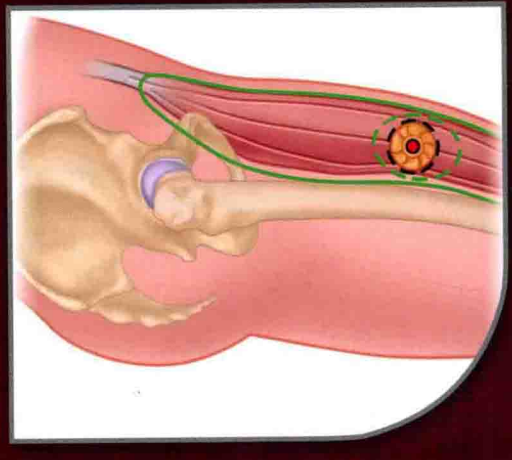
CAMPBELL'S TWELFTH EDITION
OPERATIVE ORTHOPAEDICS

英文影印版

坎贝尔骨科手术学

第 12 版

骨肿瘤分册



S. Terry Canale • James H. Beaty

天津出版传媒集团
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影印版序

《坎贝尔骨科手术学》由世界级专家联袂编撰，自1939年问世以来，这部巨著伴随了一代又一代骨科医生的成长，成为全球骨科医生不可或缺的参考书，是骨科学领域最权威的著作，同样也被我国广大骨科医生奉为经典。

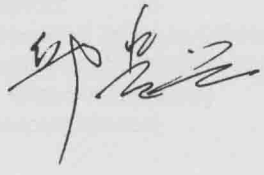
2013年初，Elsevier出版公司出版了这部骨科学“圣经”的最新版本——第12版，作为一名旧版的老读者，再次切身感受到该书的严谨、科学。新版分4卷，19部分，89章。介绍了骨科手术的基本原理，详细讲述了髋、膝、踝、肩肘关节置换术，以及截肢与感染、骨肿瘤、先天性异常和发育异常、脊柱损伤、运动损伤、成人骨折与脱位、周围神经损伤、手和足踝部损伤的各种手术技术、儿童神经系统疾病及骨折与脱位。此外，还介绍了关节镜及显微外科的先进手术技术和经验。本书的特点是详细地叙述了各种手术的细节，包括手术指征、手术前后处理和并发症防治的原则、各种技巧和注意事项，还配备详细的手术图解，编排合理，非常符合临床骨科医生的学习需要。

新版《坎贝尔骨科手术学》达到了“去粗存精”、“去伪存真”之目的，删除了第11版中一些陈旧的观点和方法，吸取了近年来的最新成果，除保留作为“金标准”的经典技术之外，还介绍了大量新技术、新装备，并强调了微创骨科技术，对当前及今后一段时间的骨科临床和科研具有非常重要的指导作用。新版配图7000余幅，其中很多图片为重新绘制，直观展现骨科手术技术要点。

随着我国骨科界对外交流的日益增加，以及骨科医生英语水平的整体提高，越来越多的骨科医生希望能够尽快读到原汁原味的国外经典之作，恰逢此时，天津科技翻译出版有限公司在第12版《坎贝尔骨科手术学》刚刚推出之际，便立即引进了这部巨著的影印版本，几乎与原版同步出版，让国内读者在第一时间即能零距离地领略到这部经典原著的风采，更直接地分享这些国际骨科权威专家们对骨科手术学的真知灼见！考虑到读者的需求，出版社将影印版设计为两种形式出版。一种是如原版书，做成精装四卷的形式，另一种则按照骨科学的分支，将这套专著做成平装版，分为14个分册，可以让读者各取所需。此外，影印版均采用优质铜版纸印刷，保持了原版书的风貌，其性价比之高在近些年的影印版书中亦不多见。

最后，借此书出版之际，愿全体骨科同仁不断更新知识、锻炼技能，更好地为广大患者解除病痛，为我国的骨科事业的快速、健康发展做出更大的贡献！

中国工程院院士



PREFACE

As with every edition of this text, we have been amazed by the multitude of new techniques, new equipment, and new information generated by our orthopaedic colleagues worldwide. The emphasis on less-invasive surgical techniques for everything from hallux valgus correction to spine surgery to total joint arthroplasty has produced a variety of new approaches and new devices. The use of arthroscopy and endoscopy continues to expand its boundaries. We have attempted to include the latest orthopaedic procedures, while retaining many of the classic techniques that remain the "gold standards."

Some of the changes in this edition that we believe will make it easier to use include the complete redrawing of the thousands of illustrations, the combining of some chapters and rearrangement of others to achieve a more logical flow of information, the addition of several new chapters, and the placement of references published before 2000 on the website only. Full access to the text and to an increased number of surgical videos is available on ExpertConsult.com, which is included with the purchase of the text. This combination of traditional and electronic formats, we believe, will make this edition of *Campbell's Operative Orthopaedics* easily accessible and useable in any situation, making it easier for orthopaedists to ensure the highest quality of patient care.

The true "heroes" of this work are our dedicated authors, who are willing to endure time away from their families and their practices to make sure that their contributions are as up-to-date and informational as possible. The revision process is lengthy and arduous, and we are truly appreciative of the time and effort expended by all of our contributors. As always, the personnel of the Campbell Foundation—Kay Daugherty, Barry Burns, Linda Jones, and Joan Crowson—were essential in getting the ideas and information from 40 authors into a workable form. The progress of the book was marked by the proliferation of paper-stuffed file folders spread across their offices. Managing to transform all of that raw material into readable text and illustrative images is always an amazing accomplishment. Our thanks, too, to the individuals at Elsevier publishing who provided much guidance, encouragement, and assistance: Taylor Ball, Content Development Editor; Dolores Meloni, Executive Content Strategist; Mary Gatsch, Publishing Director; and John Casey, Project Manager.

We are most grateful to our families, especially our wives, Sissie Canale and Terry Beaty, who patiently endured our total immersion in the publication process.

The individuals who often are overlooked, or at least not recognized often enough, are the community of orthopaedic surgeons to whom we are indebted for their expertise and innovation that make a textbook such as ours necessary. As Dr. Campbell noted in the preface to the first edition of this text, "In some of the chapters we have drawn heavily from authoritative articles on special subjects; the author gratefully acknowledges his indebtedness for this material." We are indeed grateful, and honored and humbled, to be the conduit of such remarkable skill and knowledge that help us to make the most current information available to our readers. We hope that this latest edition of *Campbell's Operative Orthopaedics* will prove to be a valuable tool in providing the best of care to orthopaedic patients.

