For many patients, bone marrow biopsy is a dreaded procedure. In addition to it being uncomfortable, if not painful, patients experience anxiety that the results may mean further treatment and yet another confrontation with one’s mortality. Bone marrow biopsy is a diagnostic procedure commonly used to (a) detect and stage malignancy, (b) differentiate benign hematologic diseases (e.g., aplastic anemia, Waldenstrom macroglobulinemia), and (c) evaluate progression of human immunodeficiency virus. Traditionally, physicians have performed this procedure, with the nurse present for assistance and as a source of emotional support for patients. As the role of the advanced practice nurse (APN) in oncology has evolved, specially trained nurse practitioners (NPs) and, in some states, certified baccalaureate nurses now perform bone marrow aspiration and biopsy independently. Training requirements vary by institution but include satisfaction of competencies that address responsibility and accountability issues. After observing a physician or certified member of the medical team, APNs must successfully perform several supervised and independent demonstrations of the procedure. These nurses play a key role in obtaining bone marrow samples, supporting patients during the procedure, and teaching patients about the results. This article presents information about bone marrow examination, techniques for collection, and procedural pain management. With this knowledge, nurses can more effectively help their patients through an anxious time and enhance their understanding of their diagnosis.

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Indications for Bone Marrow Assessment

Examining bone marrow is critical to assessing hematopoietic function. Evaluation is necessary to investigate the etiology of abnormal peripheral blood counts. Bone marrow aspiration and biopsy are used to confirm diagnosis and staging of primary and metastatic disease and to guide decision making for treatment. For example, in patients with fever of unknown origin, bone marrow biopsy may reveal metastatic disease or a nonhematologic disorder, such as infectious mononucleosis (Hyun, Stevenson, & Hanau, 1994).

The procedure is indicated when peripheral blood differential counts reveal unexplained granulocytosis or neutropenias. In myeloproliferative disorders, such as chronic myelogenous leukemia, myelodysplasia, or idiopathic myelofibrosis, abnormalities in more than one hematopoietic cell line occur. Study of the marrow morphology is key in the classification of these diseases. Bone marrow evaluation can classify an anemia as hypoproliferative, a maturation disorder, or resulting from hemorrhage or hemolysis (Hillman & Ault, 1998). Other indications for bone marrow examination include evaluation of immunodeficiency syndromes, confirmation of unusual infections in the marrow (e.g., miliary tuberculosis, fungi), and sampling of marrow for chromosomal analysis (see Figure 1).

In addition to the diagnostic value, bone marrow examination is a means to follow clinical response after treatment with chemotherapy, hematopoietic growth factors, radiation, or stem cell transplant. In acute and chronic leukemias, bone marrow aspiration is performed to evaluate remission after induction chemotherapy and at regular intervals during consolidation and maintenance therapy to monitor disease relapse (Ryan & Cohen, 2000). Sequence of chemotherapy depends on patients’ responses as measured by percentage of leukemic cells present in the bone marrow. Leukemic cells can be detected earlier in the marrow than in peripheral blood. Chimerism is the existence of diverse genetic material in an organ. Chimeric studies of bone marrow measure the degree of engraftment, or percentage of cells of recipient or donor origin, after allogeneic peripheral blood stem cell transplant in patients with malignancies (e.g., leukemia, lymphoma, multiple myeloma, some solid tumors) and in patients with nonmalignant diseases (e.g., thalassemia) (Winiarski et al., 1998).

Bone Marrow Structure

Bone marrow consists of a hematopoietic cell compartment and a stromal component that supports proliferation of the hematopoietic cells. From every hematopoietic stem cell, also referred to as totipotent or pluripotent stem cell, the bone marrow can produce about 10 cells that differentiate into cells with distinct functions in the body’s defense system (Wheeler, 1997). Hematopoietic marrow is contained in all bones at birth. With age, fat cells begin to replace the hematopoietic marrow in the bones of the extremities. By adolescence, only the bones of the axial skeleton, including the sternum, ribs, vertebrae, clavicles, scapulae, skull, pelvis, and proximal ends of the femur and humerus, contain hematopoietic marrow. When the body is under unusual stress, as in severe hemolytic anemia, extramedullary hematopoiesis sometimes is present, with extension into the femur and humerus.

