Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Bone Marrow Aspirate and Trephine (BMAT): Navigating Challenges and Optimizing Diagnostic Yield - A Comprehensive Review

Haram Awadelkarim [1], Bahariah Khalid [1*], Rahayu Mohd Eusni [2], Osama Ali Altayeb [3]

[1]Haematology Department; Faculty of Medicine and Health Sciences; Universiti Putra Malaysia;43400 UPM Serdang; Selangor; Malaysia

[2]Pathology Department; Faculty of Medicine and Health Sciences; Universiti Putra Malaysia;43400 UPM Serdang; Selangor; Malaysia

[3]Flow cytometry Department; Armed Force Hospital Southern Region; 61961 Khamis Mushait; Asir; Saudia Arabia

*** Corresponding author**

Email ID : bahariah@upm.edu.my

Cite this paper as: Haram Awadelkarim , Bahariah Khalid , Rahayu Mohd Eusni , Osama Ali Altayeb , (2025) Bone Marrow Aspirate and Trephine (BMAT): Navigating Challenges and Optimizing Diagnostic Yield - A Comprehensive Review. *Journal of Neonatal Surgery*, 14 (32s), 4815-4823.

ABSTRACT

The Bone Marrow Aspirate and Trephine biopsy (BMAT) procedure is fundamental for diagnosing, staging, and monitoring hematological and non-hematological disorders. Achieving a comprehensive morphological evaluation often requires a multi-faceted approach, including aspirate smears, trephine biopsy, imprint preparations, spicule crush, and clot preparations. (1,2)

This review aims to provide a comprehensive overview of the BMAT procedure, highlighting common challenges encountered in obtaining adequate and representative samples and critically evaluating evidence-based strategies to optimize diagnostic yield. We synthesize current literature, including best practice guidelines from the International Council for Standardization in Hematology (ICSH), alongside clinical experience, to enhance the understanding of clinicians and medical students. Furthermore, we discuss the implications of common discrepancies and propose mitigation strategies to improve diagnostic accuracy and patient management.

Keywords: *BMAT Procedure, Morphological Examination, BMAT Discrepancies, Hematological disorders, Non-Hematological disorders.*

1. INTRODUCTION

Bone marrow examination is a pivotal diagnostic tool widely used to evaluate patients with various hematological disorders. It is a critical part of the patient's pathway used for diagnosis, staging, and therapeutic monitoring. BMAT encompasses two complementary procedures—aspiration and trephine biopsy, which provide complementary cytological and architectural insights. (1,2) An estimated 20,000 bone marrow aspirates, with or without trephine biopsies, are performed annually in the UK alone. (3) However, variations in specimen collection, processing, and interpretation can lead to diagnostic inconsistencies. This review seeks to address these issues by examining the key steps of the BMAT procedure, identifying common pitfalls that compromise sample quality, and critically appraising strategies proposed in the literature to overcome these challenges, ultimately aiming to promote best practices. The information presented herein is based on a synthesis of peer-reviewed articles, international guidelines, and the authors' clinical experience.

1.1Indications for Bone Marrow Examination

BMAT is indicated in the evaluation of unexplained cytopenia, suspected hematological malignancies (e.g., leukemia, lymphoma, multiple myeloma), staging of malignancies, fever of unknown origin, storage disorders, and monitoring treatment response.

A) Diagnostic Applications

- Evaluation of hematologic disorders and neoplasms (e.g., unexplained cytopenia, abnormal peripheral cells).
- Investigation of pyrexia of unknown origin (PUO).
- Microbiological diagnosis of infections (e.g., leishmaniasis, HIV, extrapulmonary TB, histoplasmosis, malaria).
- Diagnosis of deposition/storage diseases (e.g., amyloidosis, Gaucher disease).

- Evaluation of unexplained splenomegaly or iron metabolism issues.
- Confirmation of marrow involvement in secondary malignancies (e.g., breast or lung cancer)

B) Staging of Neoplastic Disorders

Staging of lymphoproliferative diseases, neuroblastoma, and paediatric tumors.

C) Therapeutic Monitoring

Assessing marrow damage from myelotoxic agents (radiation, chemotherapy).

