VOLUME TWO

Seventh Edition

CAMPBELL'S OPERATIVE ORTHOPAEDICS

Edited by

A.H. CRENSHAW

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with 6917 illustrations and 8 color plates

The C. V. Mosby Company

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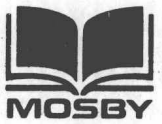

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Developmental editor: Kathryn H. Falk
Project editor: Teri Merchant
Editing and production: Robert A. Kelly,
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Contributors

JAMES H. BEATY, M.D.

Chapters 61, 62, and 63

Clinical Assistant Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Chief, Tennessee Crippled Children's Service; Active Staff, Campbell Clinic, Baptist Memorial Hospital, LeBonheur Children's Medical Center, Regional Medical Center at Memphis, University of Tennessee Medical Center/William F. Bowld Hospital; Consultant Staff, Veterans Administration Medical Center, Arlington Developmental Center.

ROCCO A. CALANDRUCCIO, M.D.

Chapter 41

Professor of Orthopaedic Surgery and Chairman of Department of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Chief of Staff Emeritus, Campbell Clinic; Active Staff, Baptist Memorial Hospital, Regional Medical Center at Memphis; Consultant Staff, University of Tennessee Medical Center/William F. Bowld Hospital.

S. TERRY CANALE, M.D.

Chapters 36, 47, and 55

Clinical Associate Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Chief of Pediatric Orthopaedics, LaBonheur Children's Medical Center; Active Staff, Campbell Clinic, Baptist Memorial Hospital, and Regional Medical Center at Memphis.

PETER G. CARNESALE, M.D.

Chapters 26 through 34

Clinical Associate Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, and Regional Medical Center at Memphis; Consultant Staff, St. Joseph Hospital, LeBonheur Children's Medical Center, St. Jude Children's Research Hospital, and Veteran's Administration Medical Center; Courtesy Staff, Methodist Hospital.

A.H. CRENSHAW, M.D.

Chapters 1, 2, and 49

Clinical Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital and Regional Medical Center at Memphis; Consultant Staff, Methodist Hospital; Associate Staff, LeBonheur Children's Medical Center.

ALLEN S. EDMONSON, M.D.

Chapters 68, 70, 71, and 72

Clinical Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, Regional Medical Center at Memphis and LeBonheur Children's Medical Center.

BARNEY L. FREEMAN III, M.D.

Chapters 50, 51, 52, and 69

Clinical Assistant Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, Regional Medical Center at Memphis; Consultant Staff, LeBonheur Children's Medical Center, and Veterans Administration Medical Center.

ALVIN J. INGRAM, M.D.

Chapter 66

Professor and Chairman Emeritus, Department of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Chief of Staff Emeritus, Campbell Clinic; Orthopaedic Consultant, Richards Medical Company; Emeritus Staff, Baptist Memorial Hospital and LeBonheur Children's Medical Center.

E. JEFF JUSTIS, JR., M.D.

Chapters 53 and 54

Clinical Associate Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, Regional Medical Center at Memphis; Consultant Staff, Arlington Developmental Center, LeBonheur Children's Medical Center, Veterans Administration Medical Center; Courtesy Staff, Methodist Hospital; Consultant to the Surgeon-General, United States Air Force; Consultant in Hand Surgery, Mississippi and Tennessee Crippled Children's Services.

DAVID G. LAVELLE, M.D.

Chapter 41 (Section on Deep Venous Thrombosis and Pulmonary Embolism)

Clinical Instructor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, Regional Medical Center at Memphis, University of Tennessee Medical Center/William F. Bowld Hospital; Consultant Staff, LeBonheur Children's Medical Center and Veterans Administration Medical Center.

LEE MILFORD, M.D.

Chapters 3 through 20

Clinical Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn., Chief of Staff, Campbell Clinic; Active Staff, Baptist Memorial Hospital and Regional Medical Center at Memphis; Consultant Staff, University of Tennessee Medical Center/William F. Bowld Hospital.

E. GREER RICHARDSON, M.D.

Chapters 35, 37, and 44 (section on Foot and Ankle)

Clinical Associate Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, University of Tennessee Hospital, and Regional Medical Center at Memphis; Consultant Staff, Veterans Administration Medical Center and University of Tennessee Medical Center/William F. Bowld Hospital; Courtesy Staff, LeBonheur Children's Medical Center.

THOMAS A. RUSSELL, M.D.

Chapters 38, 39, and 48

Clinical Instructor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Chief of Orthopaedic Service, Presley Trauma Center; Active Staff, Campbell Clinic, Baptist Memorial Hospital, Regional Medical Center at Memphis, University of Tennessee Medical Center/ William F. Bowld Hospital, Consultant Staff, Veterans Administration Medical Center.

FRED P. SAGE, M.D.

Chapters 65 and 67

Clinical Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, and Regional Medical Center at Memphis; Chief of Staff, Crippled Children's Hospital; Consultant Staff, LeBonheur Children's Medical Center and Methodist Hospital.

T. DAVID SISK, M.D.

Chapters 42, 43, 44, 45, 46, 56, 58, 59, and 60

Clinical Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, LeBonheur Children's Medical Center, and Regional Medical Center at Memphis.

ROBERT E. TOOMS, M.D.

