The Washington
Manual of Surgery

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- Greetings -

Respect goes to MedScut (the iSilo king), the PDA
People, xylarr, taihenchen, ZD, the "group" moderators and those that have
made and still make the Skyscape stuff possible.

p.s. thanks to **How**, **Guiga**, **Super Falcão**, the "Brazilian PalmBoys"

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Dedication

To the patients who have taught us how to best care for them, with the hope that we will remember the lessons of the past and recognize the lessons of the future

Foreword

This is the third edition of *The Washington Manual of Surgery*. This effort reflects the ongoing commitment of the Department of Surgery at Washington University to medical education both within and outside the institution. This commitment to resident and medical student education began with our first full-time Chairman of Surgery, Evarts A. Graham (1919–1951). Not only did Dr. Graham help to found the American Board of Surgery, but he was also instrumental in several other areas. He developed new surgical techniques (including the one-stage pneumonectomy), collaborated to develop oral cholecystography with Mallinckrodt Institute of Radiology investigators, and utilized an epidemiologic approach to make the first link of cigarette smoking to lung cancer development.

Dr. Carl Moyer (1951–1965), who was regarded as a superb educator, continued Dr. Graham's legacy. Dr. Walter Ballinger (1967–1978) brought with him the Hopkins tradition of resident education and a focus on the importance of the surgeon/scientist. Dr. Samuel A. Wells, Jr. (1978–1997) was responsible for assembling a world-class faculty and significantly increasing the number of surgeon/scientists within the department. Dr. Wells emphasized basic and translational research and placed a great emphasis on educating academic leaders of surgery. Dr. Wells is currently the Group Chair and Principal Investigator of the American College of Surgeons Oncology Group (ACOSOG).

In keeping with this rich tradition, residents of the Department of Surgery authored this third edition of *The Washington Manual of Surgery*, with each resident assisted by a senior faculty co-author. This edition of the manual provides a complete reference that can be utilized by medical students, house officers, and practicing surgeons, presenting brief and logical approaches to the management of patients with various surgical problems. The manual does not attempt to extensively cover pathophysiology or history, but does provide the most up-to-date and important diagnostic and management information for a given topic. There are selected references included in each chapter that the reader may use to further their education about the topic. The manual is also standardized with respect to structure so that the reader will be able to most easily obtain information.

Dr. Gerard M. Doherty continues to serve as the principal editor of the manual. Four associate editors, each of whom is currently a chief resident in the Department of Surgery, assist Dr. Doherty. The manual begins with general care of the surgical patient that includes areas of general knowledge such as nutrition, life support, perioperative medical care, and critical care management. The second section is devoted to the evaluation of abdominal diseases as well as gastrointestinal surgical disease. The third section includes discussions on vascular disease, endocrine surgery, trauma, and transplantation surgery. The final section of the manual is devoted to the surgical subpecialties and unique problems associated with them as well as common surgical procedures. This edition also has an appendix of commonly used laboratory values and formulas.

I am extremely proud of the residents and faculty who have done such an outstanding job in this third edition. They have made this edition easier to read, which I hope will result in it becoming a more convenient reference for the management of surgical diseases. It is a fine example of the unique collegiality that exists in our department between faculty and residents and of our commitment to surgical education. I hope that you will find this edition an often-used reference.

Timothy J. Eberlein, M.D.

Preface

This third edition of *The Washington Manual of Surgery* has been designed to complement *The Washington Manual of Medical Therapeutics*. This book was written by members of the Department of Surgery and presents a brief, rational approach to the management of patients with surgical problems. The text was directed to the reader at the level of the second- or third-year surgical house officer, although surgical and nonsurgical attendings, medical students, physician assistants, and others who provide care for patients with surgical problems will find it of interest and assistance. The book provides a succinct discussion of surgical diseases, with algorithms for addressing problems based on the opinions of the physician authors. Although multiple approaches may be reasonable for some clinical situations, this manual attempts to present a single, effective approach for each. We have limited coverage to diagnosis and therapy; this is not an exhaustive surgical reference. Coverage of pathophysiology, the history of surgery, and extensive reference lists have been specifically excluded from most areas. This third edition of the manual, which was published initially in 1997, followed by a second edition in 1999, includes updated coverage of each topic, as well as substantial new material.

This is a resident-prepared manual. Each chapter was revised by a resident with assistance from a faculty co-author. The project was separated into four subsections; editorial oversight was performed for each section by one of the four chief resident co-editors (John E. Mason, M.D., Chapters 1–10; Jennifer K. Lowney, M.D., Chapters 11–21; Michael A. Smith, M.D., Chapters 22–32; and Scott I. Reznik, M.D., Chapters 33–43 and the Appendixes). The tremendous effort of all involved residents and faculty members, and particularly the chief resident co-editors, is reflected in the quality and consistency of the chapters.

I am grateful for the invaluable assistance of Lisa Williams, who has served unfailingly as the editorial coordinator; she has kept each of us in line. Lisa McAllister and Lisa Consoli from Lippincott Williams & Wilkins have been understanding and encouraging as they carried the project through to production. We are very fortunate to have such outstanding support from the publisher, which allows the attention to detail necessary for such a project.

Finally, we have all benefited from the guidance of an outstanding department chair during the production of this book. Timothy J. Eberlein, M.D., has actively participated in the book by serving as senior author for two chapters and has served as an inspiration for each of us by his leadership and example of hard work and honesty.

G.M.D

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1 General Care of the Patient

Nahush A. Mokadam and Jeffrey F. Moley

Introduction

Patient care is not only dependent on a fund of medical knowledge but also on appropriate and accurate documentation of that care. Proper documentation ensures communication with other physicians as well as administrators and provides the basis for all reimbursement. It is imperative for all documentation to include a date, time, and signature.

Patient Care

I. Hospital orders

A. **Admission orders** detail every aspect of a patient's care for the administration, nursing staff, pharmacy, and ancillary care services. The mnemonic **ABC DAAVVIDD** is a simple device to signify routine admission, postoperative, and transfer orders.
   1. **Admit.** Include nursing division, surgical service, attending physician, and admission status (in-patient vs. 23-hour observation).
   2. **Because (diagnosis).** The principal diagnosis and, if relevant, care path. Any operations performed should also be included.
   3. **Condition.** Distinguish between good, satisfactory, serious, and critical.
   4. **Diet.** Include diet type (regular, American Diabetes Association, renal, etc.) and consistency (clear liquids, full liquids, pureed, etc.) as well as supervision instructions, if applicable. Also include “ins and outs.”
   5. **Allergies.** Include specific reactions if known.
   6. **Activity.** Include necessary supervision and weightbearing status, if applicable.
   7. **Vitals and other nursing orders.** Include frequency and special instructions, such as pulse oximetry, neurologic checks, and vascular checks. Also include dressing care, drain care, urine output monitoring, and antiembolic stockings. Include specific parameters for physician notification for abnormal results (such as low urine output or low blood pressure).
   8. **Ventilator settings** (if applicable). Include mode, tidal volume, rate, pressure support, positive end-expiratory pressure, and oxygen percent.
   9. **Intravenous fluids.** Include fluid type, rate, and time interval.
   10. **Drugs (medicines).** Include home medicines if appropriate. Reference to patient-controlled anesthesia forms should be made here.
   11. **Diagnostics.** All necessary laboratory and radiographic investigations should be listed here, as well as electrocardiograms, cardiac diagnostic laboratory testing, pulmonary function tests, and other special procedures.