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CONTENTS

PART VIII

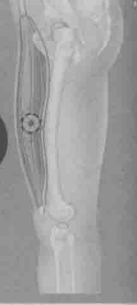
TUMORS

List of Techniques

GENERAL PRINCIPLES OF TUMORS

Patrick C. Toy • Robert K. Heck, Jr.

CHAPTER 24



A team comprising an orthopaedic surgeon, radiologist, pathologist, radiation oncologist, and medical oncologist is necessary to treat the spectrum of musculoskeletal tumors. Other surgical specialists frequently are required, such as a vascular surgeon, thoracic surgeon, or plastic surgeon. The orthopaedic surgeon must be well versed in the principles of oncological surgery, and the radiologist and pathologist should have a special interest in bone and soft tissue tumors. The medical oncologist coordinates the adjuvant therapies and becomes the primary physician for a patient who has a metastatic tumor.

DIAGNOSTIC EVALUATION

GENERAL APPROACH TO MUSCULOSKELETAL NEOPLASMS

An adequate history and physical examination are the first and most important steps in evaluating a patient with a musculoskeletal tumor. Patients may present to the orthopaedic oncologist with pain, a mass, or an abnormal radiographic finding detected during the evaluation of an unrelated problem. Patients with bone tumors most frequently present with pain. The pain initially may be activity related, but a patient with a malignancy of bone often complains of progressive pain at rest and at night. Patients with benign bone tumors also may have activity-related pain if the lesion is large enough to weaken the bone. Other benign lesions, most notably osteoid osteoma, may cause night pain initially. Conversely, patients with soft tissue tumors rarely complain of pain but more often complain of a mass. Exceptions to this rule are patients with nerve sheath tumors who have pain or neurological signs.

Although some tumors show a sex predilection (e.g., female predominance with giant cell tumors), this is rarely of diagnostic significance. Race likewise is of little significance, with the exception that Ewing sarcoma is exceedingly rare in individuals of African descent. Family history occasionally can be helpful, as in cases of multiple hereditary exostosis (autosomal dominant inheritance) and neurofibromatosis (autosomal dominant inheritance). Age may be the most important information obtained in the history, however, because most benign and malignant musculoskeletal neoplasms occur within specific age ranges.

■ PHYSICAL EXAMINATION

The physical examination should include evaluation of the patient's general health and a careful examination of the part in question. A mass should be measured, and its location, shape, consistency, mobility, tenderness, local temperature, and change with position should be noted. Atrophy of the surrounding musculature should be recorded, as should neurological deficits and adequacy of circulation. Café-au-lait spots or cutaneous hemangiomas also may provide diagnostic clues. Potential sites of lymph node metastases should be palpated. Although lymph node metastases are rare with most sarcomas, they often are present with rhabdomyosarcomas, epithelioid sarcomas, and synovial sarcomas.

■ RADIOGRAPHIC EXAMINATION

All suspected musculoskeletal neoplasms should be evaluated initially with plain biplanar radiographs. Compared with any other test, conventional radiography provides more useful diagnostic information for evaluation of bone lesions. Often, the patient's age and plain radiographic findings are sufficient to arrive at a specific diagnosis. Radiographic evaluation should begin by determining the site of the lesion because many bone tumors have specific site predilections (Boxes 24-1 to 24-4). An epiphyseal lesion in a skeletally mature patient is likely to be a giant cell tumor, whereas an epiphyseal lesion in a skeletally immature patient is likely to be a chondroblastoma. The differential diagnosis for diaphyseal lesions includes Ewing sarcoma, osteomyelitis, osteoid osteoma, osteoblastoma, histiocytosis, lymphoma, fibrous dysplasia, and adamantinoma (especially in the tibia). Most vertebral

BOX 24-1 Differential Diagnosis for Epiphyseal Lesions

- Chondroblastoma (ages 10-25)
- Giant cell tumor (ages 20-40)
- Clear chondrosarcoma (rare)

BOX 24-2 Differential Diagnosis for Diaphyseal Lesions

- Ewing sarcoma (ages 5-25)
- Lymphoma (adult)
- Fibrous dysplasia (ages 5-30)
- Adamantinoma (consider in the tibia)
- Histiocytosis (ages 5-30)

BOX 24-3 Differential Diagnosis for Lesions of the Spine

Older than 40 Years

- Metastases
- Multiple myeloma
- Hemiangioma
- Chordoma (in sacrum)

Younger than 30 Years

- Vertebral body
  - Histiocytosis
  - Hemangioma
- Posterior elements
  - Osteoid osteoma
  - Osteoblastoma
  - Aneurysmal bone cyst

BOX 24-4 Differential Diagnosis for Multiple Lesions

- Histiocytosis
- Enchondroma
- Osteochondroma
- Fibrous dysplasia
- Multiple myeloma
- Metastases
- Hemangioma
- Infection
- Hyperparathyroidism

lesions in adult patients are metastases, myelomas, or hemangiomas. In the sacrum, chordoma and giant cell tumor are at the top of the list of differential diagnoses. In younger patients with a vertebral body lesion, the most likely diagnosis is histiocytosis; if the lesion is in the posterior elements, the differential diagnoses include aneurysmal bone cyst, osteoblastoma, and osteoid osteoma. Even if a specific diagnosis cannot be made, the aggressiveness of the lesion, and whether it is likely to be benign or malignant, usually can be determined by careful evaluation of the plain films. Lesions of low biological activity are usually well marginated, often with a surrounding rim of reactive bone formation. Aggressive lesions usually have a less well-defined zone of transition between the lesion and the host bone because the host response is slower than the progression of the tumor. Cortical expansion can be seen with aggressive benign lesions, but frank cortical destruction usually is a sign of malignancy. Periosteal reactive new bone formation results when the tumor destroys cortex and may take the form of Codman's triangle, "onion-skinning," or a "sunburst" pattern. It usually is a sign of malignancy but may be present with infection or histiocytosis. Often, bone lesions replace the normal trabecular pattern of bone with a characteristic matrix. Punctate, stippled calcification is suggestive of cartilage formation in bone lesions such as an enchondroma or chondrosarcoma. Matrix ossification combined with destructive features of host bone is a radiographic finding in a typical osteosarcoma. The irregular osteoid trabeculae in a collagenous stroma produce the classic radiographic "ground glass" appearance in fibrous dysplasia. Plain radiographs are less helpful for soft tissue lesions but nevertheless should be obtained in all patients because some useful information can be acquired, such as the presence of myositis ossificans, phleboliths in a hemangioma, calcification in a synovial sarcoma, or a fat density with a lipoma.