Chapters 22, 23, 24, 25, and 40

Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital; Consultant Staff, LeBonheur Children's Medical Center and Regional Medical Center at Memphis; Medical Director, University of Tennessee Rehabilitation Engineering Center; Medical Director, Regional Spinal Cord Injury Center; Chief, Child Amputee Clinic and St. Jude Amputee Clinic.

GEORGE W. WOOD II, M.D.

Chapters 70, 73, 74, and 75

Clinical Associate Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Active Staff, Campbell Clinic, Baptist Memorial Hospital, Regional Medical Center at Memphis; Consultant Staff, LeBonheur Children's Medical Center, Veterans Administration Medical Center, University of Tennessee Medical Center/William F. Bowld Hospital.

PHILLIP E. WRIGHT, M.D.

Chapters 21, 42, 57, and 64

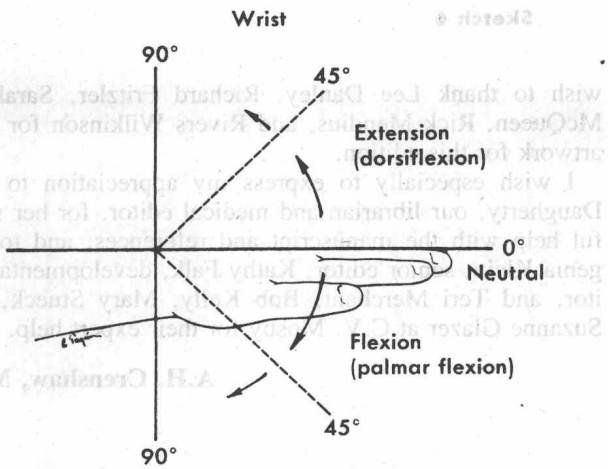
Clinical Associate Professor of Orthopaedic Surgery, University of Tennessee, Memphis, Tenn.; Chief, Hand Surgery Service, Regional Medical Center at Memphis; Active Staff, Campbell Clinic, Baptist Memorial Hospital, and Regional Medical Center at Memphis; Consultant Staff, LeBonheur Children's Medical Center, Veterans Administration Medical Center, and Active Staff University of Tennessee Medical Center/William F. Bowld Hospital.

Preface to seventh edition

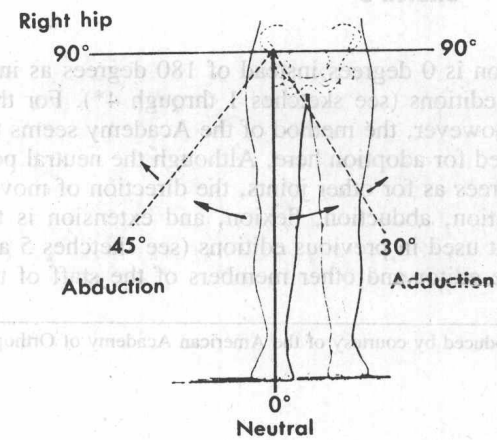
The format for this edition has been changed completely from that of previous editions. The material has been reorganized into 75 chapters divided into 17 parts for better presentation. Some chapters as such have been deleted and new ones on microsurgery, fractures in children, osteonecrosis, foot in adolescents and adults, low back pain and disorders of intervertebral discs, arthroscopy, paralytic disorders, and inheritable progressive neuromuscular diseases have been added. All retained chapters have been rewritten or revised extensively. For the first time since the First Edition all contributors are members of the staff of the Campbell Clinic.

For ease in handling, the material is divided among four volumes instead of two. Of approximately 6900 illustrations, 3000 are new. Included are eight four-color plates.

We have continued to use almost entirely the method of measuring joint motion that has been advocated by the American Academy of Orthopaedic Surgeons. The neutral



Sketch 1



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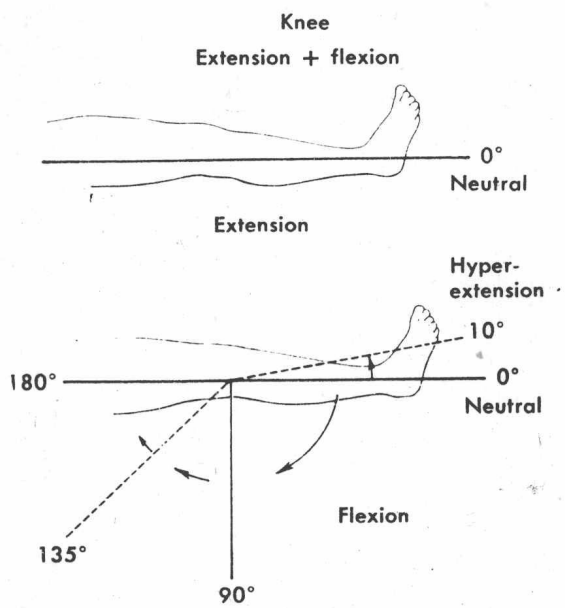

