></td>
</tr>
<tr>
<td>17.0 (14.0 – 21.0)</td>
<td>17.0 (13.0 – 20.5)</td>
</tr>
<tr>
<td><strong>2 weeks</strong></td>
<td></td>
</tr>
<tr>
<td>14.5 (11.0 – 19.0)</td>
<td>13.0 (10.0 – 16.5)</td>
</tr>
<tr>
<td><strong>1 month</strong></td>
<td></td>
</tr>
<tr>
<td>13.0 (9.5 – 17.0)</td>
<td>11.0 (7.0 – 14.0)</td>
</tr>
</tbody>
</table>

Below 29 weeks refer to departmental guidelines.
3 Management

Management of a haemoglobinometer includes how to set up and use the device, prepare the patient, conduct and conclude the assessment.

SETTING UP FOR A PATIENT

1 Collect: (Figure 3.1)
   - Haemoglobinometer
   - Test strip or microcuvette

2 Turn on the haemoglobinometer by pressing the power button.

3 If using a microcuvette, some cuvette holders need to be pulled out to the loading position. If using a test strip insert it into the device.

4 A quality control test should be conducted in accordance with the manufacturer’s recommendations.

Figure 3.1 Haemoglobinometer overview.
PREPARING A PATIENT

1. Assess patient for clinical conditions associated with anaemia.

2. Always explain the purpose, benefits and risks of a procedure to guardians BEFORE performing the procedure.

3. Collect:
   - Gloves
   - 70% alcohol
   - Cotton wool or gauze

4. Follow handwashing protocol and put on gloves.

5. Make plans and preparations to manage the patient’s pain.

6. Consider warming the foot to improve blood flow before proceeding.

7. Disinfect the skin on the outer or inner edge of the patient’s heel using cotton wool or gauze soaked in 70% alcohol. (Figure 3.2) Allow to dry before testing. Capillary blood samples on newborns are taken from the outer or inner area of the heel to protect the nerves and blood vessels. Samples should never be taken from the finger or toe. Avoid areas of skin that are poorly perfused, oedematous, inflamed or infected.

   Figure 3.2 Disinfect the outer or inner edge of the heel using cotton wool or gauze soaked in 70% alcohol.

TESTING A PATIENT

1. Collect:
   - New lancet
   - Haemoglobinometer
   - Unexpired Test strip/microcuvette
   - Cotton wool or gauze
   - 70% alcohol
   - Gloves
   - A small tray to carry the items
   - Sharps container

2. Follow handwashing procedures and put on gloves if not already done.
3 Make sure the haemoglobinometer is switched on if required.

4 Obtain a capillary blood sample from the disinfected outer or inner edge of the heel and apply it to the test strip or microcuvette. **(Alert 3.1)**
   
a. If using a test strip: see **Point-of-Care Diagnostics | Point-of-Care Testing** section for further details on test strip sample collection.

b. If using a microcuvette. **(Figures 3.3, 3.4)**
   
   - Place the tip of the microcuvette in the drop of blood. Ensure that the drop of blood is large enough to completely fill the microcuvette. Fill the microcuvette in one continuous process. Do not refill a partially filled microcuvette
   - Carefully wipe off any excess blood from outside the microcuvette. Avoid touching the open end.
   - Visually inspect the microcuvette for any air bubbles near the optical eye. If bubbles are present the microcuvette should be discarded and a new sample should be taken.

### Alert 3.1 Best practices for best results

Before taking a sample make sure the site has dried.

**Figure 3.3** Prick the disinfected inner or outer edge of heel using a lancet.

**Figure 3.4** Collect blood drop with microcuvette.
5 Following blood collection, apply pressure to stop bleeding. (Figure 3.5)

6 Insert the prepared sample into the haemoglobinometer. (Figure 3.6) NOTE: The permissible time between sample collection and testing varies widely depending on the device. Make sure to follow the manufacturer’s recommendation for your particular device.

7 Haemoglobin level will be displayed as a number on the haemoglobinometer screen. (Figure 3.7) Read and record this result. Refer to your departmental guidelines to determine what action is required. If the measurement is not in accord with the patient’s clinical condition, repeat the test or consider confirmatory laboratory testing if available.

CONCLUDING ASSESSMENT

The used lancet is disposed of in a sharps’ container. Dispose of the used test strip or microcuvette and gloves in a clinical waste container. Then wash your hands.
4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or disposed of promptly or adequately between patients, they may pose a significant infection risk.

**GENERAL INFECTION PREVENTION**

1. Clean hands with soap and water or 70% alcohol before and after assessing a patient using a haemoglobinometer or handling any materials that will be used on a patient (e.g., a lancet). **Gloves should be worn throughout the process of taking a haemoglobin measurement and disposed of immediately after finishing the test.**

2. Always thoroughly clean the infant’s skin before doing a test using a haemoglobinometer. Inadequate cleaning of the skin may result in an infection. Do not take a sample from an infected skin site as this risk’s dissemination of the infection.

3. Avoid pricking the same area multiple times.

4. **Never** prick different areas with the same lancet and do not re-use lancets.

