VOLUME ONE

CAMPBELL'S OPERATIVE ORTHOPAEDICS

FIFTH EDITION

A. H. CRENSHAW EDITOR

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Editor

A. H. CRENSHAW, M.D.

Memphis, Tennessee

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FIFTH EDITION

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PREFACE TO FIFTH EDITION

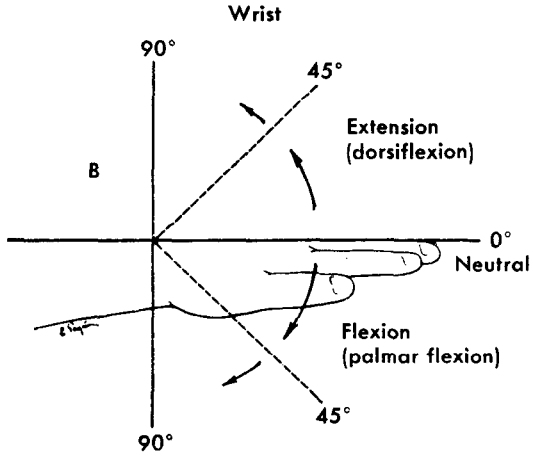
In this edition of *Campbell's Operative Orthopaedics,* which commemorates the golden anniversary of the founding of the Campbell Clinic, the revisions have been much more extensive than were anticipated by the editor and reflect the many advancements in orthopaedic surgery made during the past several years. New operations have been described for some affections, and changes in the role of surgery have been emphasized for others. Of the illustrations in this edition, approximately one fourth are new.

All chapters have been either revised or rewritten. The chapter on hand surgery has been enlarged to include new sections on amputations and other subjects. The chapter on amputations (excluding those of the hand) has been completely rewritten to include the newer techniques, such as immediate postsurgical prosthetic fitting. The section on Vitallium mold arthroplasty of the hip in Chapter 16 has also been rewritten to bring it up to date. To Chapter 22 has been added a section on spina bifida cystica.

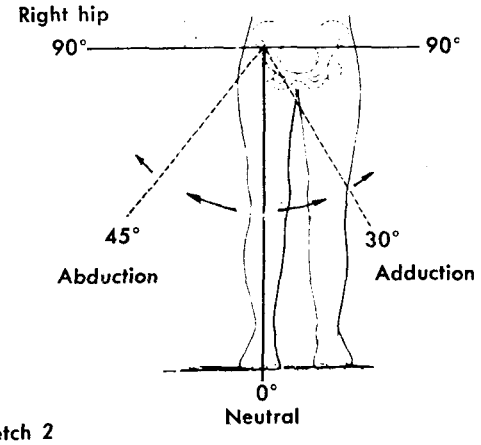
We have continued to use almost entirely the method of measuring joint motion that has been advocated by the American Academy of Orthopaedic Surgeons. The neutral position is 0° instead of 180° as in the first three editions (see accompanying sketches 1 through 4*). For the shoulder, however, the method of the Academy seems too complicated for adoption here. Although the neutral position is 0° 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 Campbell Clinic are especially indebted to those authors who are not members of the staff: Dr. Otto E. Aufranc, Dr. James E. Bateman, Dr. J. A. Pitcock, and Dr. James C. H. Simmons. We extend our thanks to Dr. Lenox