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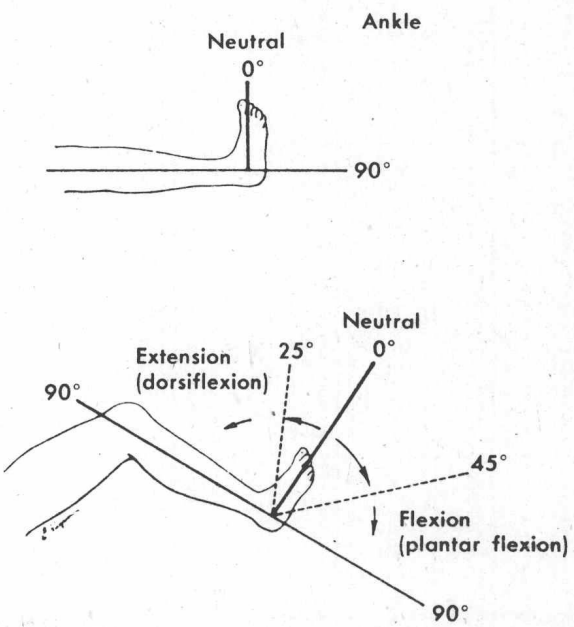

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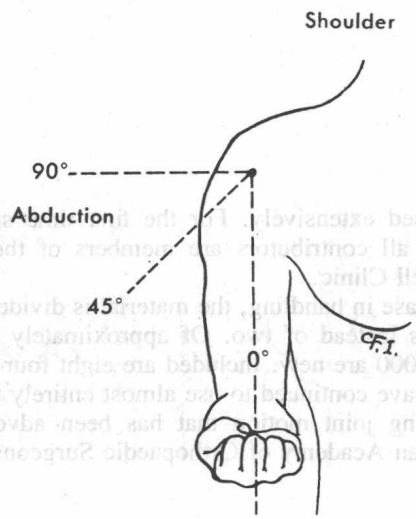

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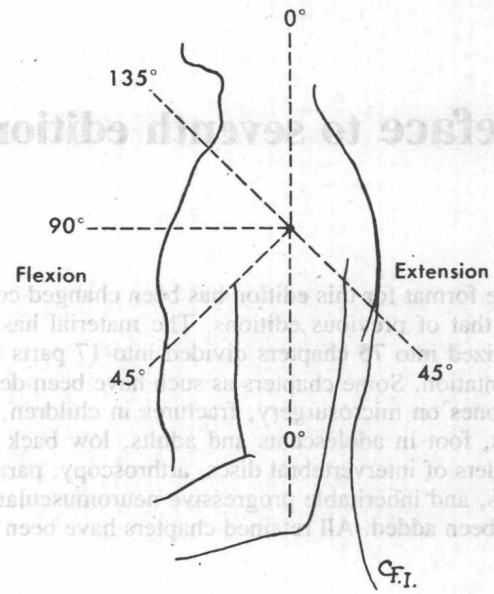

Sketch 6

position is 0 degrees instead of 180 degrees as in the first three editions (see sketches 1 through 4*). For the shoulder, however, the method of the Academy seems too complicated for adoption here. Although the neutral position is 0 degrees as for other joints, the direction of movement in adduction, abduction, flexion, and extension is the same as that used in previous editions (see sketches 5 and 6).

The editor and other members of the staff of the clinic wish to thank Lee Danley, Richard Fritzler, Sarah C. McQueen, Rick Mendius, and Rivers Wilkinson for their artwork for this edition.

I wish especially to express my appreciation to Kay Daugherty, our librarian and medical editor, for her skillful help with the manuscript and references, and to Eugenia Klein, senior editor, Kathy Falk, developmental editor, and Teri Merchant, Bob Kelly, Mary Stueck, and Suzanne Glazer at C.V. Mosby for their expert help.

A.H. Crenshaw, M.D.

*Reproduced by courtesy of the American Academy of Orthopaedic Surgeons.

Preface to first edition

The title of this book, *Operative Orthopedics,* is not intended to convey the impression that the chief or most important method of treatment of orthopedic affections is open surgery. Although many orthopedic affections are best treated by operative measures alone, the majority are successfully treated by more conservative means. Further, such measures are often essential adjuncts either before or after operation.

This volume has been written to meet the current need for a comprehensive work on operative orthopedics, not only for the specialist, but also for many industrial and general surgeons who are doing excellent work in some branches of orthopedic surgery, and are making valuable contributions to this field.

The evolution of orthopedic surgery has been exceedingly slow as compared to that of surgery in general. Not until aseptic technic had been materially refined was surgery of the bones and joints feasible. The statement is often made that the World War afforded the experience which made possible the rapid development of orthopedic surgery during the past two decades. The surgery of the war, however, was chiefly the surgery of sepsis; there was little of the refined asepsis which is required in reconstruction surgery. Undoubtedly, the demonstration during the war of the necessity and importance of this field led many able men to specialize in orthopedics, and to them considerable credit is due for its subsequent progress.

No classification of orthopedic affections is entirely satisfactory; consequently, any arrangement of operative procedures is subject to similar criticism. With the exception of the chapters on Arthroplasty and Arthrodesis, operations described in this text are grouped together according to their applicability to a given affection. This involves less repetition as to generalities of etiology, pathology, and treatment than would be necessary in a classification according to anatomic location. Operative procedures appropriate to two or more affections are described in the discussion of the one wherein they are most commonly employed.