5. The used lancet is disposed of in a sharps’ container. Dispose of the used test strip or microcuvette and gloves in a clinical waste container. Then wash your hands.

6. See the **Point-of-Care Diagnostics | IPC** section for further precautions.

**DISINFECTION AFTER USE**

1. Wearing clean gloves wipe down the haemoglobinometer with 70% alcohol. *(Figure 4.1)* Be careful not to submerge or drip alcohol onto the haemoglobinometer, particularly avoid dripping alcohol into the reading slot.

*Figure 4.1 Wipe down the haemoglobinometer with 70% alcohol.*
5 Complications

Introduction of equipment into newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximise patient safety.

DEVICE COMPLICATIONS

Clinical factors leading to inaccurate readings can be caused by:
- Hypothermia
- Metabolic acidosis
- Hyperoxia
- Leukocytosis
- Other rare causes

Technical factors leading to inaccurate readings can be caused by:
- Expired test strips: Out of date test strips or microcuvettes can produce inaccurate readings.
- Unopened test strips or microcuvettes may have a limited shelf life.
- Individually packaged microcuvettes are stable until the expiration date printed on each package.
- Improper storage of test strips/microcuvettes: the container lid should be tightly closed to protect from humidity. Keep away from any direct heat source.
- Failure to calibrate the device: not reading the test strip in the required time period.
- Improper collection and application of blood sample: contaminated blood samples.

6 Care & Maintenance

Users are responsible for basic first-line care and maintenance to ensure equipment lasts for its potential lifetime.

POWER SOURCE

Haemoglobinometers are powered either directly from the mains power or by replaceable or rechargeable batteries. (Figures 6.1a, 6.1b) If using a rechargeable device, the haemoglobinometer should be placed on the charging port when it is not in use to ensure power in the event of a power outage.
WARD LOCATION

The haemoglobinometer and associated testing strips or microcuvettes should be stored in a clean, dry and secure place. As haemoglobinometers and their testing materials are small, care should be taken to ensure that they remain on the ward and accessible for use when required.

USER PREVENTIVE MAINTENANCE

Haemoglobinometers require little preventive maintenance beyond recharging or replacing batteries and ensuring that the device is cleaned appropriately when indicated.

**Quality control tests** are recommended for most haemoglobinometers on a regular basis. Manufacturer recommendations on the frequency of quality control tests should be followed. *(Figure 6.2)*

A quality control test using the control solutions provided with the haemoglobinometer may be used. Most haemoglobinometers with this functionality will have a specific quality control testing mode to switch to within the device menu. The control solution should be placed on the test strip or microcuvette as one would with a normal sample. The value will need to be compared against the manufacturer’s references. If the device does not pass the quality control test, contact the manufacturer to who may recommend steps to repair, calibrate or replace as needed.
Clean a microcuvette holder and the optronic unit if appropriate in accordance with the manufacturer guidelines.

7 Troubleshooting & Repair

Although users are not responsible for repairing their devices, there are steps that may be taken to troubleshoot first-line errors that may occur before contacting maintenance or engineering support.

1 The haemoglobinometer is not turning on:
   - Charge the device or replace the batteries.
   - If the haemoglobinometer still does not turn on, contact your maintenance department.

2 The haemoglobinometer is providing results consistently incompatible with patient condition:
   - Ensure the test strips or microcuvettes are not expired.
   - Some strips are very sensitive to humidity. If you suspect the packet may have been left open in a humid environment, use a strip from a new packet.
   - Confirm that you are using the test strips or microcuvettes that are compatible with the haemoglobinometer.
   - If the results are still inconsistent, complete a quality control test as described in [Haemoglobinometer: Care & Maintenance](#) | User Preventive Maintenance.
   - If the results are still inconsistent, contact your maintenance department.
Assessment Questions

1. List three clinical factors that might cause a haemoglobinometer to give an inaccurate reading.  
   Answer: Poor peripheral circulation, metabolic acidosis, high haemocrit, hyperoxia, leukocytosis, contaminated samples, improper blood samples.

2. If using a haemoglobinometer with a microcuvette, what should you do if you observe air bubbles near the optical eye?  
   Answer: The microcuvette should be discarded and a new sample should be collected.

3. If the test result does not reflect your clinical assessment of the newborn what should you do?  
   Answer: Repeat the test and if the result is still unexpected send a blood sample for lab testing.
REFERENCES


3 Sharma, G. Infection Prevention and Control at Neonatal Intensive Care Units. 134.


7 Barria, R. M. Selected Topics in Neonatal Care. (BoD – Books on Demand, 2018).


Newborn Essential Solutions and Technologies – Education
Clinical Modules: Point-of-Care Diagnostics

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The authors have made every effort to check the accuracy of all information and instructions for use of any devices or equipment. As knowledge base continues to expand readers are advised to check current product information provided by the manufacturer of each device, instrument or piece of equipment to verify recommendations for use and/or operating instructions.

In addition, all forms, instructions, checklists, guidelines and examples are intended as resources to be used and adapted to meet national and local health care settings’ needs and requirements.
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