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



Sketch 1

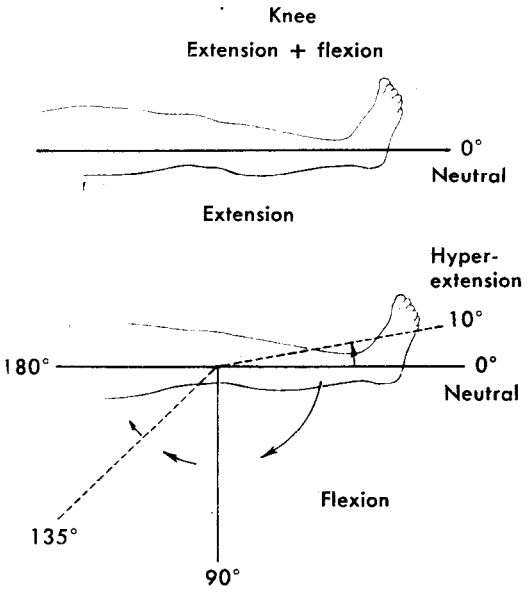


Sketch 2

D. Baker, Dr. Walter P. Blount, Dr. David M. Bosworth, Dr. William F. Enneking, Dr. Herbert Knodt, and Professor A. R. Hodgson, who have offered special suggestions and comments or have proofread material for this edition or the fourth edition. We also extend our thanks to the many surgeons who so kindly permitted us to reproduce their illustrative material.

I wish especially to express my appreciation to Mrs. I. C. Harper for her skillful assistance with the manuscript and references, and to Miss Jan Hawkings, our librarian and medical editor, for her help. I wish also to thank Mr. C. F. Ingram, our medical artist, and Miss M. Irene Jones, the librarian of the University of Tennessee College of Medicine.

A. H. Crenshaw, M.D.



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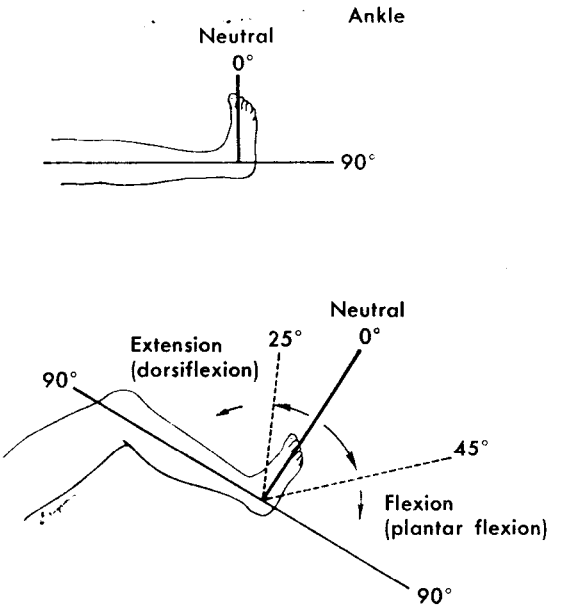

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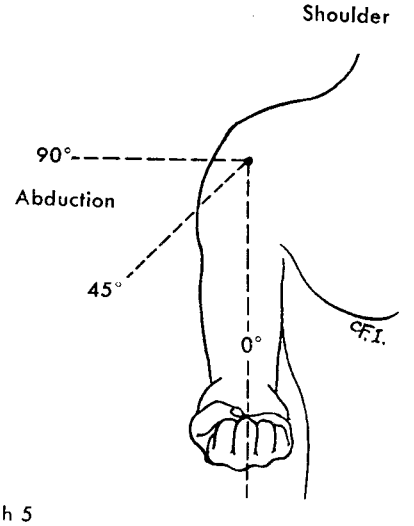

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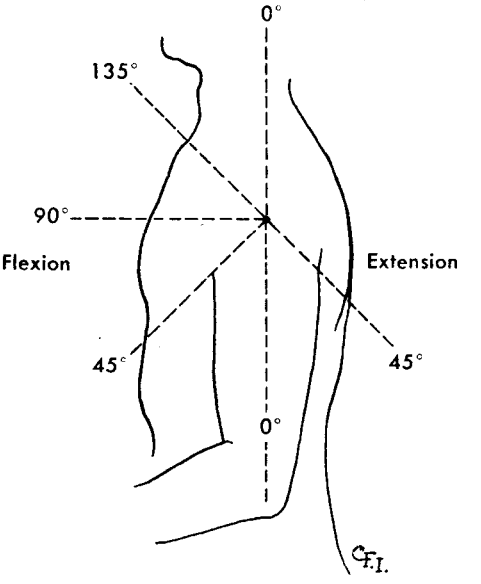