■ OTHER IMAGING EXAMINATIONS

The resolution of CT is most helpful in assessing ossification and calcification and in evaluating the integrity of the cortex. It also is the best imaging study to localize the nidus of an osteoid osteoma, to detect a thin rim of reactive bone around an aneurysmal bone cyst, to evaluate calcification in a suspected cartilaginous lesion, and to evaluate endosteal cortical erosion in a suspected chondrosarcoma. Reconstructions in the sagittal and coronal planes may provide useful information with regard to surgical planning. CT of the lungs also is the most effective study to detect pulmonary metastases. In cases where MRI is prohibited (i.e., pacemaker), CT with intravenous contrast is useful in differentiating cystic lesions from vascular lesions in soft tissue tumors.

Technetium bone scans are used to determine the activity of a lesion and to determine the presence of multiple lesions or skeletal metastases. Bone scans frequently are falsely negative in multiple myeloma and some cases of renal cell carcinoma. Excluding these exceptions, however, most other malignant neoplasms of bone show increased uptake on technetium bone scans. A normal bone scan is reassuring; however, the converse statement is not true because benign active lesions of bone also show increased uptake.

Positron emission tomography (PET) records the whole-body distribution of positron-emitting radioisotopes linked to biologically active molecules. This modality provides a noninvasive three-dimensional visualization and quantitative assessment of in-vivo physiological and biochemical processes. Although still considered investigational in the field of musculoskeletal oncology, PET is proving to be useful in staging, planning the biopsy, evaluating the response to chemotherapy, and helping to direct subsequent treatment. Fluorine-18 (^{18}F)-fluorodeoxyglucose-labeled positron emission tomography (FDG-PET) has a growing role as an

imaging modality in the detection, staging, and management of sarcomas. FDG is an analogue of glucose that becomes trapped in malignant cells in proportion to their respective rate of glycolysis. When used in conjunction with other imaging modalities (i.e., CT and MRI), it can be used to differentiate viable tumor cells from postoperative changes. Early results in its application have been encouraging, but the number of published studies is limited.

MRI has replaced CT as the study of choice to determine the size, extent, and anatomical relationships of bone and soft tissue tumors. It is the most accurate technique for determining the extent of intramedullary and extraosseous disease and the relationship to neurovascular structures. MRI may yield a specific diagnosis with tumors such as lipoma, hemangioma, hematoma, or pigmented villonodular synovitis, all of which have characteristic appearances. With regard to most neoplasms, however, the MRI appearance is nonspecific. Likewise, MRI is not useful in differentiating benign from malignant lesions. A study at our institution found substantial differences between MRI-based opinions given by specialized musculoskeletal radiologists and those given by outside radiologists: only about half of the outside reports listed the most likely diagnosis as such, and only 60% listed it at all. In general, any soft tissue neoplasm deep to the fascia or larger than 5 cm in its greatest dimension should be considered highly likely to be a sarcoma.

Ultrasonography is useful for distinguishing cystic from solid soft tissue lesions but otherwise offers little information. Angiography, which previously was used to determine the relationship of a neoplasm to the vessels, has been supplanted by MRI. Angiography still is useful, however, to rule out nonneoplastic conditions, such as pseudoaneurysms or arteriovenous malformations, and for preoperative embolization of highly vascular lesions, such as renal cell carcinoma and aneurysmal bone cysts. Gallium scans are the most sensitive tests for locating nonpulmonary metastases but are no longer routinely used by most centers for the evaluation of musculoskeletal neoplasms.

■ LABORATORY TESTS

Blood and urine tests rarely lead to a diagnosis but can be useful in selected situations. A basic metabolic panel may be indicated to evaluate the overall health of a patient. Risks of wound healing problems and infection have been shown to be significantly greater in patients whose serum albumin value is less than 3.5 g/dL or whose total lymphocyte count is less than 1500/mL. A complete blood cell count may be helpful to rule out infection and leukemia. The erythrocyte sedimentation rate usually is elevated in infection; metastatic carcinoma; and small "blue cell" tumors, such as Ewing sarcoma, lymphoma, leukemia, and histiocytosis. Serum protein electrophoresis should be ordered if multiple myeloma is part of the differential diagnosis. Likewise, a prostate-specific antigen test should be ordered if prostate carcinoma is a possibility. Hypercalcemia may be present with metastatic disease, multiple myeloma, and hyperparathyroidism. Alkaline phosphatase may be elevated in metabolic bone disease, metastatic disease, osteosarcoma, Ewing sarcoma, or lymphoma. Blood urea nitrogen and creatinine may be elevated with renal tumors, and a urinalysis may reveal hematuria in this setting. Brown tumors of hyperparathyroidism sometimes can look like giant cell tumors and can be evaluated with serum calcium and parathyroid hormone levels. Finally, Paget disease may be in the differential diagnosis and can be evaluated by serum alkaline phosphatase and urinary pyridinium cross-links.

Musculoskeletal neoplasms should be evaluated completely before biopsy is done. The differential diagnosis, extent of the lesion, and potential resectability of the lesion can affect the type of biopsy, the placement of the biopsy incision, and the pathological management of the tissue obtained. A complete workup helps to narrow the differential diagnosis and to bring about a more accurate pathological diagnosis. Finally, tests, such as MRI or bone scanning, can be adversely affected by postoperative changes in the tissues. Bone and soft tissue neoplasms suspected of being malignant should be evaluated with radiographs of the involved limb and a chest radiograph to evaluate possible metastases. MRI of the lesion delineates the extent of the lesion in the bone and soft tissue involvement and the relationship to other anatomical structures. A bone scan should be obtained to detect any other areas of skeletal involvement, and a CT scan of the chest should be obtained to rule out pulmonary metastases. Other tests may be added to this minimum basic workup as indicated.