B. **Review orders with nursing staff.** All orders should be reviewed with the nursing staff, particularly any unusual orders or orders that must be expedited.

C. **STAT orders** should be designated as such on the order form and brought to the attention of the nursing staff. This is especially true for orders for new medicines because the pharmacy must be notified and the medicine brought to the floor.

D. **Discharge orders**
   1. **Discharge** should include location and condition. If a transfer to another institution is planned, copies of all medical records and a copy of current orders should be included.
   2. **Activity limitations**, if applicable, should be included. Workplace or school documentation may also be necessary.
   3. **Medicines.** Prescriptions for new medicines as well as detailed instructions are required.
   4. **Follow-up.** Follow-up plans with the appropriate physicians should be clearly indicated. Contact information for their offices should also be included.
   5. **Special.** Wound care, catheter care, physical therapy, or special studies should be described before discharge.

II. Hospital notes

A. **History and physical examination.** The admission history and physical examination should be a complete record of the patient's history. Include past medical and surgical history, social history and family history, allergies, and home medicines with dosage and schedule. Outpatient records are often helpful and should be obtained if possible.

B. **Preoperative notes** summarize the pertinent laboratory and other investigations before one proceeds to the operating room (Table 1-1).

Table 1-1. Preoperative note

C. **Operative notes.** A brief operative note should be placed in the written medical record immediately following the operation, including the operative findings. The surgeon should also complete a dictated operative note immediately after the operation (Table 1-2). In addition, a dictated note should include specific operative indications, preparation and drape position, sponge and instrument count, and copy distribution.

Table 1-2. Brief operative note

D. **Postoperative check.** Several hours after an operation, a patient should be examined and vital signs and urine output reviewed. Documentation in the medical record in the form of a SOA/P (subjective-objective-assessment/plan) note should be included. **Discharge summary.** A detailed account of a patient's hospitalization should be dictated at the time of discharge (Table 1-3). If a dictation confirmation number is provided, it should be recorded in the written medical record as the final note of the hospitalization. A dictated discharge summary must accompany any patients who are being transferred to other institutions.

Table 1-3. Discharge summary (dictated)

III. Informed consent

A. **Obtaining informed consent.** The patient must choose whether or not to undergo a medical procedure or operation. The physician provides information to the patient so that an informed decision can be made. To be informed, the patient must understand the disease process, the natural course of the disease, the risks and benefits of the procedure under consideration, and potential alternative therapies. The most common and serious risks of the procedure and the patient's condition that might affect the outcome of a planned procedure or might place the patient at increased risk should be discussed. Recovery time, including amount and expected duration of postoperative pain, should also be reviewed. The use of invasive monitoring devices, including arterial and pulmonary artery catheters, should be explained. These discussions should use terms that are readily understood by the patient.
B. **Documentation of informed consent.** An informed consent form is completed and signed by the patient before any elective operative procedure. In addition to the generic consent form, informed consent discussions should be documented in the progress notes section of the medical record. These notes should document the salient features of the informed consent discussion and specifically document that the potential complications and outcomes were explained to the patient. The patient's refusal to undergo a procedure that has been advised by the physician should be documented clearly in the chart. In certain situations, such as a medical emergency, it is impossible to obtain informed consent. Inability to obtain consent should be documented carefully in the medical record. Local medical bylaws generally have provisions for these types of situations and should be consulted on a case-by-case basis.

IV. Advanced directives. These are legal documents that allow patients to provide specific instructions for health care treatment in the event that the patient is unable to make or communicate these decisions personally. Advanced directives commonly include standard living wills and durable powers of attorney for health care. With the growing realization that medical technology can prolong life considerably and sometimes even indefinitely beyond the point of significant or meaningful recovery, the importance of these issues is clear. Patients should be offered the opportunity to execute an advanced directive on admission to the hospital.

A. **Living wills** provide specific instructions for the withdrawal of medical treatment in the event that a patient is unable to make treatment decisions and is terminally ill. Living wills do not include withdrawal or withholding of any procedure to provide nutrition or hydration.
B. **Durable powers of attorney for health care.** These directives allow a patient to legally designate a surrogate or proxy to make health care decisions if the patient is unable to do so.
C. **Implementation.** Advanced directives are personal documents and therefore differ from patient to patient. These documents should be reviewed carefully before implementation. Advanced directives are legal documents, and they should be displayed prominently in the medical record. To be legally binding, the documents must be executed properly. If there is any question of validity, the risk management or legal staff of the hospital should be consulted. The most effective advance directives include specific instructions for health care decisions. Important issues to be addressed include the following:
    1. **Intravenous fluids**
    2. **Enteral and parenteral nutrition**
    3. **Medicines**
    4. **Inotropic support**
    5. **Renal dialysis**
    6. **Mechanical ventilation**
    7. **Cardiopulmonary resuscitation**
D. **Conflicts.** Although advance directives can be helpful in the management of critically ill patients, their implementation often is difficult. Advance directives, by their nature, cannot provide for every medical situation. For this reason, it is important to communicate with the patient and family before the execution of an advance directive and with the family in the event that a patient becomes incapacitated. If no advance directive is available, the physician and family must consider carefully when life-prolonging medical treatments are no longer beneficial to the patient. In such a case, the state's interest in preserving life might conflict with the desires of the family and physician. Advance directives avoid these legal ambiguities and protect the desires of a patient once he or she is incapacitated. If the family and physician do not agree, the hospital ethics committee or risk management staff should be consulted.

V. Occupational transmission of disease. As a rule, all occupational exposures should be reported to appropriate staff (student health, employee health), and a frank discussion regarding chemoprophylaxis should ensue.