Sketch 6

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 com-

ponent 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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CHAPTER 1

CARE BEFORE AND AFTER SURGERY

P. T. CRAWFORD

The orthopaedist holds no unique position in the field of surgery. He is bound, as all surgeons are, by these fundamental principles: careful evaluation of the whole patient, well-founded indications for the specific surgery contemplated, and deft technique in the operating room. The orthopaedist, however, must also take time to consider the environment and occupation of the patient as part of his indications for surgery, because his operations usually require much longer periods of convalescence and rehabilitation than those of the general surgeon. The combinations of such factors as age, sex, occupation, and financial position vary so much among patients that it is impossible to lay down specific rules; yet these factors are of prime importance in decisions regarding orthopaedic surgery. It is always desirable to consider and discuss these with the patient before surgery is undertaken. There are, of course, emergencies in which the surgeon must make immediate decision. In evaluating patients for surgery it is convenient to divide them into three broad groups: (1) those in an elective status, (2) those in an emergency status, and (3) those who constitute semiemergencies.

In the first category are those patients of all age groups who suffer from chronic conditions that are painful, deforming, or disabling to such an extent that they seek relief. Time is adequate for thorough consideration of available techniques, the selection of the appropriate procedure, and a general medical evaluation to establish the patient's ability to withstand the surgery which is being contemplated.

In the second category are those patients suffering from conditions of immediate importance on whom surgery must be performed within a matter of minutes or hours. Most patients in this group are those with acute trauma. The fact that a patient has had an accident or has suffered severe trauma usually, in itself, means that he is an active person and, consequently, healthy and rarely suffering from chronic illness.

In the third category are those patients with injuries or conditions that do not require immediate attention but should have a definitive operative procedure within a few days. In this group are elderly patients with trochanteric or cervical fracture of the femur and also patients with other fractures requiring open reduction and internal fixation but with no need for haste.

Patients in all these categories demand general medical evaluation, and the only significant difference among them is the element of time. Time must allow for that *sine qua non* of the practice of medicine, the history and physical examination, no matter how esoteric orthopaedic surgery may become or what the demands are of a busy practice. In the *history* the immediate complaint may be determined quickly and easily, but the historian must take time for the usual review of systems in a search for symptoms of specific organic or metabolic disease such as hypertension, cardiac abnormalities, urinary difficulties, diabetes mellitus, or gout. In addition to this search for systemic disease, he should also inquire about allergies (bronchial asthma for its relation to the choice of anesthetic agent, sensitivity to drugs that might be used during the course of the patient's hospitalization, and skin sensitivity to such things as adhesive tape or antiseptic agents), medications that the patient may have been taking (corticosteroids for which adequate coverage must be maintained, antihypertensive drugs that should be omitted before surgery, etc.), previous immunizations such as tetanus toxoid (which may be important in recent or remote injury), and bleeding tendencies (including the current use of anticoagulant drugs). The patient's general habitus, activities, and state of nutrition must be determined not only from the history but also from the physical examination.

General observation of the patient on physical examination may reveal emaciation, dehydration, or suggestions of chronic disease, malnutrition, or vitamin deficiency. The temperature, pulse rate, and respiratory rate not only may disclose simple upper respiratory infection but also may bring suspicion that uncovers more serious infection or other organic disease. The blood pressure must be recorded

more than once. Certainly in severe injury in which shock may occur, the blood pressure must be determined at regular intervals so that rapid changes do not go unobserved. Or blood pressure elevated by severe pain may return to a normal level when suffering is alleviated. If shock has occurred or is impending, then further trauma must be avoided, but hypertension alone is not a contraindication to surgery. If the blood pressure is not dangerously high, as judged by the age and sex of the patient and the duration of the hypertension, and if renal or cardiac complications have not occurred, then hypertension is not a menace.