METASTASES OF UNKNOWN ORIGIN

In a patient older than age 40 with a new, painful bone lesion, multiple myeloma and metastatic carcinoma are the most likely diagnoses even if the patient has no known history of carcinoma. Prostate cancer and breast cancer are the two most common primary sources for bone metastases. If a patient has no known primary tumor, however, the most likely sources are lung cancer and renal cell carcinoma. Rougraff et al. described the proper evaluation of a patient with suspected metastases of unknown origin. The evaluation begins with a history focusing on any previous malignancies, even in the remote past, followed by a physical examination that includes not only the involved extremity but also the thyroid, lungs, abdomen, prostate in men, and breasts in women. Laboratory analysis should include complete blood cell count, erythrocyte sedimentation rate, electrolytes, liver enzymes, alkaline phosphatase, serum protein electrophoresis, and possibly prostate-specific antigen. Plain radiographs of the involved bone and the chest should be obtained. A whole-body bone scan should be ordered to evaluate other possible areas of skeletal involvement, and a CT scan of the chest, abdomen, and pelvis should be obtained (Fig. 24-1). A mammogram is not routinely indicated as an initial procedure because breast cancer is a rare source of metastases without a known primary lesion. The authors were able to identify the primary lesion in 85% of patients with skeletal metastases of unknown origin using this simple approach. They listed six reasons why the biopsy should not be done until the evaluation is complete: (1) The lesion may be a primary sarcoma of bone that may require a biopsy technique that allows for future limb salvage surgery; (2) another, more accessible lesion may be found; (3) if renal cell carcinoma is considered likely, the surgeon may wish to consider preoperative embolization to avoid excessive bleeding; (4) if the diagnosis of multiple myeloma is made by laboratory studies, an unnecessary biopsy can be avoided; (5) the pathological diagnosis is more accurate if aided by appropriate imaging studies;

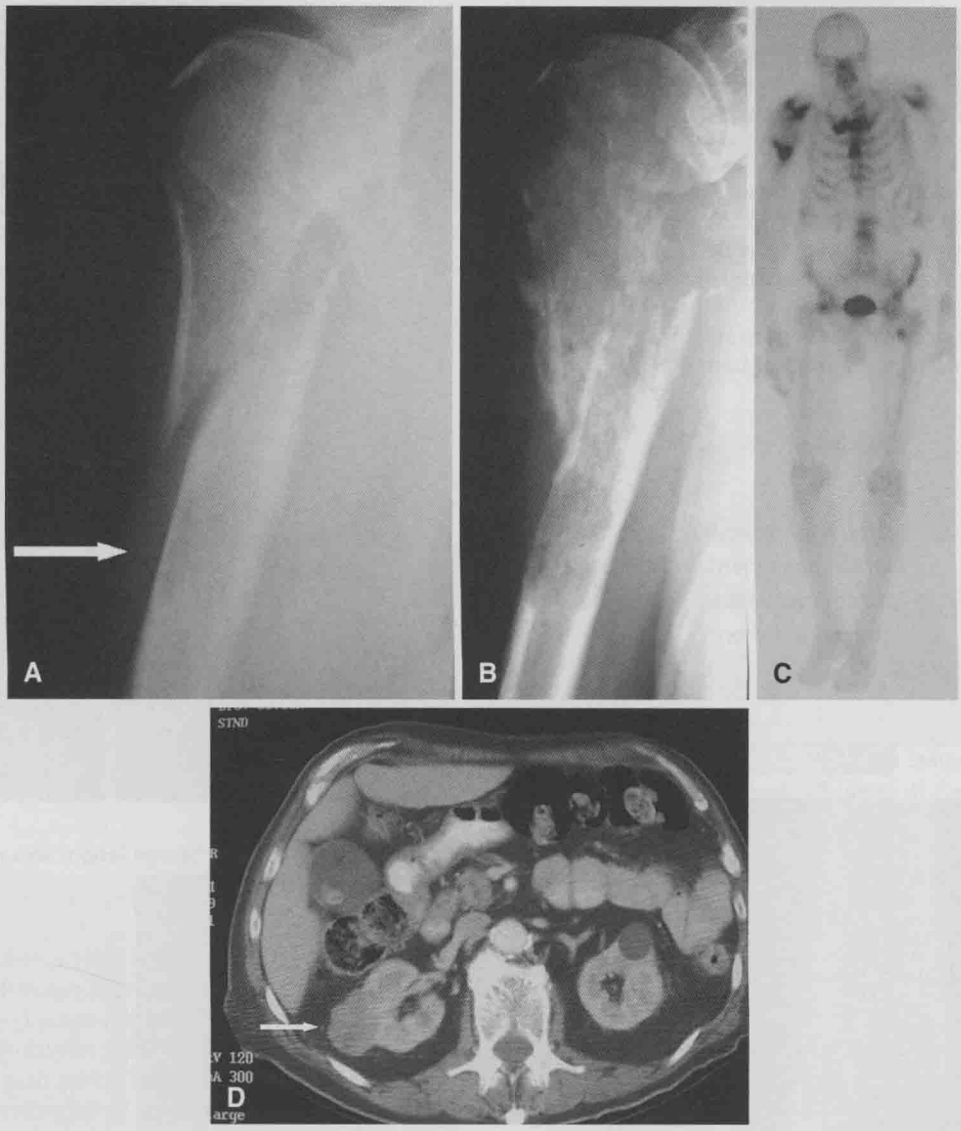


FIGURE 24-1 Humeral fracture after minimal trauma in 81-year-old man with no known history of malignancy. **A,** Lesion *(arrow)* was not identified initially, and patient was treated conservatively at another institution. **B,** Radiograph 10 weeks after injury shows progression of malignant process. Patient was referred to orthopaedic oncology center, where most likely diagnosis was thought to be either multiple myeloma or metastatic carcinoma. **C,** Bone scan reveals multiple sites of disease. **D,** CT of abdomen reveals lesion in the right kidney, which proved to be primary lesion (*arrow*).

and (6) the pathologist and surgeon may be more assured of a diagnosis of metastasis made on frozen section analysis if supported by the preoperative evaluation. This is important if stabilization of an impending fracture is planned for the same procedure.

STAGING

Enneking and others have shown the desirability of staging benign and malignant musculoskeletal tumors to aid in treatment decision making, provide some determination of prognosis, and allow meaningful comparisons of treatment methods. Benign and malignant tumors of bone and soft tissue can be staged according to the Enneking staging system (Table 24-1). The stages of benign tumors are designated by Arabic numbers, and malignant tumors are designated by Roman numerals.

Benign tumors are staged as follows: stage 1, latent; stage 2, active; and stage 3, aggressive. Stage 1 lesions are intracapsular, usually asymptomatic, and frequently incidental findings. Radiographic features include a well-defined margin with a thick rim of reactive bone. There is no cortical destruction or expansion. These lesions do not require treatment because they do not compromise the strength of the bone and usually resolve spontaneously. An example is a small asymptomatic nonossifying fibroma discovered incidentally on radiographs taken to evaluate an unrelated injury (Fig. 24-2). Stage 2 lesions also are intracapsular but are actively growing and can cause symptoms or lead to pathological fracture. They have well-defined margins on radiographs but may expand and thin the cortex. Usually they have only a thin rim

TABLE 24-1 Enneking System for Staging Benign and Malignant Musculoskeletal Tumors

BENIGN

1. Latent—low biological activity; well marginated; often incidental findings (i.e., nonossifying fibroma)
2. Active—symptomatic; limited bone destruction; may present with pathological fracture (i.e., aneurysmal bone cyst)
3. Aggressive—aggressive; bone destruction/soft tissue extension; do not respect natural barriers (i.e., giant cell tumor)