To overcome the too widespread conception of orthopedic surgery as a purely mechanical equation, an effort is made in the first chapter of this book to correlate the mechanical, surgical, and physiologic principles of orthopedic practice, and throughout the book to emphasize the practical application of these physiologic principles. A special chapter has been written on surgical technic, for the purpose of stressing certain details in preparation and aftertreatment which vary to some extent from those described in works on general surgery. A thorough knowledge of these phases of treatment is a requisite to success. To avoid constant repetition, chapters have been included on apparatus and on surgical approaches; repeated reference is made to these chapters. The aftertreatment is given in detail for practically all operative technics. This is a most essential, yet too often neglected, factor in the success of any surgical treatment.

In giving the position or range of motion of a joint, only one system has been followed: with the exception of the ankle and wrist, the joint is in neutral position when parallel with the long axis of the body in the anteroposterior and lateral planes. As the joint proceeds from the neutral position in any direction, the number of degrees in which such movement is recorded decreases progressively from 180 to 170, 160, and so on, to the anatomic limit of motion in that particular direction. To illustrate, complete extension of the knee is 180 degrees; when the joint is flexed 30 degrees, the position is recorded as the angle formed between the component parts of the joint, i.e., the leg and thigh, or 150 degrees. Flexion to a right angle is 90 degrees, and full flexion 30 degrees. In the wrist, the joint is at 180 degrees, or in the neutral position, when midway between supination and pronation, and flexion and extension. In the ankle joint, motion is recorded as follows: the extreme of dorsiflexion, 75 degrees; right angle, 90 degrees; and the extreme of plantar flexion, 140 degrees.

In some instances, the exact end results have been given, to the best of our knowledge. So many factors are involved in any one condition, that a survey of end results can be of only questionable value unless the minute details of each case are considered. Following arthroplasty of the knee, for example, one must consider the etiology, pathology, position of the ankylosed joint, the structure of the bones comprising the joint, the distribution of the ankylosis, and the age of the patient, in estimating the end result in each case. Further, a true survey should include the results of *all* patients treated over a period of *many* years, and should be made by the surgeon himself, rather than by a group of assistants, or by correspondence.

In our private clinic and the hospitals with which we are associated, a sufficient amount of material on every phase of orthopedic surgery has been accumulated during the past twenty years or more to justify an evaluation of the various procedures. From this personal experience, we also feel that definite conclusions may be drawn in regard to the indications, contraindications, complications, and other considerations entering into orthopedic treatment. In all surgical cases, mature judgment is required for the selection of the most appropriate procedure. With this in mind, the technics which have proved most efficient in the author's experience have been given preference in the text.

In addition, after a comprehensive search of the literature, operative measures have been selected which in the judgment of the author are most practicable.

Although no attempt has been made to produce an atlas of orthopedic surgery, an effort has been made to describe those procedures which conform to mechanical and physiologic principles and will meet all individual requirements. In any work of this nature, there are sins of omission; also, many surgeons in the same field may arrive independently at the same conclusions and devise identical procedures. We have endeavored, however, to give credit where credit was due. If there are errors, correction will gladly be made. In some of the chapters we have drawn heavily from authoritative articles on special subjects; the author gratefully acknowledges his indebtedness for this material. He also wishes to thank those authors who have so graciously granted permission for the reproduction of original drawings.

In conclusion, I cannot too deeply express my sincere appreciation and gratitude to my associate, Dr. Hugh Smith, who has untiringly and most efficiently devoted practically all of his time during the past two years to collaboration with me in the compilation and preparation of material, which alone has made this work possible. I also desire to express appreciation to Dr. J. S. Speed for his collaboration on the sections on Spastic Cerebral Paralysis and Peripheral Nerve Injuries; to Dr. Harold Boyd for anatomic dissections verifying all surgical approaches described, and for his assistance in preparing the chapter on this subject; to Dr. Don Slocum for his aid in the preparation of the chapter on Physiology and Pathology; to Mrs. Allene Jefferson for her efficient editorial services, and to Mr. Ivan Summers and Mr. Charles Ingram for their excellent illustrations.

Willis C. Campbell

1939

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Color Plates

CHAPTER 30

General principles of tumors

Peter G. Carnesale

A team composed of a surgeon, diagnostic radiologist, pathologist, and often a medical oncologist and radiotherapist is necessary to treat the spectrum of tumors involving the extremities and spine. The surgeon should be well read and have experience in the surgical techniques necessary to treat tumors. Both the radiologist and pathologist should have a special interest in tumors, especially tumors of bone, and be able to participate in the clinical evaluation including the determination of the optimal site for biopsy. The medical oncologist frequently treats patients with malignancies of soft tissues and bone, because it is increasingly apparent that systemic control of many of these tumors requires adjuvant therapies. The radiotherapist participates either in primary control of the lesion or in adjuvant therapy.

DIAGNOSTIC EVALUATION—GENERAL

The history must be the first step in the evaluation of a patient with a tumor. Initial complaints are usually pain, mass, disability of a part, or the incidental discovery of an abnormality on a roentgenogram. Occasionally constitutional symptoms such as anorexia, weight loss, or fever may be present. The age and sex of the patient may be important in differential diagnosis.

The physical examination should include a general evaluation in addition to a careful examination of the extremity or part in question. A mass should be measured and its location, shape, consistency, mobility, tenderness, and local temperature considered. Atrophy of surrounding musculature and restriction of motion of contiguous joints or effusion of joints should be recorded. A careful neurologic examination and an assessment of the status of the arterial and venous circulation should be made.