A. **Bloodborne pathogens.** Health care workers are at risk of becoming infected with bloodborne pathogens, such as hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV), through occupational exposure. Surgeons are at increased risk because of the frequency of percutaneous injuries during operative procedures. Although occupational exposure to HIV is a frightening aspect of the surgical profession, a surgeon is, in fact, much more likely to become infected with HIV through other means.
    1. **Risk of disease transmission.** The risk of disease transmission depends on several factors, including the prevalence of disease in the patient population, frequency of exposure, and efficiency of disease transmission after exposure. Recognizing the risk of occupational exposure to bloodborne pathogens, the Centers for Disease Control and Prevention have issued guidelines for universal infection control practices (*MMWR Morb Mortal Wkly Rep* 37:377, 1988). Adherence to these guidelines now is mandated and regulated federally by the U.S. Occupational Safety and Health Administration.
    2. **Universal precautions.** Occupational Safety and Health Administration regulations emphasize the concept of universal precautions, stressing that every patient should be treated as if infected with bloodborne pathogens. Barrier protection should be used at all times to prevent skin and mucous membrane contact with blood or bloody body fluids. Other body fluids that might be infectious for HIV include amniotic, pericardial, peritoneal, pleural, synovial, and cerebrospinal fluids as well as semen and vaginal secretions. Fluids that are not considered infectious for HIV include saliva, sputum, tears, urine, sweat, vomitus, and stool. Specific recommendations include the following:
        a. **Wear two pairs of gloves** when direct contact with blood or bloody body fluids is expected, when touching mucous membranes or nonintact skin, or when performing venipuncture or other invasive procedures.
        b. **Wear a mask or protective eyewear**, or both, when there is a risk of splashes of blood or body fluids.
        c. **Wear a gown** when clothing is likely to become soiled.
    3. **Behavior modification.** Although universal precautions are an important element of risk prevention, they do not prevent exposure that is associated with sharp objects, such as needles. Sharps injuries are a well-documented route of transmission of HBV, and sharps injury with hollow-bore needles is the most common event leading to HIV transmission in health care workers. To avoid sharps injuries, the following behavior modifications are recommended:
        a. **Needles should not be bent or recapped.**
        b. **Routine double gloving in the operating room.** Double gloving decreases the risk of perforation and, in the event of perforation, is associated with a decreased inoculum size.
        c. **Palpation of sharps.** One's hand should not be used to palpate sharps during suturing in the operating room.
        d. **Suture needles.** Instruments should be used to hold suture needles at all times.
        e. **Wound retraction.** Wound retraction should be performed with instruments only. Gloved hands should not be used for wound retraction.
        f. **Instrument tray.** An instrument tray should be positioned between the scrub nurse and surgeon, so that sharps can be placed on a tray instead of passed directly.
    4. **HIV**
        a. **Risk.** The risk of occupational exposure to HIV has been evaluated prospectively in multicenter trials (*Curr Probl Surg* 29:197, 1992). These trials reveal that blood or bloody body fluids were the source of infection in all well-documented cases. Needle-stick injury (hollow-bore needle) is the primary cause of occupational HIV infection. The risk of HIV infection after percutaneous exposure is estimated at 0.3%. The risk of HIV infection after mucocutaneous exposure is too low to quantify, although transmission by this route has been documented. In needle-stick injuries, the risk of transmission depends on the volume of the inoculum, the quantity of virus in the source, the depth of penetration, and the type of needle (hollow-bore needle injury is associated with a higher risk than that of suture needle). No transmission by aerosols, casual contact, or suture needles in the operating room has been documented.
        b. **Response to occupational exposure**
            1. **Cleanse wound immediately** with soap and water or with an effective antiviral agent.
            2. **Report exposure** to the employee health clinic.
            3. **Evaluate the patient for HIV, HBV, and HCV** after informed consent.
            4. **Baseline serology.** Evaluate the affected health care worker for evidence of HIV, HBV, and HCV immunity.
            5. **Counseling**
            6. **Chemoprophylaxis**
        c. **Chemoprophylaxis**
            1. **Decision to institute chemoprophylaxis.** Risk factors for infection should be balanced against the toxicities of the antiretroviral regimen. Chemoprophylaxis is recommended after high-risk percutaneous exposures to patients with known HIV infection. Chemoprophylaxis should be offered after lower-risk exposures to patients with known HIV infection. After exposures to patients with unknown HIV status, the decision to institute

chemoprophylaxis should be made on a case-by-case basis.

2. **Prophylaxis regimen.** The latest recommendations of the Public Health Service (*MMWR Morb Mortal Wkly Rep* 45:468, 1996) are for a combination of zidovudine with lamivudine, with the addition of the protease inhibitor indinavir for highest-risk exposures. These medications should be initiated as soon as possible after exposure and continued for 4 weeks. The recommended doses are as follows:
   a. **Zidovudine**, 200 mg p.o. t.i.d.
   b. **Lamivudine**, 150 mg p.o. b.i.d.
   c. **Indinavir**, 800 mg p.o. t.i.d.

d. **Follow-up care.** Periodic testing for HIV should be performed for 6 months after exposure, after which time seroconversion is extremely rare.

e. **Risk of transmission to patient.** Only one documented cluster of HIV infections has been associated with an infected health care worker, but this case has been highly publicized. Based on statistical factors, the estimated rate of transmission of HIV to patients from an HIV-positive surgeon would be extremely low, at 1 per 83,000 hours of surgery (*J Am Coll Surg* 184:403, 1997).

5. **HBV**

a. **Risk of transmission to health care worker.** Although HIV and HBV are transmitted in the same manner, the efficiency of HBV transmission is much greater. Transmission after needle-stick exposure from a source who is hepatitis B early antigen positive is estimated to be 30%. Unlike HIV, HBV is a preventable disease, and the following prophylactic measures are strongly recommended:

b. **Prophylaxis**

   1. **Hepatitis B vaccine.** All surgeons should receive the hepatitis B vaccine unless antibody status documents active immunity. The vaccine is an inactivated or recombinant subunit vaccine and is administered intramuscularly at 0, 1, and 6 months.
   2. **Antibody titers.** Although routine monitoring of HBV antibody titers is not recommended, antibody titers should be checked after a known exposure to HBV to determine whether further prophylactic therapy is required. Antibody titer levels of greater than 10 mIU/mL within the 24 months preceding exposure are considered protective.
   3. **Hepatitis B immune globulin** is recommended after exposure to HBV unless antibody status reveals active immunity in the health care worker.

c. **Risk of transmission to patient.** Transmission of HBV from surgeon to patient has been well documented (particularly for surgeons who are positive for hepatitis B early antigen), which underscores the importance of disease prevention. Surgeons who are infected actively with, or who are carriers of, HBV should consult with the local hospital infection control committee before operating.

6. **HCV.** HCV is a recently characterized bloodborne pathogen. Chronic hepatitis develops in more than 50% of infected adults.

a. **Risk of transmission to health care worker.** The risk of disease transmission from an infected patient to a health care worker through a percutaneous exposure is estimated at 3–10% (*N Engl J Med* 332:444, 1995). Transmission through mucocutaneous contact has been documented, but the risk has not been quantified.

b. **Postexposure treatment.** No vaccine is available for HCV, and no benefit is associated with treatment with immune globulin or any other prophylactic regimen. After a possible exposure to HCV, health care workers should undergo baseline testing for HCV antibodies, followed by repeat testing 6–9 months later. The risk of secondary transmission of HCV by exposed health care workers through patient contact or other means appears to be low.

B. **Tuberculosis (TB)**

1. **Risk of transmission to health care workers.** TB is a well-documented occupational hazard for health care workers. The resurgence of TB in the general population and the emergence of drug-resistant strains of TB have increased this risk. One study of physicians at Barnes Hospital demonstrated that 8.6% of the study population had undergone skin test conversion (*Infect Control Hosp Epidemiol* 15:95, 1994). The predominant route of disease transmission is respiratory.

2. **Respiratory isolation.** All patients with active TB should be maintained in respiratory isolation. Respiratory isolation includes caring for the patient in a room with negative-pressure ventilation and the use of suitable respiratory protection devices. Surgical masks are not considered adequate respiratory protection. Although respiratory isolation is an important element in limiting the risk of occupational exposure to TB, health care workers remain at risk from exposure to unidentified cases of TB.

3. **TB surveillance and prophylaxis**

a. **Annual TB skin tests are recommended.** Physicians who undergo skin test conversion should be evaluated with a chest X-ray and considered for prophylactic therapy.

b. **Prophylaxis.** Isoniazid therapy is considered effective in preventing the development of active TB and is recommended after skin test conversion. Therapy also is recommended for health care workers who are exposed to TB and have medical conditions, such as renal insufficiency, diabetes, and HIV infection, all of which increase the risk of developing active TB. The dose of isoniazid is 300 mg per day for 1 year. Hepatic toxicity is one of the adverse effects of isoniazid therapy.