Monitoring response to treatment in transplantation or marrow-ablative chemotherapy.

Moreover, Common indications for bone marrow examination are listed in Table 1 : [1,2,4]

Table 1: Specific Indications for Bone Marrow Aspiration and Trephine Biopsy

Major Indication	***Diseases/Conditions***
Hematological Disorders	Pancytopenia or unexplained anemia, leukopenia, or thrombocytopenia Leukemia (Acute/Chronic) Myelodysplastic syndrome Myeloproliferative disease Plasma cell dyscrasia Non-Hodgkin lymphoma Hodgkin lymphoma Aplastic anemia Thrombotic thrombocytopenic purpura Primary amyloidosis
Non-Hematological Disorders	Pyrexia of unknown origin (PUO) Small cell tumors of childhood Mast cell disease Disseminated granulomatous disease. Metabolic bone disease Microbiological culture for investigations of pyrexia of unknown origin or specific infections, e.g., military tuberculosis, leishmaniasis, malaria Investigation of lipid/glycogen storage disorders Investigation of suspected bone marrow metastases
Therapeutic Follow-Up	Post-chemotherapy Transplantation monitoring Treatment of isolated cytopenia Evaluation of iron stores

2. Bone Marrow Procedures

Bone marrow aspiration and trephine biopsy are invasive techniques requiring skilled execution to obtain high-quality diagnostic samples. [5] Steps and explanation figures are shown below.

2.1 Preliminary Preparation

The Operator reviews the clinical history and indication.

Ensure appropriate analgesia/sedation.

Assess for bleeding risk (thrombocytopenia/coagulopathy).

Explain the procedure clearly to the patient and/or their family. In detail, its indication, potential benefits in diagnosis and treatment, risks, and all questions answered to the satisfaction.

Obtain informed consent detailing potential risks (infection, bleeding, inadequate sample, pain, scar formation, and failure to obtain adequate specimens).

Anatomical Site & Positioning

Position: The patient is positioned in a lateral decubitus position (laterally C-shape), with the top leg flexed and the lower leg straight. Alternatively, the patient may be placed in a prone position. And the Common site is the posterior superior iliac crest.

Monitoring: The patient is connected to the monitoring device to monitor vital signs, including blood pressure and heart rate.

Preparation: Prepared all the required equipment for Bone Marrow Examination Kits, and septic precautions and full PPE must be used.

Skin antisepsis: preferably with chlorhexidine gluconate or povidone-iodine.

Anesthesia: Local anesthesia with 1% lidocaine using 3 mL to anesthetize the skin and subcutaneous tissue. Then, gently inject lidocaine at various points on the cortical bone, administering 1 ml of anesthetic with each injection.

If the patient is anxious about pain, they may be given an IV medication so that either completely or partially sedated during the bone marrow exam.

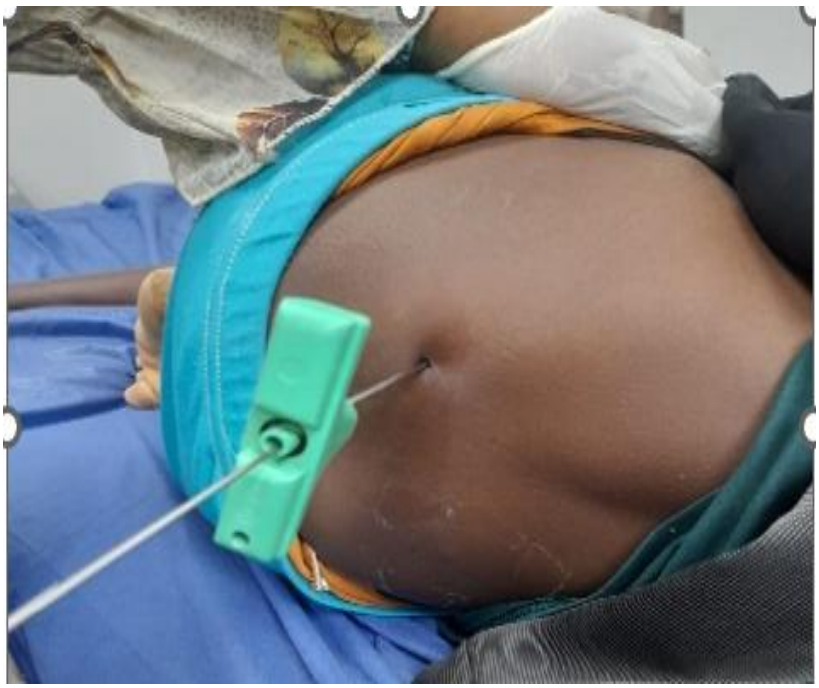

Figure1: Patient position (posterior superior iliac crest)