Laboratory studies performed routinely should include a blood count, urinalysis, sedimentation rate, and serum calcium, phosphorus, alkaline phosphatase, and protein. Other studies such as serum acid phosphatase and serum and urine electrophoresis should be obtained as indicated.

Roentgenograms of the part should, with rare exception, be made in at least two planes at 90-degree angles. A chest roentgenogram is indicated in the evaluation of a suspected neoplasm. Computed tomography is the most sensitive technique for detecting pulmonary metastases in malignant lesions. Tomograms of the affected part along with computed tomography, arteriography with or without subtraction, xeroradiography, and arthrography may be helpful. Ultrasonography and nuclear magnetic resonance (magnetic resonance imaging) are being used with increasing frequency.

Radioisotopic scans are often helpful as follows: tech-

netium bone scans help detect the extent of bone tumors or of occult bone metastases and assess bone involvement in malignant soft tissue tumors; gallium scans may be helpful in assessing malignant bone and soft tissue tumors; liver scans are useful in detecting hepatic metastases although computed tomography may be more sensitive.

Recently Enneking et al. and others have demonstrated convincingly the desirability of staging malignant musculoskeletal lesions so that meaningful comparisons of treatment methods can be made. They have also shown that staging predicts accurately the type of surgical procedure needed for local control of the tumor. For example, for stage IA lesions (low-grade intracompartmental) a local procedure can usually achieve the necessary wide margins, whereas Stage IB lesions (low-grade, extracompartmental) usually require amputation at an appropriate level to achieve the necessary margins. Stage II lesions (high-grade [Broder's III and IV]) have been shown to require radical margins. Margins are discussed later in the section on surgical techniques.

Staging is accomplished by the combination of physical examination, radiologic and radioisotopic methods discussed, and biopsy. The system proposed by Enneking et al. follows:

IA	Low-grade intracompartmental (lesion confined to a single anatomic compartment)
IB	Low-grade extracompartmental (lesion extends beyond a single compartment)
IIA	High-grade intracompartmental
IIB	High-grade extracompartmental
III	Lesion of low or high grade either intracompartmental or extracompartmental but with either regional or distant metastasis

Biopsy

Biopsy is the ultimate diagnostic technique for evaluating neoplasms. It may be accomplished either by needle aspiration or by surgical sampling. The latter may be incisional (that is, removal of a small portion of the tumor) or excisional (removal of the entire tumor, usually without a margin of surrounding normal tissue). A biopsy of a tumor suspected of being malignant should be done either by needle aspiration or by incisional means in such a manner that only a minimum of normal tissue is contaminated. The incision for extremity lesions should be longitudinal and for any location should be carefully planned so that definitive surgery can remove the biopsy site. Ideally the biopsy and definitive procedure should be carried out in the same institution, the biopsy being performed by an experienced tumor surgeon; Mankin has shown that inappropriate biopsy technique is a significant problem. Excisional biopsy should be reserved for benign lesions.

Needle biopsy carried out by experienced personnel using the image intensifier to guide needle placement and with capable histologists and cytologists to interpret the material can yield accurate diagnoses in two thirds of bone lesions and three fourths of soft tissue lesions. The technique probably should not be used for cartilage lesions because inadequate sampling may fail to detect the most aggressive portion of the tumor.

Bone marrow aspiration may be useful in such malignancies as lymphoma or multiple myeloma.

NEEDLE BIOPSY

A variety of needles for bone biopsy are available, including those described by Akerman, Berg, and Persson, Craig, Ottolenghi, and Turkel and Bethell. Most consist of guide, cannula, and cutting needle. When the bone lesion is purely lytic or if there is an associated soft tissue extension, Westerman-Jensen, Vin-Silverman and Lee have designed needles to be used for soft tissue biopsy. General or local anesthesia may be used. Roentgenographic control is usually necessary, and image intensifier television fluoroscopy is desirable.

TECHNIQUE. Make a 2 or 3 mm stab incision through the skin to facilitate introduction of the cannula and guide. Direct the guide to the site of the lesion using roentgenographic control if necessary. Introduce the cutting needle through the cannula into the lesion, and apply suction to aspirate lesional tissue into the needle.

Needle biopsy of vertebrae. Open biopsy of lesions of the cervical spine is advised most often; however, Ottolenghi et al. have published a method for needle biopsy of cervical vertebrae. Sage at this clinic has successfully performed biopsies on the second cervical vertebral body using a transpharyngeal needle under image intensifier control. Valls, Ottolenghi, and Schajowicz have introduced needle biopsy of dorsal and lumbar vertebrae.