2 Nutrition

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Introduction

Nutritional support in the surgical patient remains an essential component of perioperative care. Approximately one-half of all hospitalized patients experience or are at risk for **malnutrition**, with severe protein-calorie malnutrition (PCM) evident in 1 in 10 patients. Malnourished surgical patients have increased mortality and are two to three times more likely to incur complications. In addition, these patients have longer lengths of hospital stay and higher hospital charges [*Nutr Clin Pract* 16(2):69, 2001]. Many studies have found that appropriate nutritional intervention can improve postoperative outcomes and decrease costs. Most patients who undergo surgical procedures have adequate fuel reserves to tolerate a short period of starvation and catabolism; however, some individuals require nutritional support—in particular, those in whom complications of major surgery, trauma, or sepsis have developed, as well as those with cancer-related cachexia. Adequate nutrition sustains basal metabolism, wound healing, and the immune response, all of which are essential for timely recovery.

Metabolism

I. Metabolism of proteins, carbohydrates, and fats

A. **Proteins** are important for the biosynthesis of enzymes, structural molecules, and immunoglobulins. Accordingly, the balance between protein synthesis and degradation is critical.
   1. **Digestion of proteins** yields dipeptides and single amino acids, which are actively absorbed. The duodenum is the site of the majority of protein digestion and absorption, although exposure to pepsin in the stomach initiates the process. Pancreatic proteases, activated on exposure to enterokinase found throughout the duodenal mucosa, are the principal effectors of protein degradation. This accounts for the fact that almost 50% of protein absorption occurs in the duodenum, and complete protein digestion is achieved by the midjejunal level. Protein absorption can effectively occur at every level of the small intestine; therefore, clinically significant protein malabsorption is relatively infrequent, even after extensive intestinal resection. The quality of a protein is related to its amino acid composition. The 20 amino acids are divided into essential amino acids and nonessential amino acids, depending on whether they can be synthesized *de novo* in the body.
   2. **Major roles of amino acids** include the following:
      a. **Synthesis and recycling** of proteins
      b. **Catabolic reactions**, resulting in energy generation and the production of carbon dioxide
      c. **Incorporation of nitrogen** into the production of nonessential amino acid and nucleotides
   3. **Metabolism of absorbed amino acids**, primarily by the liver, regulates accumulation of plasma amino acids. Administration of parenteral nutrition initially bypasses the liver by delivering amino acids directly into the systemic circulation.
   4. **Total body protein** in a 70-kg person is approximately 10–11 kg, concentrated mostly in skeletal muscle. Daily protein turnover is 250–300 g, or approximately 3% of total body protein. The primary site of protein turnover is the gastrointestinal (GI) tract, where shed enterocytes and secreted digestive enzymes are regularly lost. Excessive GI tract losses from a fistula, ileostomy, or draining gastrostomy, as well as partial- or full-thickness skin burns or seeping wounds, provide other potential sources of significant protein loss in surgical patients. Protein turnover decreases with age, from 25 g/kg per day in the neonate to 3 g/kg per day in the adult.
   5. **Protein requirements** in the average healthy adult without excessive losses are approximately 0.8 g/kg body weight. In the United States, the typical daily intake is, on average, twice this amount. Requirements for patients with acute illness increase to 1.2 g/kg per day, and up to 2 g/kg per day is necessary for severely physiologically stressed patients in the intensive care unit. Amino acids contribute only 15% of the normal energy expenditure, with the remainder supplied by carbohydrates and fat. Each gram of protein can be converted into 4 kcal energy.

B. **Carbohydrates** are the body's primary energy source, providing 30–40% of calories in a typical diet.
   1. **Carbohydrate digestion** is initiated by the action of salivary amylase, and absorption is generally completed within the first 1.0–1.5 m of the small intestine. Salivary and pancreatic amylases cleave starches into oligosaccharides on contact. Surface oligosaccharidases then hydrolyze and transport these molecules across the GI tract mucosa. Deficiencies in carbohydrate digestion and absorption are rare in surgical patients. Because pancreatic amylase is abundant, even in patients with limited pancreatic function, maldigestion of starch does not usually occur. Diseases that result in generalized mucosal flattening (e.g., celiac sprue, Whipple's disease, and hypogammaglobulinemia) may cause diminished uptake of carbohydrate byproducts because of resultant deficiencies in oligosaccharidases.
   2. **Glucose stores.** More than 75% of ingested carbohydrate is broken down and absorbed as glucose. Carbohydrate stores are exhausted after a 24-hour fast. Liver glycogen is used first, followed soon thereafter by muscle glycogen. Glucose drives insulin secretion, which in turn influences protein synthesis. An intake of as little as 400 calories of carbohydrate per 24 hours minimizes protein breakdown, particularly after adaptation to starvation. Uptake of glucose, under normal conditions, also inhibits lipolysis. Glucose is essential for wound repair, but excessive amounts can have adverse effects, including hepatic steatosis and neutrophil dysfunction. Each gram of enteral carbohydrate provides 4 kcal energy, similar to protein. Parenteral carbohydrate (e.g., dextrose) provides 3.4 kcal/g.

C. **Lipids**, the third fuel component, provide the remaining 25–45% of calories in the typical diet. During starvation, the majority of calories are provided by lipids in the form of ketone bodies converted by the liver from long-chain fatty acids (see section **II.A**).
   1. **Digestion and absorption of lipids** is complex and requires coordination between **biliary and pancreatic secretions**, as well as functional jejunum and ileum. The introduction of fat to the duodenum leads to secretion of cholecystokinin and secretin, which in turn produces gallbladder contraction and pancreatic enzyme release. **Pancreatic secretions** contain a combination of lipase, cholesterol esterase, and phospholipase A_2. In the alkaline environment of the duodenum, lipase hydrolyzes triglycerides to a monoglyceride and two fatty acids. Bile salts lead to emulsification. **Micelle formation** is the most important step in lipid absorption, facilitating absorption of fats across the mucosal barrier. Reabsorption of bile salts is necessary to maintain the bile salt pool. The liver is able to compensate for the moderate intestinal bile salt losses by increased synthesis from cholesterol. Major ileal resection may lead to depletion of the bile salt pool and subsequent fat malabsorption. Lipolysis is stimulated by steroids, catecholamines, and glucagon but is inhibited by insulin. **Stress results in dramatic lipolysis.** Each gram of lipid provides 9 kcal energy.
   2. The **essential fatty acids**, linoleic and linolenic acid, are required for cell membrane integrity. Dietary fats are the sole precursors to eicosanoid production and as such are potent immunomodulators. Arachidonic acid, a vital component in prostaglandin synthesis, can be manufactured from linoleic acid. Clinical deficiency results in a generalized scaling rash, poor wound healing, hepatic steatosis, and bone changes. This condition is usually a consequence of long-term, fat-free parenteral nutrition, in which high glucose levels inhibit lipolysis, preventing peripheral essential fatty acid liberation. It is remedied by providing as little as 3% of calories as parenteral lipid.

