VOLUME THREE

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
ST. LOUIS • WASHINGTON, D.C. • TORONTO 1987

A TRADITION OF PUBLISHING EXCELLENCE

Acquisition editor: Eugenia A. Klein
Developmental editor: Kathryn H. Falk
Project editor: Teri Merchant
Editing and production: Robert A. Kelly,
Mary G. Stueck, Suzanne C. Glazer
Design: John Rokusek

SEVENTH EDITION

Printed in the United States of America

The C.V. Mosby Company
11830 Westline Industrial Drive, St. Louis, Missouri 63146

Library of Congress Cataloging-in-Publication Data

Campbell, Willis C. (Willis Cohoon), 1880-1941.
Campbell's operative orthopaedics.

Includes bibliographies and index.
1. Orthopedic surgery. I. Crenshaw, A. H. (Andrew Hoyt), 1920- . II. Title. III. Title: Operative orthopaedics. [DNLM: 1. Orthopedics. WE 168 C192o]
RD731.C28 1987 617'.3 86-23562
ISBN 0-8016-1065-6

C/VH/VH 9 8 7 6 5 4 3 2 1 02/A/210

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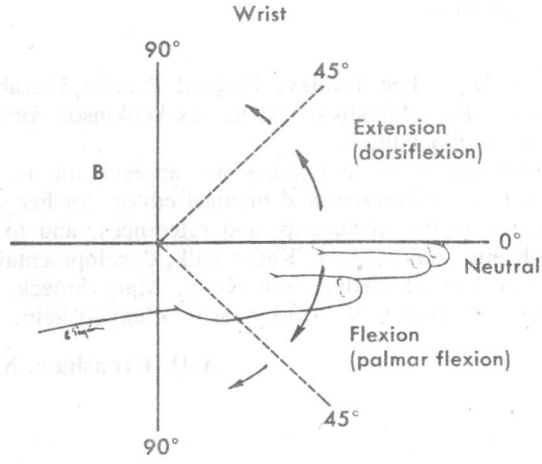
Preface to seventh edition

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



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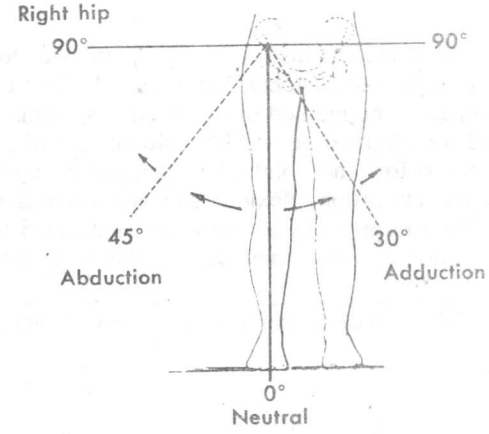

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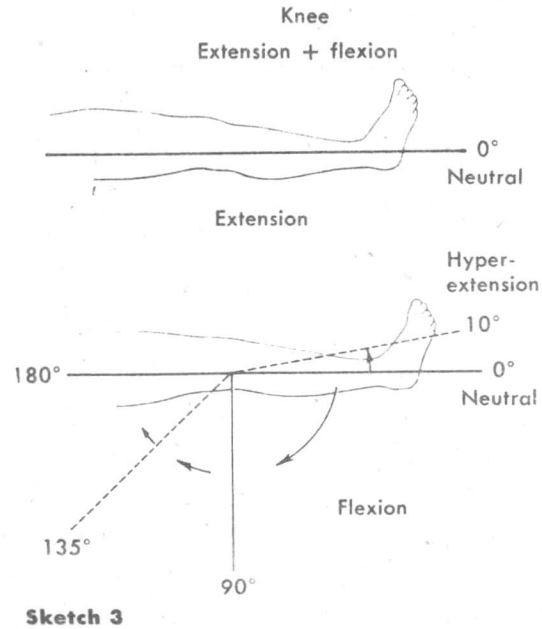

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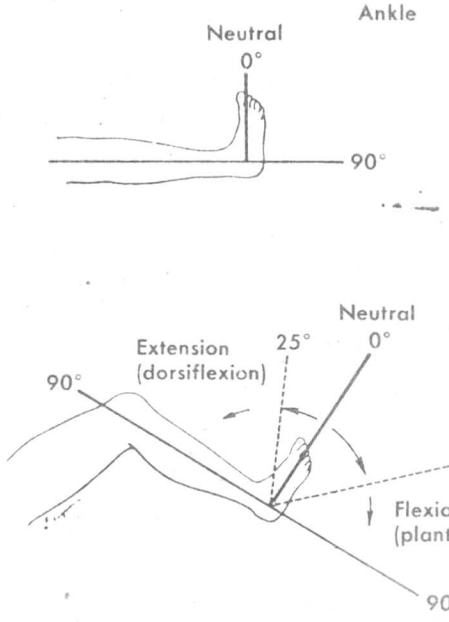