Examination of the *head and neck* may be brief but of great significance. The conjunctivae and sclerae may show evidence of systemic disease, recent or remote, such as anemia or jaundice. The presence of petechiae may lead the examiner to suspect early fat embolism. Examination of the pupils may suggest old disease of the central nervous system or recent trauma. A smooth tongue may be the warning sign to make the examiner suspect vitamin deficiency or pernicious anemia. The throat must be inspected and the neck must be palpated to exclude pre-existent disease such as thyroid abnormalities or lymphomas and to make sure that the patient's airway will be patent during anesthesia. Motion in the cervical spine may be limited by acute injury or by old arthritis and perhaps forbid endotracheal anesthesia.

On examination of the *heart,* displacement of the apex beat, abnormalities in the rhythm, and the presence of murmurs should be specifically noted. Any deviation from normal may demand full cardiac evaluation, and since this probably will require the attention of an internist or a cardiologist, it will not be discussed here.

Injury to the myocardium must be suspected with any severe trauma to the anterior chest wall. Contusion of the heart is becoming increasingly important in victims of automobile accidents and is seen especially when the driver of the vehicle is thrown against the steering wheel. Shortly after the injury there may be little evidence of cardiac abnormality other than tachycardia, but cardiac contusion must be suspected in all injuries to the anterior chest wall, and an electrocardiogram should be made. If cardiac contusion has occurred, arrhythmia may follow on about the third day, and this increase in irritability of the myocardium may persist for 2 weeks or longer. For this reason, necessary surgery should either be carried out within the first 24 hours, if this is at all reasonable, or be delayed until all signs of increase in myocardial irritability have subsided. Here again consultation with a cardiologist may be necessary.

Adequate *pulmonary ventilation* must be evaluated by observing the excursions of the chest wall, finding a resonant percussion note over the lung fields, and hearing good breath sounds. Whenever pulmonary disease is suspected, especially after accidents in which chest injury may have occurred, roentgenograms of the chest should be made. One point for particular attention in instances of acute trauma must be brought out here. If the chest injury was of such nature that the sternal plate may have become detached by multiple rib fractures or costochondral separations, this may be masked by splinting of the chest by voluntary muscles. It must be suspected from the type of injury (usually the driver of an automobile has struck the steering wheel in a collision) and by slight retraction of the sternum on inspiration. Roentgenograms may be helpful by disclosing multiple anterior rib fractures bilaterally, but may be misleading by not showing costochondral separations. The danger of this injury may not become apparent until the patient is subjected to anesthesia: the voluntary muscles then relax, the sternum retracts, and a flail chest and poor respiratory exchange result. Whenever this condition is suspected, the anesthetist should be alerted so that he may be prepared to carry out tracheal intubation if necessary.

Pulmonary conditions that produce excessive bronchial secretions or diseases that have destroyed lung tissue may obviate elective surgery but may demand an orthopaedic operation to allow the patient to be turned or placed in a wheelchair. When surgery is carried out on patients with pulmonary disease, adequate facilities and highly trained anesthesiologists are required. However, when these are available, necessary surgery may be performed even on patients with zero vital capacity from poliomyelitis.

Examination of the *abdomen* must include inspection for gross abnormalities that might indicate masses or collections of fluid and palpation for evidence of muscle spasm that might indicate an acute surgical abdomen following injury. It is extremely difficult if not impossible to differentiate the muscle spasm and paralytic ileus due to retroperitoneal or spinal injury from that due to direct intra-abdominal injury such as a ruptured viscus. Frequent observation of the patient's general condition as well as the local condition of the abdomen must be corre-

lated with available aids from the laboratory and with roentgenograms. Unless the demands of the orthopaedic procedure are imperative, it may be wiser to delay surgery until the status of the viscera is determined.