II. Stress metabolism

A. **Starvation.** After an overnight fast, liver glycogen is rapidly depleted because of a fall in insulin and a rise in glucagon levels in plasma. In the first few days of starvation, caloric needs are supplied by fat and protein degradation. Generally, a baseline nitrogen loss of 10–15 g per day occurs through urinary losses. Most of the available protein is from the breakdown of skeletal and visceral muscle and is converted to glucose by gluconeogenesis in the liver. The brain preferentially uses this endogenously produced glucose, with the remainder consumed by red blood cells and leukocytes. If starvation continues for more than a few days, the brain then uses fat as its fuel source. Because the brain cannot use free fatty acids in the same manner as other tissues do, it relies on keto acids produced by the liver. This adaptation to ketone usage has a protein-sparing effect. In summary, the adaptive changes in uncomplicated starvation are a decrease in energy expenditure, a change in type of fuel consumed (which maximizes the caloric potential), and preservation of protein.
B. **Physiologic stress.** The interaction of metabolic and endocrine responses that result from major operation, trauma, or sepsis can be divided into three phases:

1. **Catabolic phase.** After major injury, the metabolic demand is dramatically increased, as reflected in a significant rise in the urinary excretion of nitrogen (beyond that seen in simple starvation). After a major surgical procedure, protein depletion inevitably occurs because patients are commonly prevented from eating in addition to having an elevated basal metabolic rate. The hormonal response of physiologic stress includes elevation in the serum levels of glucagon, glucocorticoids, and catecholamines and decreased levels of insulin.
2. The **early anabolic phase** is also called the *corticoid-withdrawal phase*. Depending on the severity of stress, the body shifts from catabolism to anabolism. The timing of this event is variable, ranging from several days to several weeks. The period of anabolism can last from a few weeks to a few months, depending on many factors, which include the ability of the patient to obtain and use nutrients and the extent to which protein stores have been depleted. This phase is marked by a positive nitrogen balance, and there is a rapid and progressive gain in weight and muscular strength. The total amount of nitrogen gained is equivalent to the amount lost in the catabolic phase; however, the rate of repletion is much slower than the rapid rate of protein depletion after the original insult.
3. The **late anabolic phase** is the final period of recovery and may last from several weeks to months. Adipose stores are replenished gradually, and nitrogen balance equilibrates. Weight gain is much slower during this period than in the early anabolic phase due to the high caloric content of fat—the primary energy stores deposited during the early anabolic phase—as compared to protein.

Nutritional Assessment and Administration

I. Nutritional assessment is essential in identifying patients who are at risk for development of complications related to significant PCM. Preoperative nutritional support can significantly reduce perioperative morbidity and mortality in patients with severe PCM. In addition, the incidence of postoperative morbidities, such as intraabdominal abscess, anastomotic leakage, and ileus, may be decreased by the use of preoperative enteral or parenteral hyperalimentation in patients with severe PCM. Preoperative nutritional support for patients with only mild or moderate PCM is not routinely indicated (*ASPEN nutrition support practice manual*, 2nd ed. Gaithersburg, MD: ASPEN Publishers, 1998). Table 2-1 presents several nutritional and biologic indices that were developed to predict the risk of perioperative complications and mortality (*Nutr Clin Pract* 8:171, 1998).

Table 2-1. Nutritional indices

A. **Types of malnutrition.** Two forms of malnutrition have been identified (Table 2-2).

Table 2-2. Types of malnutrition

1. **Marasmus** is malnutrition that is typically caused by illness-induced anorexia, without catabolism. It is a chronic nutritional deficiency marked by losses in weight, body fat, and skeletal muscle mass (as identified by anthropometric measurements). Visceral protein stores remain normal. Patients with marasmus may lose substantial body weight but are able to resist infection and respond appropriately to minor or moderate stress.
2. **Kwashiorkor** may be, in some patients, an extension of marasmus. This form of malnutrition develops when the period of starvation is prolonged or if the stress is severe. Increased visceral protein loss and metabolic stress lead to hypoalbuminemia, edema, and anergy. Even in a well-nourished patient, a severe stress (e.g., major burn or prolonged sepsis) may rapidly lead to the depletion of visceral protein stores and impairment in immune function. Conventional anthropometric measurements may not identify these patients as being significantly malnourished.

B. **Evaluation of preexisting deficits.** A dietary history, physical examination (including anthropometric measurements), and relevant laboratory data are the appropriate tools needed to make an accurate evaluation of a patient's preoperative nutritional status (*The science and practice of nutrition support: a case based core curriculum*. Dubuque, IA: Kendall/Hunt Publishing, 2001).
   1. A **history** of weight fluctuation or a change in dietary habits is particularly relevant. In most cases, the possibility of malnutrition is suggested by the underlying disease or by a history of recent weight loss. Anorexia, nausea, vomiting, dysphagia, odynophagia, gastroesophageal reflux, or a history of generalized muscle weakness should prompt further evaluation. Recent weight loss (5% in the last month or 10% over 6 months) or a current body weight of 80–85% (or less) of ideal body weight suggests significant malnutrition. A complete history of current medications is essential to alert caretakers to potential underlying deficiencies as well as drug-nutrient interactions.
   2. **Physical examination** may identify muscle wasting (especially thenar and temporal muscles), loose or flabby skin, and peripheral edema (as a result of hypoproteinemia). More subtle findings of nutritional deficiency include skin rash, pallor, glossitis, gingival lesions, hair changes, hepatomegaly, neuropathy, and dementia (*ASPEN nutrition support practice manual*, 2nd ed. Gaithersburg, MD: ASPEN Publishers, 1998).
   3. **Anthropometric measurements**, such as triceps skinfold thickness and midarm muscle circumference, are a reflection of body-fat stores and skeletal muscle mass, respectively. These values are standardized for gender and height, and they should be reported as a percentage of the predicted value. Typically, anthropometric measurements include assessment of body weight, height, and body mass index, and these values allow the clinician to assess the patient's visceral and somatic protein mass and fat reserve.
   4. **Laboratory tests** that suggest malnutrition have a direct correlation with perioperative morbidity.
      a. **Serum albumin** of less than 3.0 g/dL in a stable, hydrated patient; half-life of 14–20 days.
      b. **Serum prealbumin** with a half-life of 2–3 days may be a more useful indicator of nutritional status. 10–15 mg/dL = mild depletion, 5–10 mg/dL = moderate depletion, and less than 5 mg/dL = severe depletion.
      c. **Serum transferrin** of less than 200 mg/dL; half-life of 8–10 days.
   5. **Immune function** is frequently altered by malnutrition and may be determined by assessing.
      a. **Delayed-type hypersensitivity** (anergy to common skin antigens)
      b. **Total lymphocyte count (TLC)** is calculated by the following formula:

Equation

where 1,500–1,800 mm^3 = mild depletion, 900–1,500 mm^3 = moderate depletion, and less than 900 mm^3 = severe depletion.

C. **Estimation of caloric and protein requirements** is necessary to provide adequate substrates for healing and tissue repair. Failure to provide adequate amounts of both calories and protein leads to further depletion of lean body mass.
   1. **Basal energy expenditure (BEE)** can be predicted using the Harris-Benedict equation:
      - BEE in kcal per day for men = 66.4 + (13.7 × weight in kg) + (5.0 × height in cm) – (6.7 × age in years)
      - BEE in kcal per day for women = 655 + (9.6 × weight in kg) + (1.8 × height in cm) – (4.7 × age in years)
   2. These equations provide a reliable estimate of the energy requirements in approximately 80% of hospitalized patients. The actual caloric needs may be substantially greater than the BEE during periods of metabolic stress (Table 2-3). Most stressed patients require 25–35 kcal/kg per day.