Bone Marrow Collection

Assessment and Consent

Once a determination has been made that bone marrow aspiration and biopsy are warranted and a physician’s order has been obtained, a thorough history and physical examination is required. The lab also requires this information for complete evaluation of the specimens and comparison with peripheral blood smears. While obtaining the history and physical, the NP has the opportunity to evaluate the patient’s understanding of the rationale, risks, and benefits of the procedure and to ensure informed consent. The complete blood count, partial thromboplastin, and prothrombin times are reviewed for risk of bleeding. Other lab tests, such as serum iron studies and reticulocyte count, may be required for a full diagnostic picture. Collecting peripheral blood samples and marrow specimens on the same day is important for accurate comparison.

Additional precautions in certain patient populations are indicated prior to bone marrow aspiration and biopsy. Prophylactic therapy with coagulation factor replacement is required before the procedure in patients with hemophilia (factor VIII or IX deficiency) and related bleeding disorders. Caution also should be exercised in patients with soft bones secondary to radiation therapy, multiple myeloma, or osteoporosis. The risk of retroperitoneal hemorrhage or injury to the bowel exists if the needle breaks through the anterior cortex of the iliac crest. Hemorrhage is possible at any biopsy site. Application of a pressure dressing usually is adequate to prevent excessive bleeding, however, even in thrombocytopenic patients. A platelet transfusion may be ordered to keep the platelet count above 50,000. Other rare complications include pulmonary emboli and pericardial tamponade after sternal aspiration and infection at marrow aspiration sites, which is more common in immunocompromised patients.

Collection Site

Patients’ ages are taken into consideration when selecting the bone marrow collection site (see Figure 2). The posterior superior spine of the iliac crest is most commonly chosen for both aspiration and biopsy. If only aspirate is required, and it cannot be obtained from the iliac crest, the sternum may be used in adults. In some patients, the sternum may be the first choice for aspiration because of positioning limitations or
obesity. However, aspiration from the sternal site poses greater risk of complications and should be performed by a physician. The tibia can be used for aspiration alone in infants younger than 18 months of age.

Control of Procedural Pain

For patients undergoing the procedure for the first time or for patients who experienced extreme pain with prior biopsies, NPs must consider the best method to minimize discomfort given the setting and the support staff available. Patients should be told about the possibility of transient procedural pain and how the pain will be controlled. Patients’ coping mechanisms and previous experience with pain interventions, both pharmacologic and nonpharmacologic, are explored.

Chronic pain in adult patients with cancer has been studied, but the literature shows limited research on acute suffering of adult patients during painful procedures. In the hospital inpatient setting, in addition to adequate use of lidocaine for local analgesia, conscious sedation is an option to control pain, promote amnesia, and prevent anticipatory anxiety for future procedures. Conscious sedation is used more routinely in the pediatric population (McCarthy, Cool, Petersen, & Bruene, 1996). As a result of inherent risks with this method of anesthesia, many hospitals have a policy that requires NPs performing the procedure to be certified in advanced cardiac life support. Conscious sedation also requires frequent monitoring of vital signs and oxygen saturation and a longer recovery time. Many bone marrow aspirations are performed in outpatient clinics and doctors’ offices where adequate emergency equipment and staff support for IV sedation may not be available. Outpatients may have poor peripheral IV access. Also, in the outpatient setting, patients must bring another person with them to receive discharge instructions and provide them with transportation to their homes after sedation. Despite these obstacles to the use of conscious sedation, NPs should consider the benefits of this option for the comfort of adult patients (Mainwaring, Wong, Lush, Smith, & Singer, 1996).