Neurologic examination is closely allied, of course, with orthopaedic studies, since many stabilizing operations or tendon transfers are carried out because of neurologic disorders. Evidence of acute injury to peripheral nerves may determine the type of procedure indicated in acute trauma. Evidence of old lesions of the central nervous system or of the peripheral nerves may strongly influence the indication for surgery, particularly in regard to trophic changes that may interfere with healing.

For the same reason the *peripheral circulation* must be evaluated. When surgery is contemplated on the lower extremities, good pulsation in the posterior tibial and dorsalis pedis arteries and the absence of ischemia when the feet are elevated are indications that circulation is adequate in the feet and that good wound healing should be anticipated, whereas the presence of edema, varicose veins, or trophic changes in the skin is warning that healing may not be prompt or that an old condition such as thrombophlebitis may be relighted by the surgical procedure.

When the history and physical examination have been completed, *laboratory procedures* are then requested, including at least a complete blood count and a routine urinalysis. Anemia, infection, blood dyscrasia, diabetes mellitus, or renal insufficiency may be suspected from these simple examinations. In adults it is wise to make determinations of the blood sugar, blood urea nitrogen, and serum electrolytes, and, in those over 40 or 45 years of age, an electrocardiogram and a roentgenogram of the chest are indicated.

A tendency to bleeding is best discovered by a careful personal and family history but occasionally may be detected in the laboratory by a determination of coagulation time. If a history of bleeding is obtained, complete studies of the coagulation mechanism are necessary. It is not practical here to enter into a detailed discussion of the treatment of abnormal coagulation mechanisms. However, consultation with a hematologist and the availability of the appropriate plasma fraction may allow necessary surgery even on patients with hemophilia. The reader is referred to a special section of the references at the end of this chapter concerning hemophilia.

Whenever any major surgical procedure is to be undertaken, plenty of whole blood should be available before the operation is started. Because it is almost impossible to detect reactions to transfused blood while the patient is under anesthesia, blood should not be given during surgery unless it is specifically indicated. Acute blood loss or chronic anemia should be corrected before surgery. If the blood loss during surgery is more than 500 ml. or if signs of shock occur, then blood should be administered immediately. Otherwise, blood should be withheld until recovery from the anesthetic has progressed to a point at which any transfusion reaction can be detected.

When all this evaluation and preparation has been completed and the decision has been made to proceed with surgery, it might be wise for the surgeon to consider whether he has fulfilled all his duties. Do the patient and his family fully understand the seriousness of the surgery? Do they understand what can be expected from the surgery? Do they understand that poor results do occur? (About 30% of fractures of the femoral neck cause avascular necrosis of the femoral head regardless of the type of treatment.) Does the patient understand that he may be trading one abnormal extremity for an extremity that is still abnormal, but that he and the surgeon both hope will be better? Does the patient need instruction in physical therapeutic measures before the operation so that he may be better able to carry them out after the operation? And finally, has the patient been under some personal or emotional stress that is not necessarily evident from his physical examination or laboratory studies, but that may make it more wise to delay surgery for at least a few days, if not a few weeks?

EMERGENCIES

This evaluation has been outlined as for elective cases. It is no less important in emergencies, but it must then be carried out quickly, with inevitable limitations. The best available history and physical examination cannot always be the most thorough. Many times the patient himself is unable to give a satisfactory history; perhaps his family can confirm or expand the available facts. When a history is not available, it is wise to remember that the lady's purse or the gentleman's billfold may well reveal not only their indentification but also important medical clues. Patients with diabetes mellitus usually carry cards that indicate that they have the disease and state their dietary or insulin requirements. Cardiac patients may sometimes be so identified, particularly those who are taking some anticoagulant drug on a long-term basis. It would be desirable for all persons who

are taking corticosteroids or who have taken them recently to carry a card to this effect.

Under emergency conditions, it is always necessary to carry out the fundamentals of first aid. We do not review these here in detail, but summarize. Supply an adequate airway and respiratory exchange! Control hemorrhage by the best readily available means! Splint fractures! Prevent aggravation of injuries from unnecessary movement or rough handling! Careful attention to these measures and prompt replacement of blood loss may well prevent the occurrence of shock.