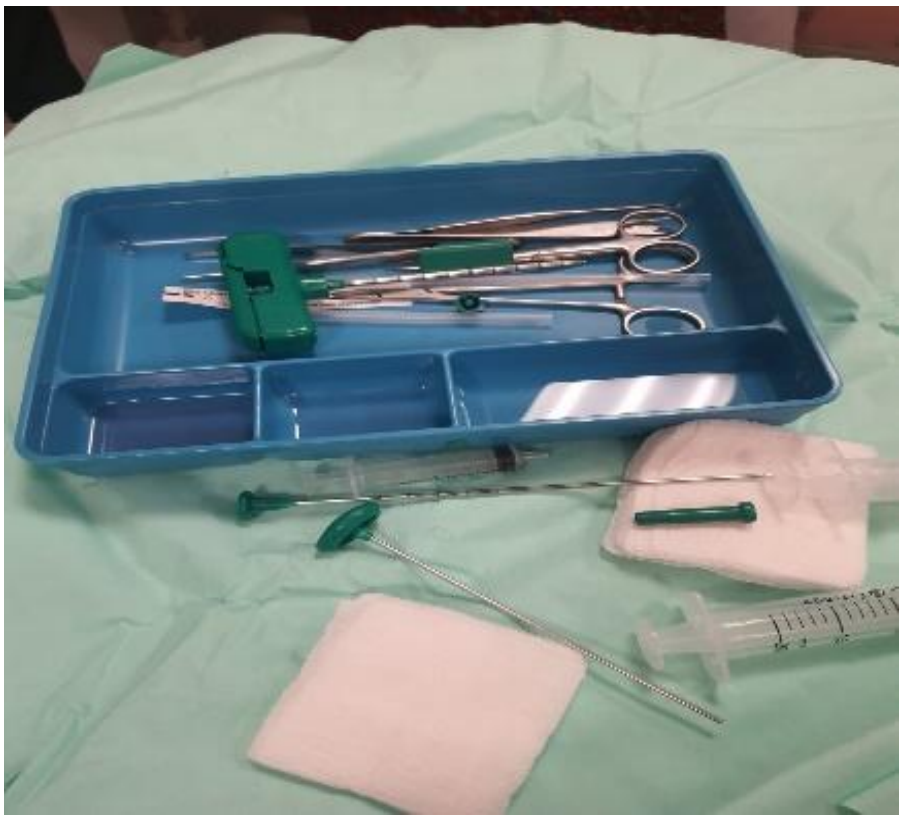

Figure 2: Equipment Preparation.