Table 2-3. Disease stress factors used in calculation of total energy expenditure

3. **Estimates of protein requirements.** The appropriate calorie-nitrogen ratio is approximately 150:1. In the absence of severe renal or hepatic dysfunction, approximately 1.5 g protein per kg body weight should be provided daily (Table 2-4).

Table 2-4. Estimated protein requirements in various disease states

a. **Twenty-four–hour nitrogen balance** is calculated by subtracting nitrogen excretion from nitrogen intake. Nitrogen intake is the sum of nitrogen delivered from enteral and parenteral feedings. Nitrogen output is the sum of nitrogen excreted in urine, fistula drainage, diarrhea, and so forth. The usual approach is to measure the urea nitrogen concentration of an aliquot of a 24-hour urine collection and then to calculate nitrogen content from the urine volume. A correction factor is added to account for nitrogen losses in the stool and from skin exfoliation. The difference in nitrogen intake minus output estimates the 24-hour nitrogen balance.
b. **Creatinine-height index (CHI)** can be used to determine the degree of malnutrition. A 24-hour urinary creatinine excretion is measured and compared to normal standards. Creatinine height index is calculated by the following equation:

Equation

where greater than 80% = zero to mild depletion, 60–80% = moderate depletion, and less than 60% = severe depletion.

II. Administration of nutrition

A. **Indications.** The need for nutritional support should be assessed continually in all patients preoperatively and postoperatively. The majority of surgical patients do not require nutritional supplementation. Most patients have adequate fuel reserves to withstand common catabolic stresses and partial starvation for at least 1 week. For these patients, intravenous fluids with appropriate electrolytes and a minimum of 100 g glucose daily (to minimize protein catabolism) is adequate. However, even **patients who were well nourished** before a major operation or trauma who subsequently enter a prolonged hypermetabolic or severely catabolic period may require nutritional support (*Curr Probl Surg* 32:833, 1995). Without nutritional intervention, these patients may have complications that are attributable to impaired immune function and poor wound healing as a result of depletion of visceral protein stores (see Chapter 9). **Patients with a significant degree of preoperative malnutrition** have less reserve, tolerate catabolic stress and starvation poorly, and are therefore at higher risk for postoperative complications.
B. **Enteral nutrition.** In general, the enteral route is preferred over the parenteral route and should be the initial step in alimentation. Enteral feeding is simple, physiologic, relatively inexpensive, and well tolerated by most patients. Enteral feeding maintains the GI tract cytoarchitecture and mucosal integrity (through trophic effects), absorptive function, and normal microbial flora. This results in less bacterial translocation and exotoxin release from the intestinal lumen to the bloodstream (*Semin Respir Infect* 9:248, 1994). **Enteral feedings are indicated** for patients who have a functional GI tract but are unable to sustain an adequate oral diet. **Enteral feedings may be contraindicated** in the patient with an intestinal obstruction, ileus, GI bleeding, severe diarrhea, vomiting, enterocolitis, or high-output enterocutaneous fistula. Contraindications to enteral feeding are in most cases relative or temporary rather than absolute. Choice of an appropriate feeding site, administration technique, formula, and equipment may circumvent many of these problems.
   1. **Feeding tubes.** Nasogastric, nasojejunal, gastrostomy, and jejunal tubes are available for the administration of enteral feeding products. Gastrostomy tubes can be placed using minimally invasive techniques, such as endoscopic or laparoscopic insertion. Jejunal tubes are preferred for long-term access and require a continuous infusion rather than bolus administration. The techniques for placement of these tubes and the common complications associated with their use are summarized in Chapter 8.
   2. **Enteral feeding products.** A variety of commercially available enteral feeding formulas are available (Table 2-5). Standard solutions provide 1 kcal/mL; calorically concentrated solutions (>1 kcal/mL) are available for patients who require volume restriction. Currently available dietary formulations for enteral feedings can be divided into polymeric (blenderized and nutritionally complete commercial formulas), chemically defined formulas (elemental diets), and modular formulas (Table 2-5).

Table 2-5. Enteral formulas

   a. **Blenderized tube feedings** can be composed of any food that can be blenderized. Caloric distribution of these formulas should parallel that of a normal diet.
   b. **Nutritionally complete commercial formulas** (standard enteral diets) vary in protein, carbohydrate, and fat composition. Several formulas use sucrose or glucose as carbohydrate sources and are suitable for lactose-deficient patients. Commercial formulas are convenient, sterile, and low in cost. They are recommended for patients experiencing minimal metabolic stress who have normal gut function.
   c. **Chemically defined formulas** are commonly called *elemental diets*. The nutrients are provided in predigested and readily absorbed form. They contain protein in the form of low–molecular-weight free amino acids or polypeptides. Amino acid (elemental) and polypeptide diets are efficiently absorbed in the presence of compromised gut function. However, they are more expensive than nutritionally complete commercial formulas and are hyperosmolar, which may cause cramping and diarrhea.
   d. **Modular formulations** include special formulas that are used for specific clinical situations (e.g., pulmonary, renal, or hepatic failure or immune dysfunction).
3. **Enteral feeding protocols.** In the past, elaborate protocols for initiating tube feedings were used. Currently, it is recommended that feedings be started with full-strength formula begun at a slow rate and steadily advanced. This reduces the risk of microbial contamination and achieves full nutrient intake earlier. This approach can also be used with high-osmolality or elemental products. Conservative initiation and advancement rates are recommended for patients who are critically ill, those who have not been fed for some time, and those who are receiving high-osmolality or calorie-dense formula.
   a. **Bolus feeding.** In general, bolus feedings are used in patients with nasogastric or gastrostomy feeding tubes. Feedings are administered by gravity and begin at 50–100 mL every 4 hours and are increased in 50-mL increments until the intake goal is reached (usually 240–360 mL every 4 hours). Tracheobronchial aspiration is a potentially serious complication. To prevent this, the patient's head should be elevated to 30–45 degrees during feeding and for 1–2 hours after each feeding. The residual gastric volume should be measured every 4 hours and before administration of the feeding bolus. If the gastric residual volume is greater than 50% of the previous bolus, the next feeding should be withheld. The feeding tube should be flushed with approximately 30 mL water after each use.
   b. **Continuous infusion** administered by a pump is generally required for nasojejunal, gastrojejunal, or jejunal feeding tubes. Feedings are initiated at 20–50 mL per hour and increased in 10- to 20-mL-per-hour increments, every 4–6 hours, until the desired goal is reached. The feeding tube should be flushed with approximately 30 mL water every 4 hours. It may be difficult to aspirate these small-bore tubes to check for residuals; however, if volumes are high, the feedings should be slowed or held. For some patients, the entire day's feeding volume can be infused over an 8- to 12-hour period at night to allow the patient to be disconnected from the infusion pump during the day.
   c. **Conversion to oral feeding.** When indicated, an oral diet is resumed gradually. In an effort to stimulate appetite, enteral feeding can be modified by the following measures:
      1. **Providing fewer feedings**
      2. **Holding daytime feedings**
      3. **Decreasing the volume of feedings.** When oral intake provides approximately 75% of the required calories, tube feedings can be discontinued.
   d. **Administration of medications.** Many oral medications can be administered through feeding tubes. The elixir form is preferred but is not always available. Medications that are not suitable for administration through a feeding tube include the following:
      1. **Enteric-coated medications**
      2. **Drugs in gelatinous capsules**
      3. **Medications that are designed for sublingual use**
      4. **Most sustained-release medications**

e. The following medications have been associated with tube clogging:
   1. **Sucralfate**
   2. **Hydrochlorothiazide-triamterene (Dyazide)**
   3. **Ibuprofen**
   4. **Psyllium**
   5. **Extended-release theophylline (Theo-Dur sprinkles)**
   6. **Chlorpromazine (Thorazine)**