MALIGNANT

STAGE	GRADE	SITE	METASTASES
IA	Low	Intracompartmental	None
IB	Low	Extracompartmental	None
IIA	High	Intracompartmental	None
IIB	High	Extracompartmental	None
III	Any	Any	Regional or distant metastases

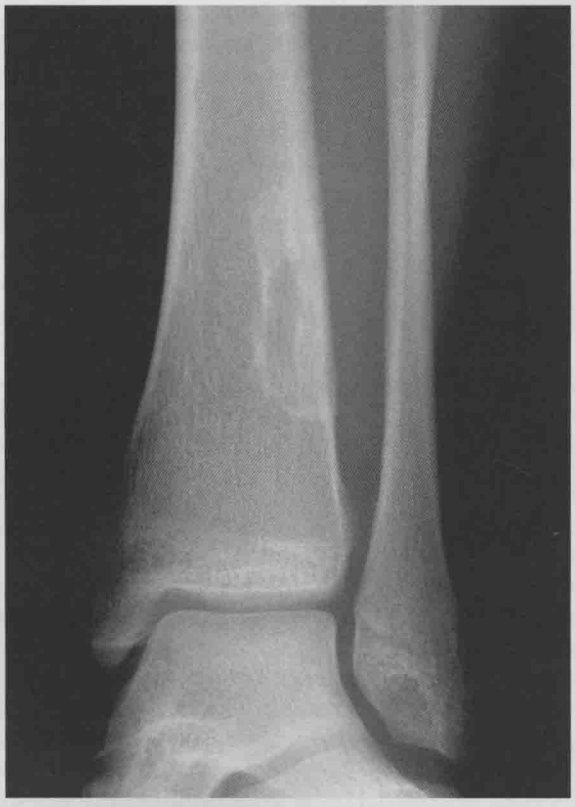


FIGURE 24-2 Stage 1 benign lesion: nonossifying fibroma of the distal tibia.

of reactive bone. Treatment usually consists of extended curettage (Fig. 24-3). Stage 3 lesions are extracapsular. Their aggressive nature is apparent clinically and radiographically. They do 'not respect natural anatomic barriers and usually have broken through the reactive bone and possibly the

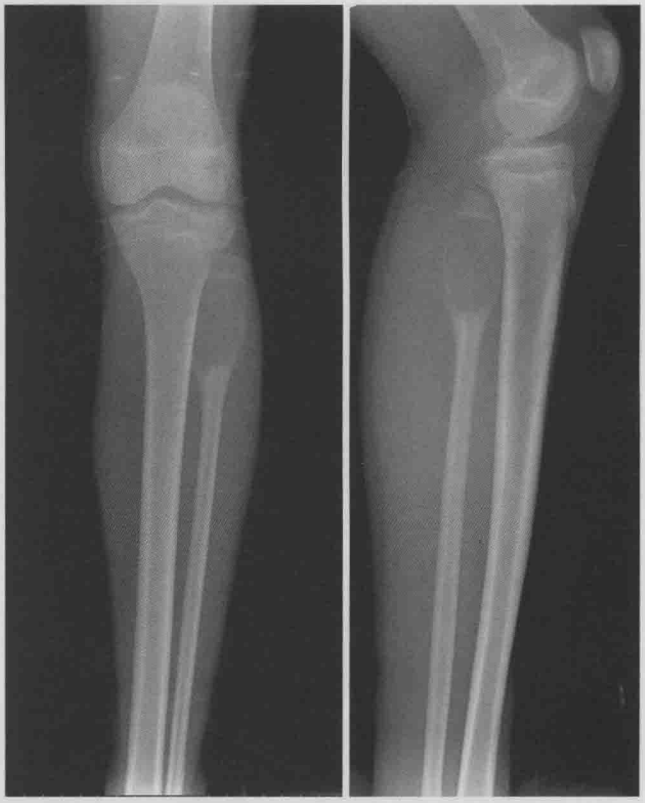


FIGURE 24-3 Stage 2 benign lesion: aneurysmal bone cyst of the proximal fibula.

cortex (Fig. 24-4). MRI may show a soft tissue mass, and metastases may be present in 5% of patients with these lesions (i.e., giant cell tumor). Treatment consists of extended curettage and marginal or even wide resection, and local recurrences are common. Reconstruction may sometimes prove difficult. Some interobserver discrepancy may be present when trying to assign a bone lesion to a particular stage.

Musculoskeletal sarcomas also can be staged according to the surgical staging system as described by Enneking et al. This system was designed to incorporate the most significant prognostic factors into a system of progressive stages that helps to guide surgical and adjuvant treatments. The system is based on the histological grade of the tumor, its local extent, and the presence or absence of metastases. Low-grade lesions are designated as stage I. These lesions are well-differentiated, have few mitoses, and exhibit only moderate cytological atypia. The risk for metastases is low (<25%). High-grade lesions are designated as stage II. They are poorly differentiated with a high mitotic rate and a high cell-to-matrix ratio. Stage I and II lesions are subdivided according to the extent of local growth. Stage IA and IIA lesions are contained within well-defined anatomical compartments (Fig. 24-5). Anatomical compartments are determined by the natural anatomical barriers to tumor growth, such as cortical bone, articular cartilage, fascial septa, or joint capsules. Stage IB and IIB lesions extend beyond the compartment of origin (Fig. 24-6). Stage III refers to any lesion that has metastasized regardless of the size or grade of the primary tumor. No distinction is made between lymph node metastases or distant metastases because both circumstances are associated with an equally poor prognosis.