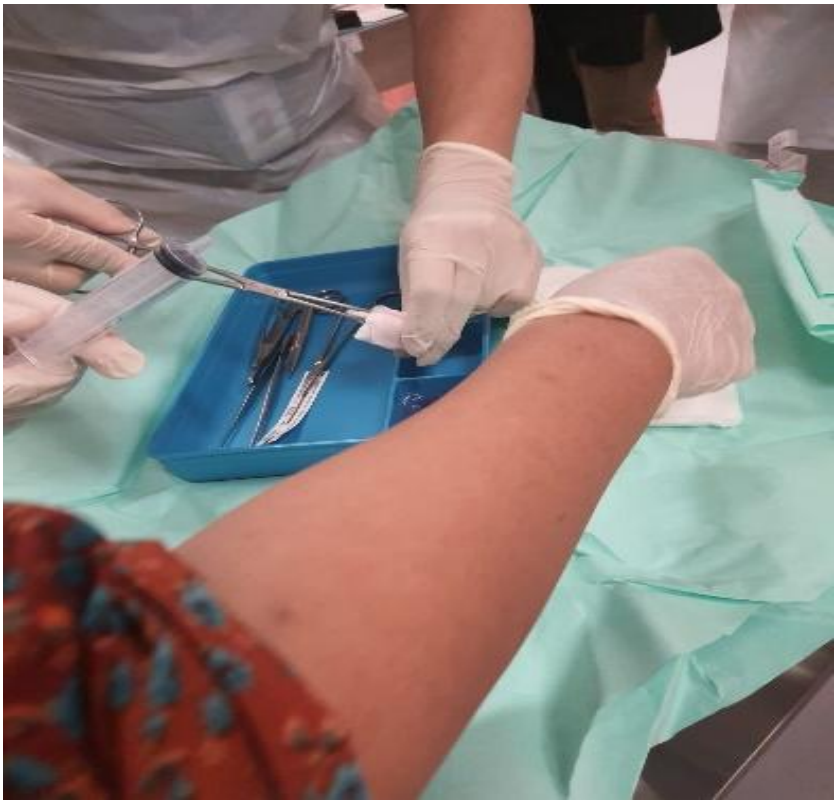

Figure 3: Skin Preparation.

Figure 4: Local anaesthesia injection.

Figure 5: Placement of needle for aspiration

Figure 6: Aspiration of bone marrow

Bone Marrow Aspiration

Bone Marrow Aspirate is a reliable and rapid method of evaluating Bone Marrow pathology. [6] It has been used for cytological assessment, with analysis directed toward morphology and the obtainment of a differential cell count. [7] Start the procedure after a waiting time of between 3 and 5 minutes. First, identify the parts of the bone marrow needle. Usually prefer to use size 11G ×10 cm Bone marrow biopsy needles.

Insert the needle at the previously marked site, through the skin and subcutaneous tissue until it abuts the bone, then push the needle through the bony cortex and ensure the needle reaches and is placed into the marrow cavity, rotating it on its axis until it is fixed in place at the desired depth. The obturator is being removed. Attach a 10- or 20-ml plastic syringe to provide adequate negative pressure, attached to the aspirating needle. [1] Gently withdraw (< 5 seconds), and approximately 0.5 ml of the initial aspirate draw should be collected. As the aspirate volume is increased, peripheral blood is gradually included to dilute it. Aliquot the aspiration into each of the 2 EDTA tubes. Mix the EDTA tubes by inversion 8-10 times; the amount of aspirate should be proportional to the amount of EDTA in the tube to minimize EDTA-induced artifacts. Apply the B.M. aspirate smears from small drops of the bone marrow aspirate placed on glass microscope slides.

Bone Marrow Trephine Biopsy

A bone marrow trephine biopsy is used to evaluate a range of hematological issues, especially when marrow cellularity, cell distribution, and the interrelationship among cell types are essential. It also plays a significant role in focused processes. The pattern of infiltration observed in bone marrow biopsy can provide extra prognostic information in certain disorders, such as lymphomas. They play a crucial role in "dry tap" situations, in which aspirate investigation fails due to fibrotic or infiltrative processes. [7] Obtain a biopsy using a B. M biopsy needle 11 G (Geotek Medical device, origin Turkey) and use the small blunt obturator with each biopsy needle to remove the biopsy core. Ideally, the core length should be about 1.5 cm to 2 cm. The current guidelines from WHO recommend the collection of ≥ 1.5cm long bone marrow core with ≥10, particularly preserved intertrabecular areas.

Preparing touch preparations from the biopsy core by gently touching a clear glass microscope slide to the biopsy core, resting on another glass slide. Cells on the surface of the core stick to the clean slide, which is later stained by the Wright & Leishman stain. Subsequently, the biopsy sample was transferred to a PBS container with a pH of 7.2 to apply the crush, and another biopsy was placed in 10% formalin for Histopathological examination. All the samples will be processed within 6–12 h of collection.

Post-Procedure Care

After the procedure, apply firm pressure with the thumb or fingers for 5 minutes at the procedure site until bleeding has completely ceased. Remove residual antiseptic to avoid further skin irritation from the solution.