TECHNIQUE OF NEEDLE BIOPSY OF CERVICAL VERTEBRAE. For biopsy of the first three cervical vertebrae use the anterior or pharyngeal approach and general anesthesia. Push the uvula and nasal tube used for endotracheal intubation to the side that affords best exposure for puncture. Perform the puncture with a short, beveled 2 mm needle under roentgenographic control, both anteroposterior and lateral views, or use image intensifier television fluoroscopy. When the needle is correctly placed, aspirate using a syringe with careful penetrating and withdrawal movements as suction is applied. Biopsy the C4 through T1 vertebral bodies from a lateral approach. Make roentgenograms of the cervical spine with a metallic marker on the skin to assist in determining the site of puncture. Then place the patient supine with the head rotated to the side opposite the puncture site and palpate the posterior border of the sternocleidomastoid muscle. Make a stab incision through the skin at the posterior margin of the muscle at the level selected for puncture. Use two needles, a 9 cm long, 2 mm diameter needle and a 12 cm long, 1 mm diameter needle. Introduce the smaller needle through the larger needle and direct it toward the midline of the body and anteriorly. Bone should be reached at a level of 3.5 cm. If blood is aspirated, it is most likely caused by puncture of the vertebral artery. Redirect the needle slightly more anteriorly to avoid the transverse process. When the tip of the needle is felt to contact bone, make anteroposterior and lateral roentgenograms to check the position. Once the correct position is verified push in the 2 mm needle until it contacts the bone. Withdraw the 1 mm needle and aspirate (Fig. 30-1).

TECHNIQUE OF NEEDLE BIOPSY OF T2 THROUGH T9 VERTEBRAE (VALLS ET AL.). Because needle biopsy of T2 to T9 vertebrae is usually painful when carried out under local anesthesia, we recommend general anesthesia with endotracheal intubation. Do the biopsy from the right side to avoid the aorta unless the lesion is in the left side of the vertebral body.

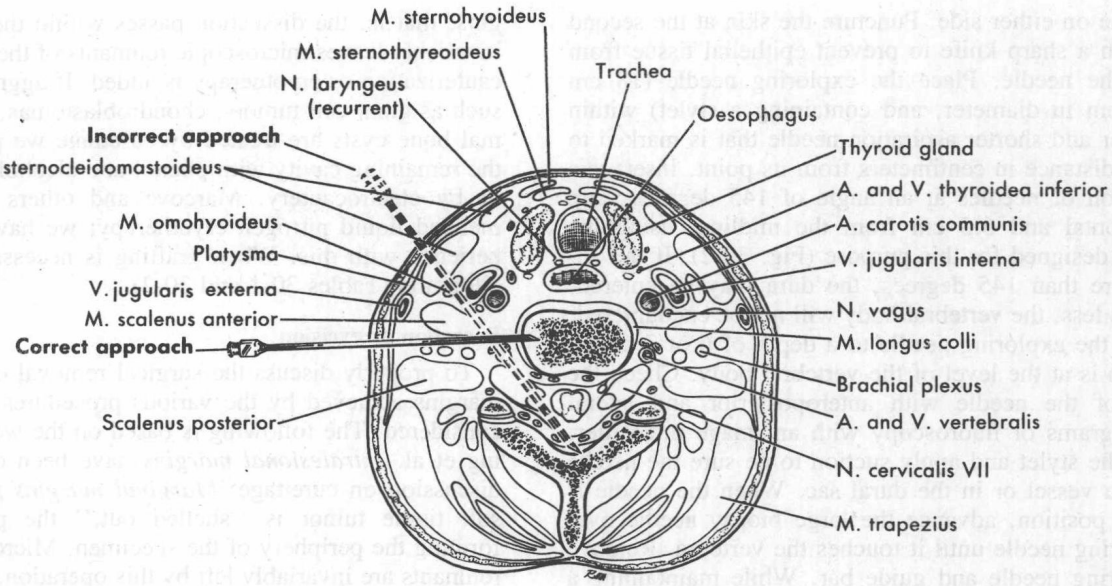

Fig. 30-1. Cross section through neck at level of seventh cervical vertebra to show the anatomic structures and needles correctly and incorrectly placed. (Redrawn from Ottolenghi, C.E., Schajowicz, F., and De Schant, F.A.: J. Bone Joint Surg. **46-A:**715, 1964.)

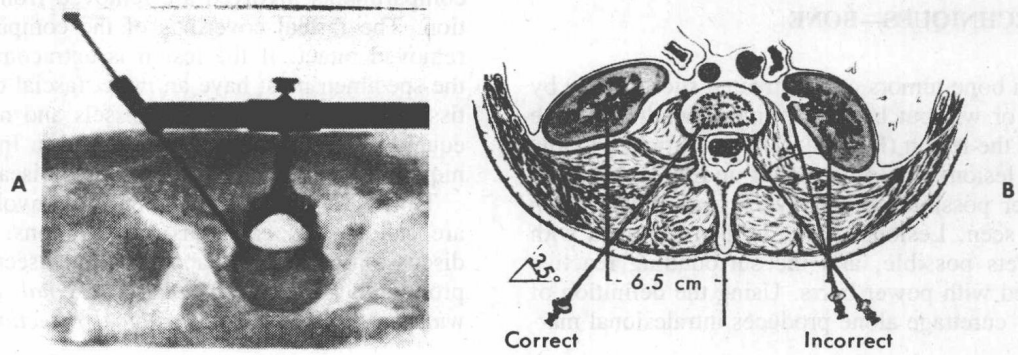

Fig. 30-2. Needle biopsy of T10 through T12 vertebrae and of lumbar vertebrae, **A,** Correct angle for insertion of needle is determined by guide bar. **B,** Correct and incorrect angles of insertion of needle. (From Ottolenghi, C.E.: J. Bone Joint Surg. **37-A:**443, 1955).