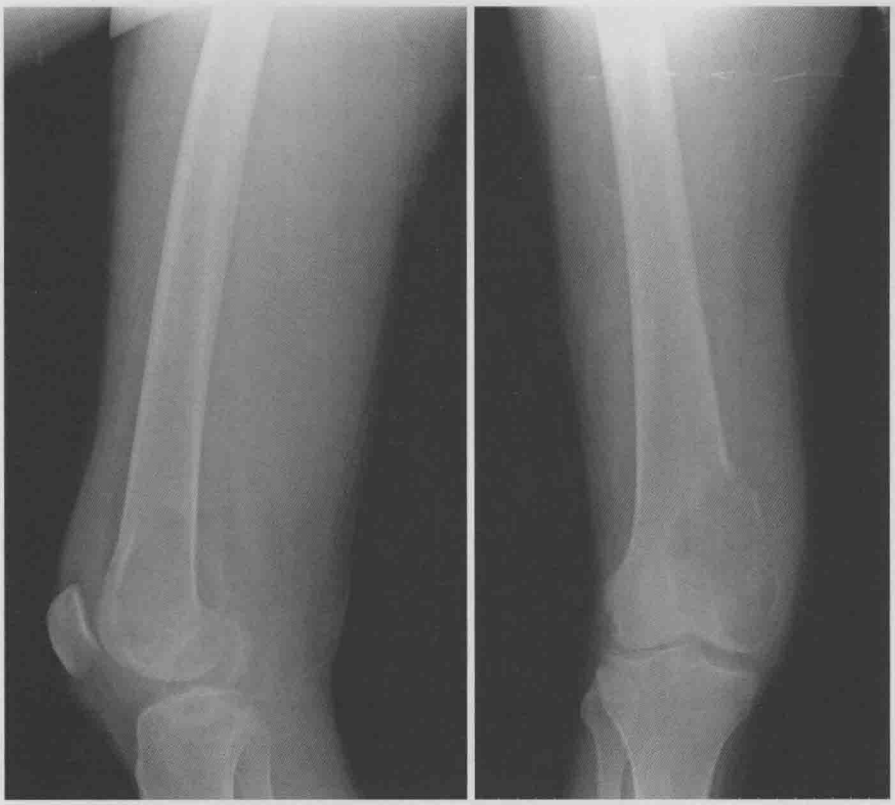


FIGURE 24-4 Stage 3 benign lesion: giant cell tumor of the distal femur.

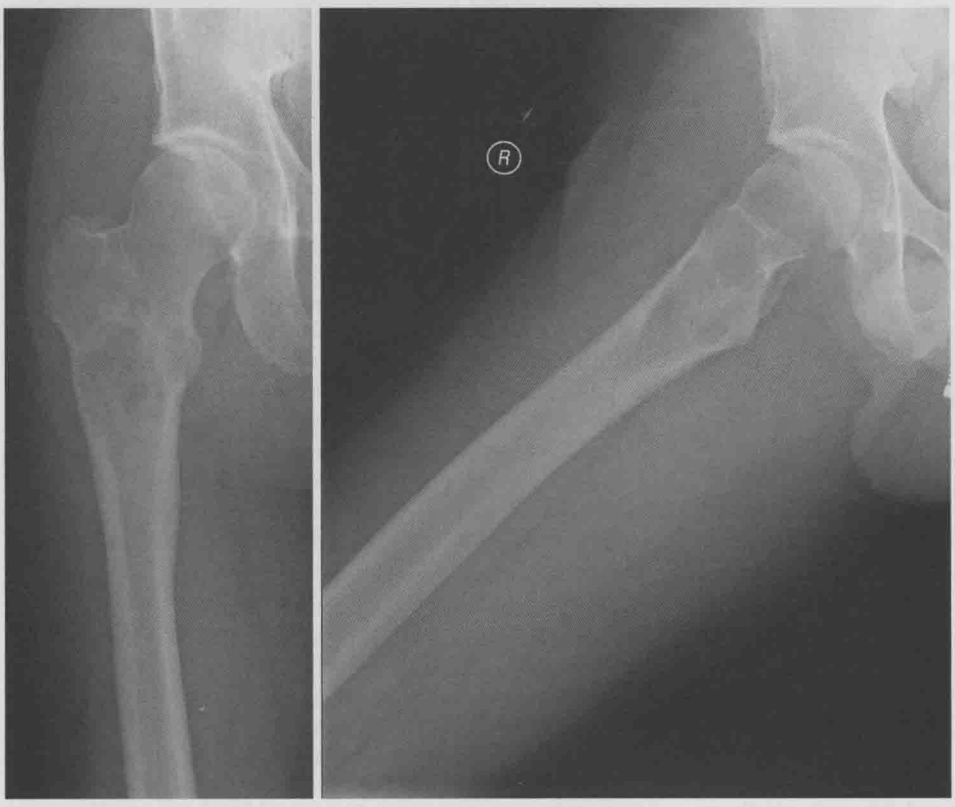


FIGURE 24-5 Stage IA malignant lesion: chondrosarcoma of the proximal femur.

Alternatively, many orthopaedic oncologists stage musculoskeletal malignancies according to the American Joint Committee on Cancer (AJCC) system. The AJCC staging system for soft tissue sarcomas (Table 24-2) is based on prognostic variables, including tumor grade (low or high), size (≤5 cm or >5 cm in greatest dimension), depth (superficial or deep to the fascia), and presence of metastases. Stage I tumors are low grade regardless of size or depth. Stage II tumors are high grade; they may be small and any depth or large and superficial. Stage III tumors are high grade, large, and deep.

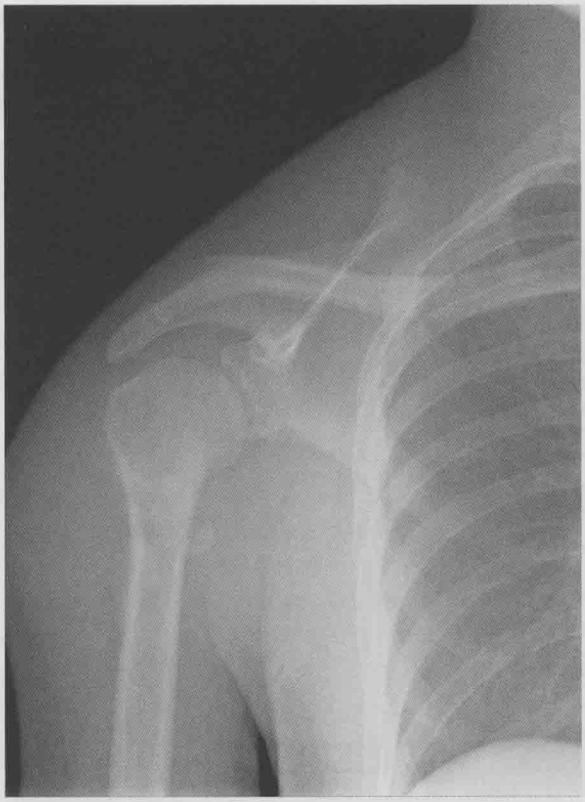


FIGURE 24-6 Stage IIB malignant lesion: osteosarcoma of the proximal humerus.

TABLE 24-2 American Joint Committee on Cancer System for Staging Soft Tissue Sarcomas

STAGE	GRADE	SIZE	DEPTH	METASTASES
I	Low	Any	Any	None
II	High	5 cm	Any	None
	High	>5 cm	Superficial	None
III	High	>5 cm	Deep	None
IV	Any	Any	Any	Regional or distant

Stage IV tumors are tumors associated with metastases (including local lymph nodes) regardless of grade, size, or depth.