A double gauze square is placed over the procedure site. Cover the area with at least two pieces of surgical tape approximately 2-3 inches long and have the patient lie supine for at least 30 minutes. Rarely, bleeding may be present; if that is the case, consider placing a pressure dressing with the patient in a supine position for an additional 1 hour. Advise the patient to remove the dressing the following day. The patient evaluation must be applied by monitoring and observing the patient, informing of any abnormalities results, or findings during observation, Position patient in a comfortable position, observing for pain management, Keeping the patient calm, and resting in bed, Continuing nursing care, and finally prepare for discharged according to physician order. All patient results will be documented in the patient record file and under privacy and confidential conditions. An expert hematologist will assess all bone marrow materials.

3. Challenges in the BMAT Procedure

Common complications and limitations include:

3.1 Inadequate Cellular Aspirate: The failure to obtain a cellular aspirate, reported in 4% to 10% of procedures, represents a significant obstacle. This can arise from technical factors, operator inexperience, or underlying marrow pathology such as myelofibrosis or dense infiltration. The implications of a non-diagnostic aspirate include potential delays or incomplete characterization of hematologic malignancies. [8,9,10]

3.2 The "Dry Tap" Phenomenon: A complete failure to aspirate marrow necessitates reliance on the trephine biopsy and ancillary techniques. While conditions like aplastic anemia and myelopathic lesions are known to cause dry taps [10], technical inadequacies can also contribute. Studies by Donald et al. and Baskota et al. [11] highlight the frequency of dry taps and their potential to hinder diagnosis, particularly in cases like plasma cell myeloma.

3.3 Aspicular Samples: A Diagnostic Limitation: The presence of Aspicular smears, lacking diagnostic marrow particles, is another common issue, with one study reporting rates as high as 20.6% even with optimized techniques [13]. Such samples limit cytological assessment and necessitate careful interpretation alongside trephine findings.

3.4 Hemodilution: Compromising Marrow Representation: Hemodilution, the contamination of the aspirate with peripheral blood, can obscure the true cellular composition of the bone marrow. This issue is exacerbated by larger aspiration volumes [1,6,13], emphasizing the need for small volume, spicular aspirates.

3.5 Procedural Artifacts: Clotted samples and biopsy damage resulting from delays or tissue factor contamination, it's sequential to aspiration and biopsy through the same needle [1]can further complicate the interpretation and quality of the specimens.

4. Strategies for Optimizing BMAT Quality and Diagnostic Yield: An Evidence-Based Approach

Optimizing Patient Positioning and Technique: Correct patient positioning and meticulous technique are fundamental in minimizing sampling errors and the occurrence of dry taps. The utility of repeating aspirations and considering bilateral biopsies in certain conditions, like Plasma Cell Myeloma (PCM) [14], and lymphoproliferative disorders [15] underscores the importance of procedural proficiency.

The Crucial Role of Touch Imprints: The literature, including studies by Baskota et al. and Chandra et al. [5, 7, 11], consistently highlights the enhanced diagnostic accuracy of touch imprint smears, particularly in dry tap scenarios. The ICSH also recommends their use for cytological evaluation, emphasizing their value as an adjunct to aspiration smears and biopsy sections.

Trephine Disaggregation for Flow Cytometry: **Expanding Diagnostic Capabilities:** When aspirates are inadequate, mechanical disaggregation of trephine biopsies for flow cytometry offers a valuable alternative for immunophenotypic analysis [(8)]. While not yet routine, this technique has shown promise in yielding aspirate-like data in a significant proportion of cases. [(9)]

The Rationale for Separate Needles: The recommendation to use separate needles for aspiration and trephine biopsy is supported by the evidence that this practice minimizes Hemodilution of the aspirate and reduces the risk of damage to the trephine core, thereby improving the quality of both specimens. [(1,2)]

Importance of Prompt Sample Handling: Strict adherence to immediate processing protocols is essential to prevent clotting and cellular degradation, ensuring the integrity of the samples for accurate analysis.