Use an aspiration needle that is 2 mm in diameter and 12 cm long with a short sharp tip and external markings to gauge its depth in the tissues. Use the Ottolenghi bar and guide, and insert the needle at an angle of 35 degrees through a small stab wound in the skin 4 cm from the midline of the spine posteriorly. The tip of the needle frequently encounters a rib. Manipulate it to pass superior to the rib. Maintain a partial vacuum in the needle with a syringe so that entering of a vessel or the neural sac is recognized immediately. When the aspiration needle has been advanced about 6 cm, insert a second needle, the exploring needle (18 cm long and 1 mm in diameter), into its lumen. Maintain a partial vacuum and advance this needle. Insert neither needle more than 7 cm. The vetebral body is encountered near the base of the pedicle. When the tip of the exploring needle is thought to be in the correct position, insert a stylet to see that the needle is not clogged and obtain anteroposterior and lateral roentgenograms. If the tip of the exploring needle is found to be at the desired part of the vertebra, advance the aspiration needle over the exploring needle and attempt to puncture the vertebral body. If the aspiration needle cannot penetrate the body of the vertebra, move its tip slightly superiorly or inferiorly and try again, but always keep it in contact with the bone. If necessary, make several roentgenograms during the procedure to be sure of the position of the needle. After penetration, if desired, move the needle around slightly inside the bone to obtain specimens from several parts of the vertebra.

TECHNIQUE OF NEEDLE BIOPSY OF T10 THROUGH T12 AND ALL LUMBAR VERTEBRAE (VALLS ET AL.). Do needle biopsy of T10 to T12 and all lumbar vertebrae with the patient under general anesthesia with intubation or under local anesthesia with the patient prone. Using an appropriate local anesthetic solution, make a wheal over the spinous process of the involved vertebra. Make a second wheal 6.5 cm from

the midline on either side. Puncture the skin at the second wheal with a sharp knife to prevent epithelial tissue from entering the needle. Place the exploring needle (18 cm long, 1 mm in diameter, and containing a stylet) within the heavier and shorter aspiration needle that is marked to show the distance in centimeters from its point. Insert this combination of needles at an angle of 145 degrees from the horizontal and 6.5 cm from the midline, using the guide bar designed for this purpose (Fig. 30-2). If the angle is more than 145 degrees, the dura may be entered, and if it is less, the vertebral body will not be encountered. Introduce the exploring needle to a depth of 6 or 7 cm so that its tip is at the level of the vertebral body. Check the position of the needle with anteroposterior and lateral roentgenograms or fluoroscopy with an image intensifier. Remove the stylet and apply suction to be sure the needle is not in a vessel or in the dural sac. When the needle is in proper position, advance the large biopsy needle over the exploring needle until it touches the vertebra. Remove the exploring needle and guide bar. While maintaining a partial vacuum in the biopsy needle with a syringe, gradually advance it into the vertebral body, but no more than a total of 9 cm or the aorta may be punctured. If considerable resistance is encountered, move the tip of the needle slightly to find a softer area for aspiration.

SURGICAL TECHNIQUES—BONE

Curettage

Many benign bone tumors can be treated successfully by curettage with or without bone grafting depending on the site and size of the lesion (Fig. 30-3). The cortical window made over the lesion should be longer and wider than the lesion whenever possible so that every part of the lesion can be readily seen. Lesional tissue is then removed with the largest curets possible, and the surrounding reactive bone is removed with power burrs. Using the definition of Enneking et al. curettage alone produces intralesional margins, that is, the dissection passes within the lesion. This invariably leaves microscopic remnants of the tumor unless cauterization or cryotherapy is added. If aggressive tumors such as giant cell tumors, chondroblastomas, and aneurysmal bone cysts are treated by curettage we prefer to treat the remaining cavity with phenol and alcohol cauterization or by electrocautery. Marcove and others have recommended liquid nitrogen cryotherapy; we have had no experience with this. When grafting is necessary we prefer allografts (Tables 30-1 and 30-2).

Resection or excision

To properly discuss the surgical removal of tumors, the margins achieved by the various procedures must first be considered. The following is based on the work of Enneking et al. *Intralesional margins* have been defined in the discussion on curettage. *Marginal margins* result when a soft tissue tumor is "shelled out," the pseudocapsule forming the periphery of the specimen. Microscopic tumor remnants are invariably left by this operation. A *wide margin* is achieved when the dissection is carried out entirely through normal tissue near the tumor. Because high-grade sarcomas spread widely along fascial planes, microscopic tumor may still be left by this technique. *Radical margins* are achieved when all normal tissues of the one or more compartments involved are removed from origin to insertion. The fascial coverings of the compartments must be removed intact. If the lesion is extracompartmental, then the specimen must have an intact fascial covering, and the tissues removed, including vessels and nerves, should be equal in length to the adjacent muscles. In theory this technique removes all local microscopic disease.