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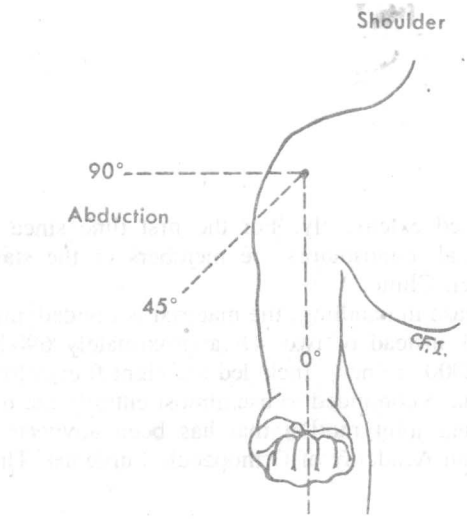

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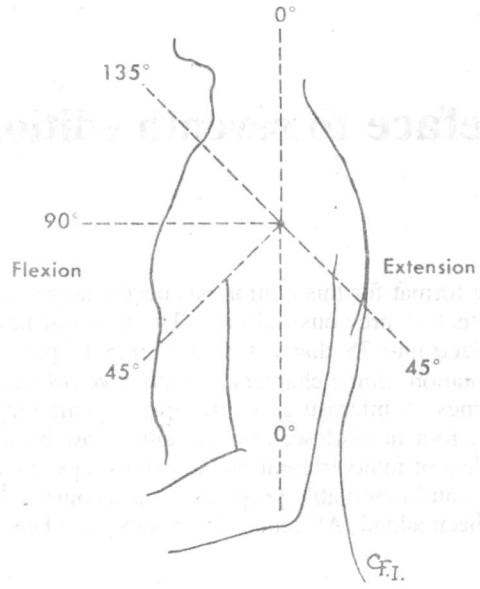

Sketch 6

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

Contents

Color Plates

PART X

Fractures

CHAPTER 43

General principles of fracture treatment

T. David Sisk

There is no class of injuries which a practitioner approaches with more doubt and misgiving than fractures, or one which demands a greater amount of ready knowledge, self-reliance, and consummate skill. Constant in their occurrence, and often extremely difficult of diagnosis and management, they frequently involve consequences hardly less serious and disastrous to the surgeon than to the patient himself. If I were called upon to testify what branch of surgery I regarded as the most trying and difficult to practice successfully and creditably, I should unhesitatingly assert that it was that which relates to the present subject, and I am quite sure that every enlightened practitioner would concur with me in the justice of this opinion. I certainly know none which requires a more thorough knowledge of topographical anatomy, a nicer sense of discrimination, a calmer judgment, a more enlarged experience, or a greater share of vigilance and attention; in a word, none which demands a higher combination of surgical tact and power. As for myself, I never treat a case of fracture, however simple, without a feeling of the deepest anxiety in regard to its ultimate issue; without a sense of discomfort, so long as I am conscious that, despite the most assiduous attention and the best efforts, the patient is likely to be lame and deformed for life.*

*From Gross, S.D.: A system of surgery: pathological, diagnostic, therapeutic, and operative, ed. 6, Philadelphia, Henry C. Lea's Son and Co., 1882, Vol. 2, p. 894.

This chapter will deal with the "how to" of surgical treatment of fractures, but perhaps more important is the question of "when to" and "when not to." Because most fractures may be reduced by closed methods, open reduction as a rule should not be considered unless it can produce a better result. Indiscriminate open reduction and internal fixation of fractures may violate many physiologic principles of healing, and its overly enthusiastic use discredits the method.

Great advances in open and closed methods of fracture management have been made during the last decade. Improved results of fractures treated by open reduction and fixation have followed the use of (1) improved medullary devices, (2) improved image intensifier television fluoroscopy to expedite medullary fixation without opening the fracture site, (3) improved implant designs and fixation techniques developed by the ASIF Group in Switzerland, and (4) improved external fixation appliances and application techniques.

Equally important have been the advances in closed management of fractures, particularly ambulatory cast methods applicable to fractures in the lower extremity. These advances have coincided with a better understanding of the biomechanical stresses and forces that act on the

musculoskeletal system and on internal and external fixation appliances, a better understanding of the biologic properties and patterns of fracture healing, and a better understanding of the blood supply of the bones. The recent use of piezoelectric potentials about the surfaces of bone to directly influence bone deposition, repair, and remodeling has stimulated the interest of those in the field of fracture healing. During the past decade, sufficient research and clinical experience have been gathered to document the efficacy of a properly applied electromagnetic field about the fracture site. These electromagnetic fields have been produced by both internally implanted and externally applied techniques. These methods have certainly added to our array of techniques used to assist fracture healing.