Shock

Shock is a clinical state characterized by a fall in systolic blood pressure, a rapid thready pulse, and pale, cool, moist skin. Unless corrective measures are prompt, the blood pressure continues to fall, the pulse rate becomes more rapid, and the respiratory rate begins to rise. The patient himself becomes apprehensive, then agitated, and later comatose; without help he eventually expires.

The causes and mechanisms of shock may be varied, but the most important and most consistent abnormality is a decrease in the volume of circulating blood. This may be due to actual exterior loss of blood, hemorrhage into body cavities, or extravasation of blood or plasma into large areas of damaged tissue. Thus, reestablishment of the circulating blood volume is the primary consideration in the treatment of shock, and whole blood is the obvious, most desirable replacement.

Prompt and accurate typing and cross matching of the patient's blood should be carried out, and every effort should be made to administer a volume equal to or greater than the known blood loss. If the state of shock is progressing or reaches serious proportions before properly selected blood is available, then blood from the "universal donor" (type O, Rh negative) should be administered until proper laboratory procedures can be carried out.

In the absence of whole blood, plasma may be administered, preferably from one donor and, if possible, free of hepatitis virus. A useful expander of plasma is dextran, a large molecule polysaccharide that tends to remain in the circulating blood. (Other plasma expanders have been used, but at present dextran is the most useful from the standpoints of availability and storage.) These two agents should not be considered substitutes for whole blood but rather emergency substances to be used until whole blood is available. Either fluid dilutes red blood cells, and dextran also dilutes the plasma proteins. Solutions of glucose or saline may be used intravenously when blood or plasma expanders are not available but usually are of little sustained value and may introduce dilution factors or electrolyte imbalances to complicate the picture further.

The measurement of the central venous pressure is of great help in determining the correct volume and rate of flow of parenteral fluids. A low central venous pressure and low blood pressure would indicate a low blood volume. A central venous pressure of 8 to 12 cm. of water would suggest caution in the further administration of intravenous fluids, and a pressure of above 15 cm. would suggest encroachment on the cardiac reserve.

As already stated, the replacement of circulating blood volume is the most important factor in the treatment of shock, and the purpose of this is to restore the blood pressure to levels that will furnish adequate oxygen and nourishment to the most vital structures—brain, heart, and kidney. Pulmonary ventilation is therefore the second most important part of the treatment of shock.

It is imperative that while intravenous therapy is being administered the patient be examined for injuries or obstructions about the air passages or the thorax that might impair respiratory exchange. Additional oxygen should be supplied, and this can be done best by the use of a nasopharyngeal catheter with an oxygen flow of 8 to 10 L./min. It may be necessary to place an airway in the patient's mouth to hold the tongue forward, particularly if he is stuporous or unconscious. If severe injury has occurred about the face or neck, an endotracheal tube or tracheostomy may be needed. Suction for the removal of secretions should be available. Elevation of the lower extremities and lowering of the head (Trendelenburg position) may aid removal of secretions from the upper air passages or the lungs and may also improve the circulation to the brain.

Pain is another factor that may play a prominent etiologic role in shock, and the relief of pain should be the next consideration. Opiates should be administered in the dose appropriate to the patient's age and weight and to the severity of his injuries. If the amount required is uncertain, the opiate may be administered slowly, intravenously, until the desired effect is achieved. If this administration is carried out calmly and slowly, with strict attention to the patient's response to pain, then there is little danger of too large a dose. If depression of the respiratory rate occurs or if large doses of opiates are necessary in children or elderly pa-

tients, nalorphine (Nalline) or levallorphan tartrate (Lorfan) may be administered at the same time, and these drugs will usually offset any respiratory depressant action of the opiate.