The AJCC system for bone sarcomas (Table 24-3) is based on tumor grade, size, and presence and location of metastases. Stage I tumors, which are low grade, and stage II tumors, which are high grade, are subdivided based on tumor size. Stage I-A and II-A tumors are 8 cm or less in their greatest linear measurement; stage I-B and II-B tumors are larger than 8 cm. Stage III tumors have "skip metastases," which are defined as discontinuous lesions within the same bone. Stage IV-A involves pulmonary metastases, whereas stage IV-B involves nonpulmonary metastases. The subdivision of stage IV was made because it has been shown that patients with nonpulmonary metastases from osteosarcoma and Ewing sarcoma have worse prognoses than patients with only pulmonary metastases.

TABLE 24-3 American Joint Committee on Cancer System for Staging Bone Sarcomas

STAGE	GRADE	SIZE	METASTASES
I-A	Low	≤8 cm	None
I-B	Low	>8 cm	None
II-A	High	≤8 cm	None
II-B	High	>8 cm	None
III	Any	Any	Skip metastasis
IV-A	Any	Any	Pulmonary metastases
IV-B	Any	Any	Nonpulmonary metastases

BIOPSY

In 1982, Mankin et al. reported 18.2% major errors in diagnosis, 10.3% nonrepresentative or technically poor biopsy specimens, and 17.3% wound complications associated with biopsy of musculoskeletal sarcomas. As a result of these complications, the optimal treatment plan had to be altered in 18.2%, including unnecessary amputations in 4.5%. These complications occurred three to five times more frequently when the biopsy was done by a surgeon at a referring institution, rather than by a member of the Musculoskeletal Tumor Society. A series of recommendations were made regarding the technical aspects of the biopsy, stating that whenever possible a patient with a suspected primary musculoskeletal malignancy should be referred before biopsy to the institution where definitive treatment will take place. The study was repeated 10 years later, and the results were essentially unchanged.

A biopsy should be planned as carefully as the definitive procedure. Biopsy should be done only after clinical, laboratory, and radiographic examinations are complete. As stated previously, completion of the evaluation before biopsy aids in planning the placement of the biopsy incision, helps provide more information leading to a more accurate pathological diagnosis, and avoids artifacts on imaging studies. If the results of the evaluation suggest that a primary malignancy is in the differential diagnosis, the patient should be referred to a musculoskeletal oncologist before biopsy.

Regardless of whether a needle biopsy or an open biopsy is done, the biopsy track should be considered contaminated with tumor cells. Placement of the biopsy is a crucial decision because the biopsy track needs to be excised en bloc with the tumor. The surgeon performing the biopsy should be familiar with incisions for limb salvage surgery and standard and nonstandard amputation flaps. If a tourniquet is used, the limb may be elevated before inflation but should not be exsanguinated by compression to prevent "squeezing" the tumors cells into the systemic circulation. Care should be taken to contaminate as little tissue as possible. Transverse incisions should be avoided because they are extremely difficult or impossible to excise with the specimen (Fig. 24-7). The deep incision should go through a single muscle compartment rather than contaminating an intermuscular plane. Major neurovascular structures should be avoided. Soft tissue extension of a bone lesion should be sampled because this leading

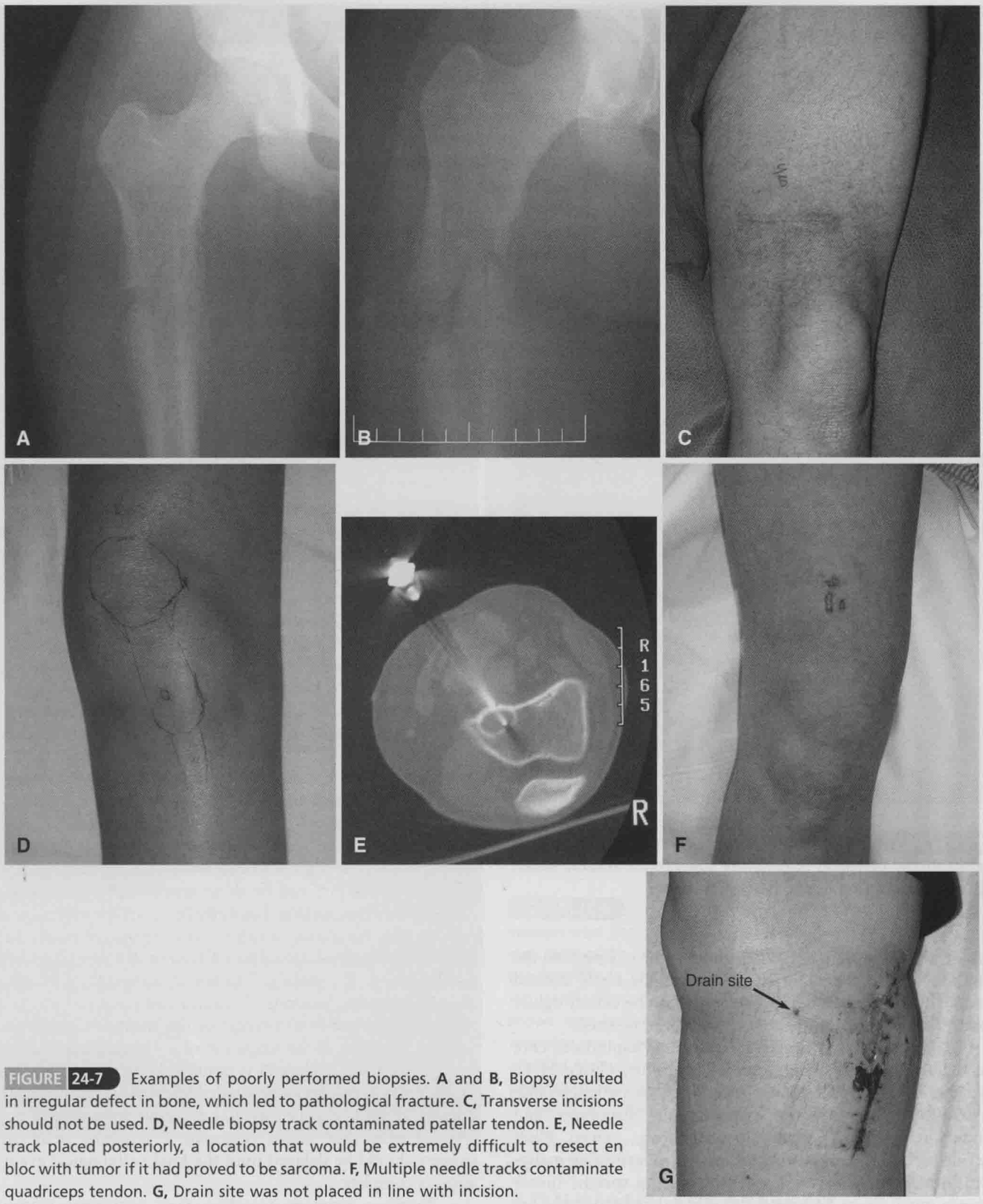


FIGURE 24-7 Examples of poorly performed biopsies. **A** and **B,** Biopsy resulted in irregular defect in bone, which led to pathological fracture. **C,** Transverse incisions should not be used. **D,** Needle biopsy track contaminated patellar tendon. **E,** Needle track placed posteriorly, a location that would be extremely difficult to resect en bloc with tumor if it had proved to be sarcoma. **F,** Multiple needle tracks contaminate quadriceps tendon. **G,** Drain site was not placed in line with incision.