Since a wide choice of treatment methods is now available, indications must be precise. We will attempt to outline these indications and recommend methods of treatment.

PRINCIPLES OF TREATMENT BY OPEN METHODS

The goal of fracture treatment is to achieve union and restore the anatomy and function of the injured part to as nearly normal as possible. Even with careful surgical technique, additional soft tissue damage is superimposed on that produced by the fracture. Disturbed healing may result if the bone fragments become necrotic from loss of blood supply. Although the stripping of the periosteum by a fracture may be minimal, bone at the ends of the fragments often becomes necrotic. Before healing is complete, circulation must be restored to these avascular areas and the necrotic bone must be replaced. The success of fracture healing is probably determined more by the adequacy of the circulation in the region than by any other factor. Knowledge of the stresses that will be applied to the bone and the fixation device as the limb returns to normal function is essential for the proper selection and placement of the fixation device. Before attempting a complicated open reduction and internal fixation, self assessment by the surgeon is necessary in regard to his training, his familiarity with the proposed procedure, and his surgical ability. All surgeons are not equally endowed with technical skills, and nowhere are these skills more critical than in the open treatment of fractures in the severely injured patient. Furthermore, the surgeon must know well the institution in which he is operating. The preferred fracture management for a polytraumatized patient in a sophisticated trauma center may not be the preferred or the safest method for the practitioner in a small general hospital. Too often the current best forms of treatment proposed from the podiums of orthopaedic meetings are those applicable to special circumstances and specific institutional situations. If an orthopaedic surgeon in a small community hospital were to accept the dictum that all fractures in the polytraumatized patient must be subjected to open reduction and internal fixation, he would invite disaster applying sophisticated trauma center protocols to his situation.

The environment in the operating suite should be superior, the personnel should be familiar with the technique, and a full set of the proper instruments and implants should be available. Good anesthesia is necessary for fracture management by open methods. In addition, a patient who is fully informed of the rewards and risks of the open method and who is willing to cooperate in rehabilitation following surgery can be the determining factor in the success of the method. If the patient is not dependable or cooperative, closed methods of treatment may be the wiser course.

When choosing a method of treatment of fractures, the following should be considered as goals:

1. Secure union
2. Restore normal function
3. Accomplish both as rapidly and as safely as possible.

Function of the adjacent soft parts and joints after fracture depends on securing union. Whereas some variation from the normal anatomy frequently is compatible with good or even normal function, sometimes the limit of variation is small, as in fractures that involve joint surfaces or epiphyseal plates.

Functional results are usually proportionate to the excellence of reconstitution of the bone after fracture healing, but are also significantly influenced by the status of the surrounding soft tissues. Joint stiffness or contracture, poor muscle tone and strength, poor soft tissue flexibility, altered or impaired neurocirculatory status, and osteoporosis have been collectively referred to as fracture disease and may occur after either open or closed methods of treatment. When open methods are selected, fixation should be sufficiently rigid to allow early mobilization and return to more normal function. The ability to return rapidly to activity not only tends to protect the soft tissues from these changes but may greatly influence the quality and rapidity of fracture union. Nevertheless, speed of recovery and related economic considerations should not be the dominant considerations when contemplating methods of treatment of a fracture; to do so increases the risk of complication or catastrophe. Although these considerations should always be weighed, they should be of secondary importance. Securing union is most important, but the other two factors influence the choice of treatment method and play an important part in determining the final results.

Attitudes regarding internal fixation of fractures have changed during the past two or three decades. Emphasis has changed from rest and prolonged immobilization to active mobilization with return to normal function as early as possible. If open treatment is selected and internal fixation is not sufficiently rigid to permit early return of function, then most of the advantages of the open method have been lost while all of the potential disadvantages remain. Although rigidity of fixation should be the goal, no internal fixation will substitute for solid bone and allow unrestricted activity; a metallic implant can fatigue, break, bend, or pull out when subjected to such forces. After open reduction and internal fixation a race of sorts goes on between the rate of healing and the rate of loss of fixation. Union usually occurs before fixation loss or implant failure when patient, fracture, implant, and technique are properly matched. A compromise between mobilization and immobilization must be drawn when, despite well-planned and well-executed surgery, rigid internal fixation is not obtained because of severe fracture comminution or other reasons. External fixation, usually cast immobilization, may be required for a time.

Although great progress has been made in the open

treatment of fractures, many unsolved problems still persist. Rigid fixation itself has produced questions concerning the quality of union that develops when normal stresses have been removed by the fixation appliance. Internal fixation appliances of varying stiffness and the piezoelectric effects on bones subjected to stress both probably will assume greater significance and importance in the management of fractures in the future.