Additional relief of pain is achieved by the application of splints or traction; therefore, prompt decision should be made and appropriate fixation should be applied. It is important to remember here that dislocation of a large joint may be the major factor in prolonging shock or in its resistance to therapy. It may be necessary to administer mild anesthesia to reduce such a joint so that response to the antishock measures may be obtained.

The use of the vasoconstrictor drugs in the treatment of shock should at least await the replacement of most of the blood lost if not the completion of all the measures already mentioned. It seems illogical to attempt to stimulate receptors which are already responding to the best of their ability. When the physician feels that the response to blood volume replacement is inadequate, ephedrine, phenylephrine (Neo-Synephrine), mephentermine (Wyamine), methoxamine hydrochloride (Vasoxyl), isoproterenol (Isuprel), or norepinephrine may be administered intravenously. Ephedrine and phenylephrine have the disadvantage of cardiac stimulation and the production or aggravation of tachycardia. Isoproterenol is probably the drug of choice. Norepinephrine is apparently the most potent of these agents, but its administration must be constantly supervised and frequently adjusted according to the blood pressure readings. It is unfortunate that such a useful drug may sometimes exert destructive degrees of vasoconstriction either at the site of the injection or at distant points such as the tips of the extremities.

Arteriolar vasoconstriction seems to be a part of the pathologic physiology of shock. It places a dam across the blood flow and blocks venous return. Chlorpromazine may be used to antagonize this effect, but the administration of phenoxybenzamine (Dibenzyline) is still to be considered experimental.

The adrenocorticosteroids have two places in the treatment of shock: first, when the patient does not respond to what was thought adequate therapy and, second, when there is a definite history of previous administration of corticosteroids. Whenever replacement of blood has been accomplished, along with appropriate supportive measures, but the patient's blood pressure or pulse rate is still not improving, then corticosteroids are indicated. After severe trauma the adrenal cortices may not be able to produce an adequate amount of hormone, or when shock has been prolonged unduly before definitive therapy is begun, these glands may be exhausted, or they may have been atrophied by previous disease or prior administration of corticosteroids. Under any of these conditions supportive therapy with corticosteroids is mandatory and may be lifesaving.

Hydrocortisone is probably the most useful of the steroids under these circumstances, and 100 mg. may be administered rather rapidly, intravenously, in a volume of only 2 ml. If the response of the patient is inadequate, or if the previous therapy has been so prolonged that the surgeon suspects rather severe adrenocortical atrophy, additional hydrocortisone may be administered by the slow infusion of several hundred milligrams. Or prednisone, prednisolone, or methylprednisolone can be used and may have some advantage because of the fact that they have less effect on electrolytes. The administration of these corticosteroids must be continued in comparatively large amounts during the period of severe stress; the dose should then be slowly reduced until it is discontinued or the patient has resumed his previous schedule.

Antibiotic therapy is frequently indicated at this point in emergency treatment. The state of shock may be caused, aggravated, or prolonged by infection. Wounds, particularly compound fractures, require early administration of large doses of antibiotics.

The possibility of infection with tetanus spores must be considered, and immunization should be started or previous immunization should be bolstered. If the patient has received adequate tetanus toxoid immunization in the past, then an additional dose of 0.5 ml. should be given intramuscularly. If no previous immunization has taken place, then active immunization should be instituted by the administration of 0.5 ml. of the toxoid, and passive immunization should be attempted by giving 250 to 500 units of human immune globulin. The toxoid injection should be repeated in 2 weeks.

When the patient has responded well to antishock therapy and his blood pressure and pulse rate have stabilized, necessary definitive surgery should be carried out. By this we mean that compound fractures should be fixed by whatever method is indicated. If shock has been severe or prolonged, surgical procedures not immediately demanded should be delayed several hours if not days. The patient should be allowed time to recover from the effects of shock and to demonstrate good function of the brain, heart, and kidney.

In the period following the emergency, particularly in the presence of multiple injuries, the most serious complications that may occur are fat embolism and renal shutdown.