A good local anesthesia with lidocaine usually is more than adequate. Oral analgesics and sedatives, such as lorazepam, given far enough in advance to be effective, are an alternative to conscious sedation. Transmucosal fentanyl is another option for short-acting pain relief without IV sedation. Providing information and employing relaxation techniques, such as visual imagery, distraction, progressive muscle relaxation, and controlled breathing, are cognitive behavioral interventions that nurses and APNs can use to help reduce patient anxiety.

Procedure

Figure 3 lists equipment required and procedural steps for a bone marrow aspiration. In the hospital and outpatient clinic setting, a trained laboratory technician often performs specimen and slide preparation during the procedure. After completion of the aspiration and biopsy, a procedure note is entered in the chart. This note includes verification of informed consent, site of aspiration, analgesia, anesthesia and equipment used, observation of sterile technique, patient status, complications, if any, postprocedure instructions, and tests requisitioned. Figure 4 presents a sample procedure note.

Interpretation of Results

A wealth of information can be derived from examination of bone marrow. See the inset for a case scenario and sample bone marrow aspiration report. Usually, both bone marrow aspiration and biopsy samples are obtained to fully evaluate the cellularity of the marrow and the nature of the cells. A marrow core sample of at least 16 mm is necessary for analysis. Core specimens shrink by about 25% during processing (Lawson, Aston, Baker, Fegan, & Milligan, 1998). Even an adequate specimen represents only a small percentage of the marrow, and detection of abnormal cells can be made more difficult by such factors as radiation-induced fibrosis and nonuniform tumor invasion. Aspirate alone is sufficient in patients with leukemia who are being followed for minimal residual disease and in pediatric patients when a potential for chromosomal abnormalities exists. Bone marrow diagnostic evaluation can include morphologic examination of stained smears, cytochemistry, histologic examination of stained sections, culture for microorganisms, immunocytochemistry, cell marker analysis by flow cytometry, cell culture assays, cyogenetics, and molecular biologic studies of gene translocations and rearrangements (Ryan & Cohen, 2000) (see Table 1). The completed bone marrow slide folder should include Wright-Giemsa-stained smears of blood, direct marrow smear, marrow particle, marrow biopsy imprint, marrow concentrate, and unstained smears of the mixed layer.

Morphologic Examination

The morphology of the bone marrow is best derived from a properly prepared direct smear because the cells are manipulated less and no anticoagulant is used with this technique.

*A full discussion of conscious sedation is beyond the scope of this article. For more information, the reader is referred to Society of Gastroenterology Nurses and Associates (2000) guidelines on the use of conscious sedation.
Figure 3. Bone Marrow Equipment and Collection Procedure

Variables that can affect the quality of the smear include the size of the aspirate marrow drop, the angle and the speed of spreading the smear, and the hematocrit of the sample. The smear, made from the first 0.5 cc of aspirate obtained, should contain spicules (particles of fatty droplets), granules, or small chunks of bone. After drying, smears are stained with Wright-Giemsa stain to accentuate the details of nuclear and cytoplasmic structure. Cellularity is an estimate of the percentage of hematopoietic components and stroma in the marrow space. In hypocellular marrow, as with aplastic anemia or in marrow packed with leukemic cells, aspirate may not be obtainable. This is known as a “dry tap.” In this case, a core biopsy specimen is needed to best assess cellularity. Touch preparations are made by lightly touching the core specimen on several slides. The core then is placed in 10% formalin for fixation and histologic sectioning.

Selection of the best quality direct smear is critical for accurate interpretation. With the microscope on low power, particle cellularity and distribution and frequency of megakaryocytes can be identified. A falsely low estimate of cellularity may be made if the specimen is diluted with peripheral blood. With medium power, the sample is inspected for leukocyte distribution, abnormal cells, smudge cells, nucleated red cells, red cell agglutination, fibrin strands, parasites, and background staining (Ryan & Cohen, 2000). On high power, cytologic detail and leukocyte differential can be determined.