2. CONCLUSION

BMAT remains an indispensable procedure in the diagnosis and management of a wide spectrum of hematological disorders. Achieving accurate and reliable diagnoses hinges on the acquisition of high-quality specimens. This review has highlighted common challenges that can impede this goal and critically examined evidence-based strategies to mitigate these issues. By emphasizing meticulous technique, the strategic use of adjunct preparations like touch imprints, and the potential of techniques like trephine disaggregation, clinicians can significantly enhance the diagnostic yield of BMAT. Future research could focus on standardizing procedural techniques and evaluating the broader implementation of novel approaches to further optimize the clinical utility of BMAT.

3. ACKNOWLEDGMENT

The authors express their sincere gratitude to the staff of Universiti Putra Malaysia (UPM) Hospital for their support and cooperation.

REFERENCES

[1] Lee, S.-H. et al.ICSH guidelines for the standardization of bone marrow specimens and reports. Int. Jnl. Lab. Hem. 30, 349-364, (2008).

[2] Gopal Patel, Zarir Karanjawala, Denis McDwyer. The Importance Of Trephine Biopsy And Aspirate In Bone Marrow Analysis By Laboratory Best Practice Blog. February 16, 2021.

[3] Bain BJ. Bone marrow biopsy morbidity: review of 2003. J Clin Pathol 2005;58:406 8.

[4] Rindy LJ, Chambers AR. Bone Marrow Aspiration and Biopsy. 2023 May 29. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan–. PMID: 32644658.

[5] Baskota, S & Joshi, AR & Singh, S.K. (2015). Bone marrow touch imprint smears as an adjunct to bone marrow aspiration smears in hematological disorders. Journal of Pathology of Nepal. 5. 739. 10.3126/jpn.v5i9.13783.

[6] Afkhami, A. et. al. Peripheral blood smears, bone marrow aspirate trephine and clot biopsies: methods and protocols, page 257-270, in Day, C. E. (Eds.): Histopathology methods and protocols. Humana Press: New York, 2014.

[7] Chandra, S., & Chandra, H. (2011). Comparison of bone marrow aspirate cytology, touch imprint cytology, and trephine biopsy for bone marrow evaluation. Hematology Reports, 3(3). https://doi.org/10.4081/hr.2011.e22

[8] Wheeler M, White G, Brockie S, Dickson M, and Weinkove R. Flow Cytometric Analysis of Mechanically Disaggregated Bone Marrow Trephine Biopsies. Cytometry Part B 2018; 94B:935 940.

[9] Astle, J. M., Xu, M. L., Friedman, T., & Brown, E. (2017). Limitations of poor bone marrow aspirations (for an accurate diagnosis) despite the multimodal analytical era: A longitudinal retrospective study. American Journal of Hematology,92(10), E600-E602. https://doi.org/10.1002/ajh.24839.

[10] Ahmad SQ, Yusuf R, Zafar N, Ali N. DRY TAP: A DIAGNOSTIC ALERT FOR UNDERLYING BONE MARROW PATHOLOGY. J Ayub Med Coll Abbottabad. 2015 Jan-Mar;27(1):120-3. PMID: 26182755.

[11] Baskota, S & Joshi, AR & Singh, S.K. (2015). Bone marrow touch imprint smears as an adjunct to bone marrow aspiration smears in hematological disorders. Journal of Pathology of Nepal. 5. 739. 10.3126/jpn.v5i9.13783.

[12] Jose Angel Hawing, Olga Graciela Cantu Rodriguez, Andrés Gómez-De León, Consuelo Mancias, Luz del Carmen Tarín Arzaga, David Gomez-Almaguer; Aspicular Bone Marrow Aspiration: A Common, but Not a Minor Problem. Blood 2019; 134 (Supplement_1): 5841. doi: https://doi.org/10.1182/blood-2019-131662

[13] Odejide OO, Cronin AM, DeAngelo DJ, et al. Improving the quality of bone marrow assessment: impact of operator techniques and use of a specimen preparation checklist. Cancer. 2013;119:3472–3478.

[14] International Myeloma Foundation. n.d. "Bone Marrow Tests." Accessed May 29, 2025.

https://www.myeloma.org/bone-marrow.

[15] Almeida J, Garcia-Marcos MA, Vallejo C, Flores MT, Caballero MD, San Miguel JF, et al. Results of 104 consecutive bilateral bone marrow biopsy specimens in lymphoproliferative disorders. Sangre (Barc). 1995;40:365-8.