Fat embolism

Fat embolism, a clinical state occurring usually after multiple severe injuries, is characterized by signs and symptoms of involvement of several systems and is seemingly due to the appearance in the bloodstream of innumerable fat droplets which act as emboli. Because of these widespread emboli, abnormalities may develop in almost any part of the body, but the most serious and sometimes lethal dysfunctions occur in the brain, heart, or lungs. The diagnosis of fat embolism may be obscured by injury to these viscera, but involvement of any or all of these systems must at least suggest the presence of fat embolism.

The diagnosis must be suspected in patients who have multiple fractures, particularly of the long bones, but in general is less common in children and in people past the age of 60 or 65 years. As already stated, the most prominent and most serious symptoms are derived from involvement of the lungs, heart, and brain. A rising respiratory rate or pulse rate without apparent cause, occurring within the first few days after injury, may be the clue to this diagnosis. When the chest or the heart has been injured, the abnormalities may be attributed to the injuries unless careful attention is given to the vital signs and a careful search is made for petechiae. Brain involvement may be evident within the first 24 hours after injury, and the differentiation between fat embolism and head injury may be extremely difficult. The patient with fat embolism has diffuse brain damage and consequently will not show local or unilateral signs. There may be mild agitation at first, with a wild-eyed stare and slight mental confusion. A neurologic examination at this point is usually entirely negative but may show signs of mild increase in intracranial pressure and sometimes positive Babinski responses bilaterally. As the condition progresses, agitation and confusion become more pronounced, and it may be necessary to restrain the patient. With the passage of time, agitation subsides and stupor supervenes. The pulse rate and respiratory rate continue to climb, and the patient may expire. The course from injury to death may cover only a few days or may require 2 or 3 weeks.

The suspicion of a diagnosis of fat embolism is probably the most important factor in its detection. When abnormal signs and symptoms are produced in one or all of the three systems just discussed, the diagnosis of fat embolism is most likely to be established or discarded by the presence or absence of petechiae. The classic petechiae of fat embolism which appear over the anterior chest and particularly along the anterior axillary fold may not become grossly apparent until the third day following injury or even later. If the diagnosis is suspected during the first 24 or 48 hours, the surgeon must search carefully the conjunctival sacs, the buccal membranes, and the hard palate, as well as the anterior chest. Two or three petechiae in these areas strongly support the suspected diagnosis; increasing numbers of petechiae added to the signs and symptoms already discussed virtually establish the diagnosis. Treatment should be instituted at the point of strong suspicion, if not before.

The search for fat droplets in the sputum or urine is a time-honored procedure when the diagnosis of fat embolism is suspected. However, it is our opinion that even if such fat droplets are demonstrated, this information may be misleading or unimportant. Fat embolism, like shock, is a clinical state, and the diagnosis is established by the recognition of the signs and symptoms with little or no help from the laboratory. However, the demonstration of low oxygen tension in the arterial blood in the absence of obstructed airway or pulmonary injury prompts a strong suspicion of fat embolism.

The treatment of fat embolism has been improved in recent years by the use of heparin. The mode of action of this substance is not clear. However, heparin has shown sufficient beneficial effect that we now use it prophylactically as well as therapeutically. It has been our practice to administer 2500 units of aqueous heparin intravenously every 12 hours to most patients in whom fat embolism might be a likely complication. Certainly it is administered as soon as the diagnosis is suspected. This dosage apparently has no significant effect on the clotting mechanism, but seems beneficial in the treatment of fat embolism.

The second most important factor in the treatment of this condition is adequate oxygenation at the tissue level, specifically the brain and heart, as they seem to suffer most from hypoxia. The determination of arterial blood gases is necessary to evaluate the results of treatment. Adequate respiratory exchange must occur even if tracheostomy is necessary to relieve obstruction to the major air passages or to remove excessive secretions from the lower respiratory tract. Injuries to the lungs or chest