In normal marrow, the percentage of myelocytes and later precursors is about the same as the percentage of mature neutrophils. Promyelocytes are fewer, comprising less than 10% of myeloid elements. Less than 5% of nonlymphoid hematopoietic cells should be blasts. The myeloid/erythroid (M/E) ratio is estimated in the context of the overall cellularity. If cellularity is not considered, whether a lower ratio is a result of myeloid hypoplasia or erythroid hyperplasia is not clear. At birth, the M/E ratio is about 4.3. After one year, the M/E ratio is about 3:1. Nonhematopoietic precursor cells, such as macrophages, osteoblasts, mast cells, and Schwann cells, are found in bone marrow. However, the presence of an increased number or morphologically abnormal cells in the aspirate is an indication for examination of a core biopsy to investigate disorders that result in infiltration of the marrow. Possible diagnoses include metastatic tumor and lipid storage disorders, such as Gaucher.

### Equipment

1. Sterile gloves
2. Sterile drape
3. Povidone-iodine
4. Bone marrow aspiration needle or 11- or 13-gauge Jamshidi needle
5. 25- and 22-gauge needles
6. No. 11 scalpel blade
7. Heparinized 10 cc syringe
8. 3 cc and 10 cc syringes
9. 1% lidocaine
10. Glass slides (10)
11. Specimen bottle with formalin
12. 4” x 4” gauze
13. Pressure dressing and tape

Optional: Sodium bicarbonate, spinal needle (Note. Prearranged bone marrow trays are available.)

### Procedure

1. Obtain physician’s order and informed consent for bone marrow aspiration/biopsy.
2. Assist the patient to assume a prone position. If unable to maintain prone position, try a lateral decubitus position, with knees bent toward chest.
3. Palpate the iliac crest and follow along to posterior superior spine. Mark site with pen.
4. Using sterile technique, prepare the surrounding skin with povidone-iodine solution. Apply sterile drape to area.
5. With 25-gauge needle, draw up 9 cc of 1% lidocaine solution (1 cc sodium bicarbonate may be added to the syringe). Inject 0.5 cc under the skin, raising a wheal. Change needle to 22-gauge. Inject more lidocaine deeper into surrounding tissue in a circular formation, locating and tapping the iliac crest to anesthetize the periosteum. Occasionally, a spinal needle is needed to reach the periosteum in a larger patient. Wait about two minutes for the anesthetic to take effect.
6. With the surgical blade, make a small incision.
7. Loosen and then relock the obturator of the Jamshidi needle with the cap secured. Introduce the needle into the incision, holding the capped end firmly in the palm of the hand. Anchor the shaft between the middle and index fingers of the other hand. With a rotating motion, carefully penetrate the soft tissue of the periosteum. Continue to maneuver the needle through the cortex of the iliac crest about 1 mm to the marrow. Release the manual pressure and slowly insert the needle about 1–2 mm further.
8. Unlock the cap, and remove the obturator. Quickly attach an empty 10 cc syringe to the end of the biopsy needle. Ask the patient to take a deep breath to minimize a momentary painful pulling sensation as a small amount, about 1 cc, is aspirated. If no aspirate is obtained, advance the needle another 1–2 mm. A good specimen contains visible bone spicules when spread on the slide. Sometimes, it is necessary to change sites and repeat the aspiration procedure.
9. If additional tests have been ordered, more aspirate may be withdrawn into heparinized syringes.
10. If a core biopsy also is required, replace the needle cap and pull back the needle about 2–3 mm to the level of the cortex. Then, advance the needle at a different angle toward the anterior iliac spine into the marrow. Remove the obturator.
11. Turn the needle clockwise and counterclockwise about three times. Then, withdraw the needle about 2–3 mm. While rocking and rotating the needle, advance it again about 5 mm.
12. Withdraw the needle. Fit the obturator into the distal end of the needle and push the specimen through the hub onto gauze or directly into specimen cup.
13. Verify labeling of all specimens and dispatch them to lab.
14. Instruct patient to lie supine for about 15–30 minutes. The site should be kept dry with the pressure dressing in place for about 24 hours. Instructions also should be given to apply additional pressure to site if bleeding occurs through the dressing.
Flow Cytometry