edge contains the most viable tumor for making the diagnosis. If a hole must be made in the bone, it should be round or oval to minimize stress concentration and prevent a subsequent fracture, which could preclude limb salvage surgery (Fig. 24-8). The hole should be plugged with methacrylate to limit hematoma formation. Only the minimal amount of methacrylate needed to plug the hole should be used because excessive amounts push the tumor up and down the bone. Care should be taken, however, to sample more than just the pseudocapsule surrounding the lesion. A frozen section should be sent intraoperatively to ensure that diagnostic tissue has been obtained. If a tourniquet has been used, it should be deflated and meticulous hemostasis ensured before closure, because a hematoma would be contaminated with

TABLE 24-4 Types of Biopsy

BIOPSY TYPE	TISSUE OBTAINED	ADVANTAGES	DISADVANTAGES
Fine-needle aspiration	Cells	Cost effective Fewer complications Good for obese patient or tumor near neurovascular structure	Small sample size Need expert pathologist
Core needle	Small tissue core	Cost effective More tissue than fine-needle aspiration	More complications* than fine-needle aspiration
Incisional biopsy	Adequate sample of mass/lesion	Adequate tissue sample (gold standard)	Increased complications* May compromise definitive resection
Excisional biopsy	Entire lesion removed	Removes entire lesion Indicated for small lesion or expendable bone	Increased complications*

*Complications include infection, bleeding/hematoma, pathological fracture, tumor contamination/seeding.

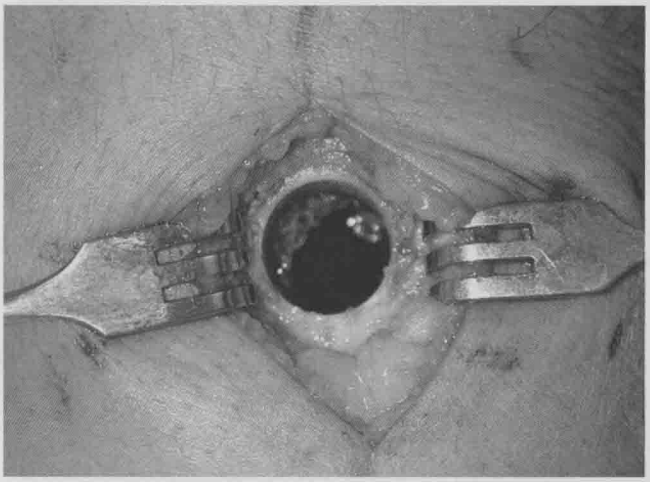


FIGURE 24-8 If hole must be made in bone during biopsy, defect should be round to minimize stress concentration, which otherwise could lead to pathological fracture.

tumor cells. If a drain is used, it should exit in line with the incision so that the drain track also can be easily excised en bloc with the tumor. The wound should be closed tightly in layers. Wide retention sutures should not be used.

A biopsy can be done by fine-needle aspiration, core needle biopsy, or an open incisional procedure (Table 24-4). Indications for needle biopsy include obese patients, close proximity of the tumor to neurovascular structures, and tumors in locations difficult to access (e.g., pelvis). Fine-needle aspiration may be 90% accurate at determining malignancy; however, its accuracy at determining specific tumor type is much lower because only cells rather than tissue are retrieved. This technique may be best applied when there is a high probability that the diagnosis is known such as metastases or infection and when evaluating lymph nodes. An experienced pathologist is helpful in determining the diagnosis because of the limited sample size obtained. A core needle biopsy uses a larger-gauge needle than a fine-needle aspiration, providing for tissue and preservation of the tissue architecture. The limited amount of tissue obtained may not be adequate, however, for accurate grading or for any additional studies that may dictate subsequent treatment. The few dedicated series that have analyzed outpatient core needle biopsies have reported an overall diagnostic accuracy ranging from 84% to 98%. A recent study of 252 outpatient core needle biopsies of malignant bone and soft tissue neoplasms reported an accuracy rate of 97% for malignancy; core needle biopsy was diagnostic and accurate for histopathological diagnosis and grade in 81%.

Open biopsy is the gold standard for biopsy of bone and soft tissue tumors, but complications are greater with incisional biopsy when compared with needle biopsy (i.e., bleeding, infection, tissue contamination). However, this procedure is least likely to be associated with a sampling error, and it provides the most tissue for additional diagnostic studies, such as cytogenetics and flow cytometry. If the administration of chemotherapy is anticipated before further surgery, a central venous access catheter may be placed at the same setting as the biopsy if the frozen section is confirmatory. The definitive procedure can be done immediately after biopsy only if the frozen section diagnosis confirms the clinical and radiographic diagnosis. In cases of discrepancy or doubt, the definitive procedure should be delayed until a firm diagnosis is established. If a giant cell tumor is suspected on clinical and radiographic grounds, definitive curettage can proceed immediately after confirmation of the diagnosis on frozen section. Likewise, if the suspicion of an impending fracture from metastatic carcinoma is confirmed on frozen section, prophylactic fixation can be applied immediately. Conversely, if the frozen section in either of these scenarios exhibited any atypical cells that might represent a sarcoma, definitive surgery should be delayed until the final pathological evaluation is complete.

Rarely, a primary resection (i.e., excisional biopsy) should be done instead of a biopsy. A small (<3 cm) subcutaneous mass that is unlikely to be malignant may be marginally resected primarily. In the rare circumstance that the lesion turns out to be malignant the tumor bed may be reexcised with wide margins without adversely affecting the outcome. Primary resection should not be done on larger soft tissue lesions or lesions deep to the fascia unless the MRI appearance is diagnostic of a benign lesion, such as a lipoma.