Tumor removing procedures not involving amputation are called local excisions or resections. Considering the discussion of margins above, local resections may be appropriately designated *local marginal resections, local wide resections,* or *local radical resections* depending on

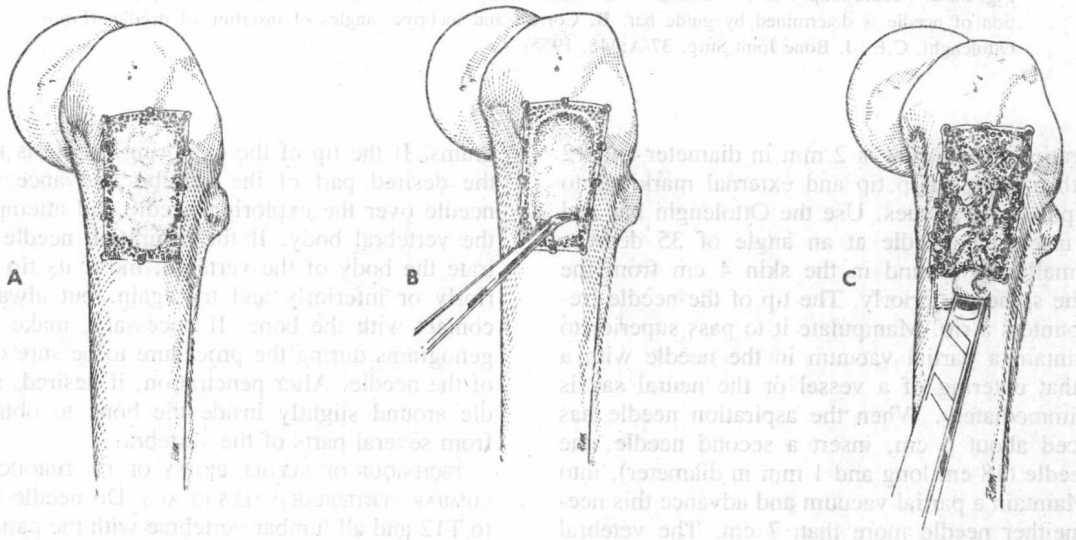

Fig. 30-3. Curettage of benign lesion. **A,** Window should be larger than lesion if possible. **B,** Lesional tissue is first removed with large curet, and then tumor margins are treated with power burrs. **C,** Cavity is filled with bone grafts; we prefer allograft.

Table 30-1. Resectable portions of skeleton

Bone	Disability*	Reconstruction
Phalanges of all toes (amputation or resection)	None to mild	Unnecessary
Metatarsals—spare first if possible (amputation or resection)	Mild to moderate	Shifting of bases of other metatarsals with amputation of distal end of ray Bone graft
Any tarsal bone except calcaneus (amputation or resection)	Mild to moderate	Resection of compensatory wedges and triple arthrodesis For talus: calcaneotibial fusion
Calcaneus	Mild to moderate	Unnecessary
Proximal four fifths of fibula	None to mild	Unnecessary
Distal one third of fibula	Mild to moderate	Bone graft: replace with proximal one third of fibula or omit reconstruction as possibly unnecessary
Distal three fourths of medial malleolus	Mild	Unnecessary if angle of mortise preserved
Patella	Mild	Unnecessary
Ischium Coccyx Spinous processes, etc. Ribs	None to mild	Unnecessary
Major portion of ilium except acetabular portion and sacroiliac joint, must preserve continuity	None to mild	Unnecessary
Medial or lateral 2.5 to 3.75 cm of clavicle	Mild	Unnecessary
Entire clavicle	Moderate	
Acromion	None to mild	Unnecessary
Entire scapula or segment of wing	Severe to moderate	Unnecessary
Head and tuberosities of humerus	Moderate	Tenoplasty or prosthesis
Proximal two thirds of humerus	Severe	Fibular transplant or prosthetic replacement
Olecranon	Mild	Unnecessary
Epicondyle	None to mild	Transplantation of ulnar nerve may be indicated
Capitulum in adult	Mild to moderate	Supracondylar osteotomy for cubitus valgus Arthroplasty or arthrodesis
Head and neck of radius	None to mild	Unnecessary
Distal 5 cm of ulna	None to mild	Unnecessary
Distal one third of radius	Mild to moderate	Replacement by proximal one third of fibula or arthrodesis to proximal carpal row
Any or all of carpal bones	Mild to moderate	Unnecessary or arthrodesis
Metacarpals—spare first if possible (amputation or resection)	Mild to severe	Bone graft Shifting bases of remaining metacarpals with amputation of affected ray
Phalanges of fingers (amputation)	Mild	Unnecessary
Six inches or less of shaft of any long bone; femur and tibia least desirable	Moderate to severe	Dual grafts Hemicylindric grafts or prosthetic replacement

*Disability estimate is that which is residual after available reconstruction procedures.

Table 30-2. Resection of joints with adjacent bone

Joint	Disability	Reconstruction
Knee with metaphyses of upper tibia or lower femur	Severe	Dual grafts to bridge defect Hemicylindric grafts
Hip with head, neck, and/or trochanter, and portions of ilium	Moderate to severe	Arthrodesis of stump to ischium
Shoulder with acromion, head, and tuberosities of humerus	Moderate	Tenoplastic reconstruction or prosthesis
Elbow joint	Moderate	Accept unstable joint or arthrodesis, total elbow arthroplasty
Carpus and minimal resection of distal end of radius	Mild to moderate	Arthrodesis and resection of distal ulna