Flow cytometry, a technique used to analyze cell surface markers, is most useful for screening leukemias and following acute lymphocytic leukemia. When lymphocytic infiltration is found in peripheral blood or bone marrow, flow cytometry can determine whether the population of cells is monoclonal or polyclonal (Winkelman, 1998). The analysis is performed on a liquid sample of bone marrow. Heparin is added to prevent the sample from clotting. Automated differentials of complete blood counts are generated with this technique. Structural complexity of a particle cell type causes a distinct light scatter pattern. The flow cytometer measures the size and granularity of the cell population by detecting pulses of scattered light as particles pass through the light beam. The technician is able to select a certain population of cells in a sample to be studied for differentiation or maturation-related proteins using labeled monoclonal antibodies or DNA binding dyes (Abrahamsen et al., 1995). Cluster designation (CD) refers to a cluster of antibodies identifying the same antigen. An ex-

Case Study

KM, a 68-year-old Caucasian male, presented to the emergency department with heart palpitations. He denied having chest pain, dizziness, or nausea and reported feeling more fatigued in the last month. He was afebrile, his blood pressure was 130/62, his pulse was 67, and his respiration were 18. Differential diagnoses included acute myocardial infarction, dysrhythmia, and anemia. An electrocardiogram showed normal sinus rhythm. A chest x-ray showed mediastinal widening. His echocardiogram was normal, and the left ventricular injection fraction was 70%. Lab results were as follows: white blood count 2,100, hemoglobin 11.8, hematocrit 33.6, MCV 102, MCH 35.2, MCHC 35, platelets 105,000. Electrolytes and cardiac enzymes were within normal range. Acute myocardial infarction was ruled out. Based on preliminary diagnoses of pancytopenia with macrocytic anemia and cardiac dysrhythmia, a hematologist was consulted and further tests were ordered. A full peripheral blood workup, including erythropoietin level, B12, folate, thyroid stimulating hormone, antinuclear antibody, rheumatoid factor, sedimentation rate, serum protein electrophoresis, immunoelectrophoresis, and 24-hour urine for total protein and immunoelctrophoresis were ordered. The marrow was diffusely infiltrated by blasts with blasts to be uniformly negative. Approximately 15%–20% of the cells were myeloperoxidase positive.

A preliminary diagnosis of acute myeloid leukemia treatment could be delayed. Final diagnosis was made after complete consideration of all studies performed on marrow samples and peripheral blood smears correlated with the clinical history.

Bone Marrow Interpretation

Peripheral blood: Aspiration and biopsy revealed the red cells to be largely normocytic and normochromic. A number of elliptocytes were present. Platelets appeared to be moderately decreased in number. White blood cells were decreased in number as well. Normal lymphocytes and neutrophils were encountered. No blasts were seen.

Bone marrow: The bone marrow was mildly hypercellular—2:3/4+. Megakaryocytes were adequate in number. No blasts were seen. The number of maturing myeloid elements was markedly reduced, and relative normoblastic erythroid hyperplasia existed. The marrow was diffusely infiltrated by blasts with moderate amounts of basophilic cytoplasm and often multiple and indistinct nucleoli. Faint cytoplasmic granularity were seen in some of the blasts. No Auer rods were seen. 

Alpha naphthyl butyrate esterase staining revealed the blasts to be uniformly negative. Approximately 15%–20% of the cells were myeloperoxidase positive.

Impression: Acute myeloid leukemia (FABM2)
example of lineage association is CD 34 expressed on lymphoid stem cells. The population of CD 34 in peripheral blood increases from 0.01% to 1% after administration of chemotherapy and granulocyte colony stimulating factor. This information may be used to decide optimum time for peripheral blood stem cell harvest in patients undergoing transplant.