Indications for open reduction

Familiarity with the treatment of fractures by closed methods is essential to successful treatment by operative measures. Open methods are not routine alternatives to closed treatment. Either closed or open reduction may be considered proper for some fractures; for most, however, either one or the other is recognized as the most satisfactory treatment and therefore is indicated. As a rule, if open reduction is performed, internal fixation should be applied.

Although no set of definite indications for open reduction will be agreed upon by all, the following are common to many.

ABSOLUTE INDICATIONS

1. *Fractures irreducible by manipulation or closed methods*. Occasionally fractures that usually respond to closed methods of treatment may not be reducible to satisfactory positions, and open reduction is then required.

2. *Displaced intraarticular fractures*. Displaced fractures involving the articulating surfaces of joints, if sufficiently large to interfere with joint function, should have open reduction and internal fixation. These fractures can rarely be anatomically reduced and held by closed methods. Resultant imperfections and incongruity of the articular surfaces lead to traumatic arthritis. Open methods have an advantage in that the fragments may be reduced more perfectly and held securely as early function of the joint is initiated.

3. *Certain types of displaced epiphyseal fractures*. Displaced Salter and Harris types III and IV epiphyseal fractures lead to epiphyseal arrest or deformity unless accurate anatomic reduction is obtained and held.

4. *Major avulsion fractures with disruption of an important muscle mechanism or ligament*. Fractures of the greater tuberosity of the humerus, the patella, the olecranon, and the intercondylar eminence of the tibia are examples.

5. *Nonunions following either open or closed methods of treatment*.

6. *Replantations of extremities, either whole or parts*.

RELATIVE INDICATIONS

1. *Delayed union*. When union is delayed or uncertain, open reduction with internal fixation and often a bone graft may be indicated.

2. *Multiple fractures*. If taken individually each fracture may be treatable by closed methods, but when taken collectively certain fractures may be better managed by open reduction. A fracture of the humeral shaft in a patient with lower extremity fractures being treated by traction is an example. Maintenance of a satisfactory reduction of both upper and lower extremity fractures is often difficult by traction or closed methods, and open reduction of either the femur or the humerus or both may be considered in these patients.

3. *Loss of reduction following either open or closed methods*. A second trial of closed treatment should be considered as an important alternative to this indication.

4. *Pathologic fractures*. Open reduction and internal fixation of one of the major long bones in an extremity may be essential in the course of treatment of the primary disease process.

5. *To improve nursing care*. Severely brain-injured patients may be unable to tolerate cast immobilization or to cooperate with traction methods.

6. *To reduce mortality or morbidity from prolonged cast or bed immobilization*. Internal fixation of trochanteric fractures in the elderly is an example.

7. *Fractures for which closed methods are known to be ineffective*. Femoral neck fractures, Galeazzi fractures and Monteggia fracture-dislocations are examples.

QUESTIONABLE INDICATIONS

1. *Fractures accompanying blood vessel or nerve repair*. In the past this was often listed as an absolute or relative indication for open reduction. However, Connolly and others have shown that well-performed vascular repairs can tolerate loads far above those ordinarily required for fracture treatment. The additional surgical trauma and operating time required for open reduction increase the incidence of postoperative infection so that open reduction and internal fixation of fractures following blood vessel or nerve repairs are not routinely performed. If possible, stabilization of the fracture fragments can be achieved more safely by traction, an external fixation apparatus, or a cast than by internal fixation. Following a brachial artery repair in a child with a supracondylar humeral fracture, Kirschner wire fixation is frequently used because it is simply and quickly performed and easily removed if infection is a problem.

2. *Open fractures*. Some investigators suggest that open fractures should be treated by rigid internal fixation and contend that stabilizing the fracture aids in preventing infection in these contaminated injuries. Although these principles may be applicable, we still are reluctant to insert definitive internal fixation devices, such as medullary rods, plates, and screws, in contaminated wounds. We usually prefer to rigidly stabilize the fracture by external fixation until the wound has healed, and then we apply the appropriate internal or external methods for definitive fracture management. There certainly are exceptions to this basically conservative approach where the advantages afforded by the internal fixation justify the risks. Such instances include certain displaced open epiphyseal fractures and displaced fractures involving the joint surfaces. If internal fixation is considered for an open fracture, the surgeon should make every effort to reduce the risk of infection by cleansing and debriding the wound to an optimal state. He may consider inserting the internal fixation through a separate surgical exposure through nontraumatized soft tissue rather than through the open wound created by the fracture. He should usually leave the traumatic wound open, facilitate drainage by suction or dependency principles, and administer the appropriate antibiotics. The decision