**Immunophenotyping**

The assumption that the phenotype of an abnormal cell is a specific pattern of marker expression and not random is the basis for the clinical relevance of immunophenotyping. Neoplastic cells at first appear to resemble normal cells in a particular lineage at a specific stage of differentiation. However, with this technology, antibody reagents can detect an aberration in the phenotype not present in the normal cell. For example, B-cells in chronic lymphocytic leukemia express the CD 5 antigen. The technique examines the cytoplasm, nucleus, or cell-surface expression of cells in a solid specimen, such as a clot or bone marrow core. Immunophenotyping is used to differentiate and classify such neoplasms as non-Hodgkin’s lymphoma, acute and chronic lymphoid leukemias, acute myeloid leukemia, and T-cell lymphomas and leukemias (Winkelman, 1998).

**Cytogenetics**

Chromosome banding techniques sometimes are employed to screen for karyotypic abnormalities, involving chromosomal rearrangements that are on segments either too small or too similar to be detected by more conventional methods. For example, when chronic myelogenous leukemia is suspected, the technique is used to look for the Philadelphia chromosome. This chromosome shows a translocation of the Abelson proto-oncogene (ABL gene) from chromosome 22 to the breakpoint cluster region (BCR) of chromosome 9 (t9;22) (Hillman & Ault, 1998). Cytogenetics also may be used to follow response to treatment and detect early relapse.

Fluorescence in situ hybridization (FISH) is an adjunct technique to banding that uses fluorescent DNA probes to detect structural and numerical abnormalities on a chromosome. One benefit of this technique is that it can be performed on nondividing cells (Chang & Mark, 1997). Besides identifying microdeletions or microduplications in certain syndromes, another application for FISH is in the transplant setting in the evaluation of bone marrow engraftment, the proportion of donor to recipient cells.

**Molecular Diagnostics**

The polymerase chain reaction test amplifies DNA at the nucleotide level. One copy can be used to generate millions of copies to produce a visible signal. This allows the detection of one abnormal cell in one million. This sensitivity allows for the detection of minimal residual disease in patients after therapy. For example, if the BCR-ABL fusion gene characteristic of the Philadelphia chromosome in chronic myelogenous leukemia recurs after treatment, a high likelihood of relapse exists.

Genetic disparity is a major cause of graft versus host disease (GVHD). Research has shown that some degree of genetic mismatching may not be harmful to patients (Madrigal, Arguello, Scott, & Avakian, 1997). A graft versus leukemia or graft versus tumor phenomenon also occurs with GVHD. Patients with leukemia who develop GVHD have lower relapse rates. Interest exists in maintaining the antileukemic effect of GVHD while preventing graft failure. Molecular analysis techniques can identify genetic mismatches that patients can tolerate and may increase the number of possible donors.
Implications for Nursing

Bone marrow examination is essential for the diagnosis and classification of many nonhematologic and hematologic disorders. More NPs in various oncology settings are being trained and certified to perform bone marrow aspirations and biopsies. Besides contributing to the efficiency of their units, NPs can provide beneficial comprehensive care to patients. A need and an interest exist for oncology nurses to learn more about the diagnostic information generated from marrow examination. NPs and staff nurses must be aware of issues surrounding this procedure, including pain management, follow-up care, and psychosocial support of the patient and family. Having a greater understanding of the procedure and the tests performed helps caregivers to provide more thorough patient education to alleviate anxiety and promote comfort. Further nursing research is necessary to improve management of procedural pain in the adult oncology population. APNs should take an active role in the development and implementation of clinical practice protocols for bone marrow examination. An opportunity exists for research to measure patient satisfaction with bone marrow collection performed by NPs. This information is needed to support the expanding role of the APN in the oncology setting.

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References


The continuing-education examination and test form for the preceding article appear on the following pages.
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**CE Test Questions**

1. Bone marrow examination is indicated when peripheral blood differential counts reveal unexplained
   a. Pancytopenia or hypercalcemia.
   b. Granulocytosis or neutropenias.
   c. Hypercalcemia or granulocytosis.
   d. Reticulocytopenia or neutropenias.

2. Indications for bone marrow aspiration and biopsy include
   a. Chromosomal analysis, introduction of chemotherapeutic agents.
   b. Evaluation of immunodeficiency syndromes, chromosomal analysis.
   c. Evaluation of immunodeficiency syndromes, evaluation of tumor lysis syndrome.
   d. Introduction of chemotherapeutic agents, evaluation of tumor lysis syndrome.

3. With age, hematopoietic marrow in the bones of the extremities is replaced with which type of cell?
   a. Fat
   b. Bone
   c. Blood
   d. Nerve

4. Prior to collection of a specimen, the lab requires a thorough history and physical for complete evaluation of the specimen and for comparison with
   a. Lab control values.
   b. Peripheral blood lab values.
   c. Peripheral blood smears.
   d. Any previously documented physical.

5. What diagnostic indicators are useful to collect prior to bone marrow aspiration and biopsy?
   a. Complete blood count and liver function studies
   b. Electrocardiogram and liver function studies
   c. Partial thromboplastin and prothrombin times and electrocardiogram
   d. Complete blood count, partial thromboplastin, and prothrombin times

6. A risk associated with bone marrow specimen collection is
   a. Anaphylaxis.
   b. Lymphadenopathy.
   c. Injury to the bowel.
   d. Muscle weakness.

7. A primary nursing consideration for patients undergoing bone marrow procedures is
   a. Control of procedural pain.
   b. Observation for anaphylaxis.
   c. Probability of false negative results.
   d. Preparing patients for the inevitability of multiple procedures.

8. What is an obstacle to use of conscious sedation during bone marrow procedures?
   a. Conscious sedation may only be used on pediatric patients.
   b. Conscious sedation will not adequately manage procedural pain.
   c. Conscious sedation requires frequent monitoring of vital signs, oxygen saturation, and a longer recovery time.
   d. Nurse practitioners are not licensed to perform bone marrow procedures if conscious sedation is required.

9. Variables that can affect the quality of the aspirate smear include the
   a. Age of the patient.
   b. Stage of the patient’s disease.
   c. Morphology of the marrow involved.
   d. Angle and speed of spreading the smear.

10. What is one observation of a successful bone marrow aspirate?
    a. Only the humerus is used.
    b. At least 10 cc of aspirate is collected.
    c. Bone spicules are visible in the specimen.
    d. No need for pressure at the site postprocedure.

11. A marrow core sample of at least 16 mm is necessary for analysis because
    a. Most of the sample will be unusable.
    b. Core specimens often will provide negative results.
    c. Most of the specimen will not include marrow cells.
    d. Core specimens shrink by about 25% during processing.

12. The presence of an increased number or morphologically abnormal cells in the aspirate is an indication for
    a. An examination of a core biopsy.
    b. A repeat peripheral blood sampling.
    c. Early initiation of radiotherapy.
    d. Delayed initiation of radiotherapy.

13. In normal marrow, the percentage of myelocytes and later precursors is about the same as the percentage of
    a. Immature neutrophils.
    b. Mature neutrophils.
    c. Mature eosinophils.
    d. Immature basophils.

14. At birth, the myeloid/erythroid (M/E) ratio is about 4:3. After one year, the M/E ratio is about
    a. 4:1.
    b. 3:1.
    c. 2:1.
    d. 1:1.
15. Flow cytometry techniques are most useful for
   a. Screening for leukemias.
   b. Following granulomas.
   c. Screening for infectious diseases.
   d. Following blast cell production.

16. One application for fluorescence in situ hybridization (FISH) is
   a. Immunophenotyping.
   b. Amplification of DNA.
   c. Analysis of cell surface markers.
   d. Evaluation of bone marrow engraftment.

Oncology Nursing Forum Answer/Enrollment Form

Bone Marrow Aspiration and Biopsy: Collection and Interpretation
(Test ID #01-28/9-08)

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   Not at all Low Medium High

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   • Objective #1
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