4. **Complications**
   a. **Metabolic complications.** Abnormalities in serum electrolytes, calcium, magnesium, and phosphorus can be minimized through vigilant monitoring. **Hyperosmolarity** may lead to the development of mental lethargy or obtundation. The treatment for this is the administration of free water by giving either 5% dextrose in water intravenously or additional water in the tube feedings. Volume overload and subsequent congestive heart failure may occur as a result of **excess sodium administration**, observed especially in patients with impaired ventricular function or valvular heart disease. **Hyperglycemia** may occur in any patient but is particularly common in individuals with preexisting diabetes or sepsis. The serum glucose level should be determined frequently, and regular insulin should be administered accordingly.
   b. **Clogging** can usually be prevented by careful attention to routine flushing of the feeding tube. Wire stylets should not be used to unclog a feeding tube because of the risk of tube perforation and injury to the esophagus or stomach. Instillation of carbonated soda, cranberry juice, or meat tenderizer (1 teaspoon papain in 30 mL water) is sometimes useful for unclogging feeding tubes. Tubes that are refractory to these remedies, as well as those with cracks, leaks, or defective connectors, should be replaced.
   c. **Tracheobronchial aspiration** of tube-feeding solutions may occur with patients who are fed into the stomach or proximal small intestine and may lead to the development of pneumonia. Patients at particular risk are those with central nervous system abnormalities and those who are sedated. Methylene blue (1 mL/L) added to the tube-feeding solutions, or glucose test strips, can be used to detect tube-feeding formula in tracheal aspirates. Historically, jejunal feeding has been the preferred route for patients who are at risk for aspiration; however, one comparison of tube feeding via jejunal and gastric routes found no difference in rates of aspiration pneumonia or other complications (*J Parenter Enteral Nutr* 24:103, 2000).
   d. **High gastric residuals** of tube feedings as a result of outlet obstruction, dysmotility, intestinal ileus, or bowel obstruction may limit the usefulness of nasogastric or gastrostomy feeding tubes. Treatment of this problem should be directed at correcting the underlying cause. If gastric retention prevents the administration of sufficient calories and intestinal ileus or obstruction can be excluded, a nasojejunal or jejunostomy feeding tube may be necessary.
   e. **Diarrhea** is a potential consequence of enteral feeding, occurring in 10–20% of patients; however, other causes of diarrhea (e.g., *Clostridium difficile* or other infectious colitis) should be considered. Diarrhea may result from numerous causes: too rapid an increase in the volume of hyperosmolar tube feedings, some medications (e.g., metoclopramide), a diet that is high in fat content, or the presence of components not tolerated by the patient (e.g., lactose). If other causes of diarrhea can be excluded, the volume or strength of tube feedings should be diminished. If no improvement occurs, a different formula should be used. Antidiarrheal agents (e.g., loperamide) should be reserved for patients with severe diarrhea. In the case of the surgical patient, *C. difficile* is a frequent cause of diarrhea due to the common use of perioperative antibiotics. Laboratory confirmation can be made with a *C. difficile* toxin assay. Treatment options include either metronidazole (Flagyl; oral or intravenous) or oral vancomycin.

C. **Parenteral nutrition** is indicated for patients who require nutritional support but cannot meet their nutritional needs through oral intake and for whom enteral feeding is contraindicated or not tolerated.
   1. **Peripheral parenteral nutrition (PPN)** is administered through a peripheral intravenous catheter. The osmolarity of PPN solutions generally is limited to 1,000 mOsm (approximately 12% dextrose solution) to avoid phlebitis. Consequently, unacceptably large volumes of solution (>2,500 mL) are necessary to fulfill the typical patient's total nutritional requirements. Temporary partial nutritional supplementation with PPN may be useful in selected patients but typically is not indicated.
   2. **Total parenteral nutrition (TPN)** provides complete nutritional support (*Surgery* 64:134, 1968). The selection of a particular solution, volume of administration, and solution additives is individualized for the patient and based on an assessment of the nutritional requirements (*N Engl J Med* 325:527, 1991).
      a. **Access.** TPN solutions must be administered through a central venous catheter. A dedicated single-lumen catheter or a multilumen catheter can be used. Catheters should be replaced for unexplained fever or bacteremia.
      b. **TPN solutions.** TPN solutions generally are administered as a 3-in-1 admixture of protein, as amino acids (10%; 4.0 kcal/g); carbohydrate, as dextrose (70%; 3.4 kcal/g); and fat, as a lipid emulsion of soybean or safflower oil (20%; 9.0 kcal/g, respectively). Alternatively, the lipid emulsion can be administered as a separate intravenous “piggyback” infusion. Standard preparations of TPN are used for most patients and provide total calories that are broken down as 50–60% carbohydrate, 24–34% fat, and 16% protein. Special solutions that contain low, intermediate, or high protein and nitrogen concentrations as well as varying amounts of fat and carbohydrate are available for some patients with diabetes, renal failure, or hepatic dysfunction.
      c. **Additives.** Other elements can be administered in conjunction with the basic caloric and protein solutions.
         1. **Electrolytes** (e.g., sodium, potassium, chloride, acetate, calcium, magnesium, and phosphate) that are added to the TPN solution should be adjusted daily. A suggested formulation often is listed on a prewritten order sheet, and these concentrations are designed for the patient whose current serum electrolytes and renal function are normal. Suggested ranges for these additives include Na, 60–80 mEq per day; K, 30–60 mEq per day; Cl, 80–100 mEq per day; Ca, 4.6–9.2 mEq per day; Mg, 8.1–20.0 mEq per day; and PO_4, 12–24 mmol per day. The number of cations and anions must balance; this is achieved by altering the concentrations of chloride and acetate. If the serum bicarbonate is low, the solution should contain more acetate. The calcium and phosphate ratio must be monitored to prevent salt precipitation.
         2. **Medications**, such as albumin, H_2-receptor antagonists, heparin, iron, dextran, insulin, and metoclopramide, can be administered in TPN solutions; however, not all medications are compatible with 3-in-1 admixtures. Regular insulin should initially be administered subcutaneously according to a sliding scale, based on determination of the blood glucose level. After a stable insulin requirement has been established, insulin can be administered in the TPN solution, generally at two-thirds of the daily subcutaneous insulin dosage.
         3. **Other additives.** Trace elements are added to the TPN solution daily using a commercially prepared mixture (e.g., 1 mL Trace Element-5: 1 mg copper, 12 µg chromium, 0.3 µg manganese, 60 µg selenium, and 5 mg zinc). Multivitamins generally are added daily to the TPN solution using a commercially prepared mixture (e.g., 10 mL MVI-12). Vitamin K is not included in most multivitamin mixtures and must be added separately (10 mg once a week). Vitamins A and C and zinc are particularly important for proper wound healing.
      d. **Routine physiologic and laboratory monitoring** should occur on a scheduled basis. This can be performed less frequently for patients whose postoperative course has stabilized and who are receiving a consistent TPN regimen. The initial frequency of monitoring includes vital signs and serum glucose every 6 hours; weight, serum electrolytes, and blood urea nitrogen daily; and triglycerides, complete blood cell count, prothrombin time, liver enzymes, and bilirubin weekly. A weekly 24-hour urine collection is valuable in estimating nitrogen losses because it provides a value for the urine urea nitrogen (UUN). Nitrogen balance is calculated as follows:

Equation

where total nitrogen loss (g per day) = 1.2 × [24-hour UUN (g per day)] + 2 g per day.

e. **Administration of TPN.** Orders, written daily, should reflect the patient's dynamic nutritional status and biochemical profile (Table 2-6).

Table 2-6. Barnes-Jewish Hospital parenteral nutrition order form

1. **Introduction of TPN** should be gradual. For example, approximately 1,000 kcal is provided the first day. If there is metabolic stability (e.g., normoglycemia), this is increased to 1,500 kcal the second day. The amount is increased by 500 kcal per day until the caloric goal is reached.
2. **TPN solutions** are delivered most commonly as a continuous infusion. A new 3-in-1 admixture bag of TPN is administered daily with a constant infusion rate over 24 hours.
3. **Cyclic administration of TPN** solutions may be useful for selected patients, including (1) those who will be discharged from the hospital and subsequently receive home TPN; (2) those with limited intravenous access who require administration of other medications, such as chemotherapeutic agents; and (3) those who are metabolically stable and desire a period during the day when they can be free of an infusion pump. Cyclic TPN is administered for 8–16 hours, most commonly at night. This should not be done until metabolic stability has been demonstrated for patients on standard, continuous TPN infusions.

4. **Discontinuation of TPN** should take place when the patient can satisfy 75% of his or her caloric and protein needs with oral intake or enteral feeding. The calories provided by TPN can be decreased in proportion to calories from the patient's increasing enteral intake. To discontinue TPN, the infusion rate should be halved for 1 hour, halved again the next hour, and then discontinued. It is not necessary to taper the rate of TPN infusion if the patient is receiving less than 1,000 kcal per day. This is done to prevent complications that are caused by hyperinsulinemia.

f. **Complications associated with TPN**

1. **Catheter-related complications** can be avoided by strict aseptic technique and routine catheter care (*N Engl J Med* 290:757, 1974).
2. **Metabolic complications.** Hyperglycemia and hyperosmolarity may lead to coma or death. In addition, hyperglycemia may be the first indication of occult infection. As noted in section **II.C.2.d**, the serum glucose level should be monitored frequently. Patients with a serum glucose level of 200–400 mg/dL should have subcutaneous regular insulin. Patients with a serum glucose level that exceeds 400 mg/dL should have intravenous infusions of regular insulin. Hyperglycemia can result in the generation of excess carbon dioxide, which may cause respiratory difficulties in patients with marginal pulmonary reserve. If such patients are ventilator dependent, they may be particularly difficult to wean (*JAMA* 243:1444, 1980). Conversely, hypoglycemia may develop on discontinuation of TPN. The refeeding syndrome may occur when TPN is administered to a severely malnourished patient, resulting in a dramatic shift of extracellular ions into the intracellular space. Additional supplementation of K, Mg, and PO_4 may be needed. A large parenteral sodium load in a severely malnourished patient may precipitate congestive heart failure. The consequences of the various electrolyte abnormalities are discussed in Chapter 4.
3. **Refeeding syndrome** occurs when excessive carbohydrate calories are administered to malnourished patients, causing a precipitous drop in serum phosphate. Phosphate levels need to be monitored frequently in these patients.
4. **Hepatic dysfunction** is a common manifestation of long-term TPN support. Steatosis is associated with mild elevations of the transaminases, alkaline phosphate, and bilirubin.
5. **Cholecystitis**, particularly the acalculous type, is common in patients who receive TPN for extended periods. Cholecystostomy or cholecystectomy is indicated for symptomatic patients. To avoid cholestasis and prevent this complication, gallbladder contraction can be stimulated with the C-terminal octapeptide of cholecystokinin, 0.02 µg/kg i.v. per day.

D. **Specialized substrates.** Promise has been shown for “nutritional pharmacology,” in which interventions with cytokines, hormones, and substrates can augment basic nutritional repletion. Cytokines, such as interleukin-1, interleukin-6, and tumor necrosis factor-alpha, contribute to the acute-phase response of inflammation, loss of skeletal muscle protein, and use of exogenous nutrients. Pharmacologic manipulation of these agents may reverse their deleterious effects (*Cancer* 79:1828, 1997). Exogenous growth hormone has been shown to accelerate lean body mass and protein gain in stable patients, thus offsetting the deposition of fat and extracellular water that are found with standard methods of nutritional support (*J Parenter Enteral Nutr* 25:519, 2001). However, complications that are associated with growth hormone administration must be fully understood and may limit its use. In addition, substrates such as arginine, glutamine, omega-3 fatty acids, and nucleic acids (RNA) may be beneficial in select patient populations. (*Nutr Clin Pract* 16:6, 2001).

E. **Disease-specific nutrition**

1. **Thermal injury** has a tremendous impact on metabolism because of prolonged, intense neuroendocrine stimulation. The increase in metabolic demands following thermal injury is proportionate to the extent of ungrafted body surface. Decreasing the intensity of neuroendocrine stimulation by providing analgesia and thermoneutral environments lowers the accelerated metabolic rate in many of these patients and helps to decrease catabolic protein loss until the burned surface can be grafted (*Compr Ther* 17:47, 1991).
2. **Diabetes** often complicates nutritional management. Complications that are associated with TPN administration (e.g., catheter-related sepsis) are more common with prolonged hyperglycemia. Unopposed glycosuria may cause osmotic diuresis, loss of electrolytes in urine, and nonketotic coma. The goal in glucose-intolerant patients is to maintain the serum glucose level at 100–200 mg/dL. Hypoglycemia can result in shock, seizures, or vascular instability. This can be prevented by adjusting the insulin dosing, with the understanding that insulin requirements will decrease as the patient recovers from the initial stress that is associated with the illness.
3. **Renal failure** may be associated with glucose intolerance, negative nitrogen balance (resulting from increased losses through dialysis), loss of protein with decreased protein synthesis, and diminished excretion of phosphorus. Dialysis should be adjusted accordingly, and these patients should be nutritionally replenished according to their calculated needs. Patients who receive peritoneal dialysis absorb approximately 80% of the dextrose in the dialysate fluid (assuming a normal serum glucose level). These factors must be considered when designing a nutritional support strategy.
4. **Hepatic failure** may result in wasting of lean body mass, fluid retention, vitamin and trace metal deficiencies, anemia, and encephalopathy. More than 70–80 g per day of amino acids is required to maintain nitrogen balance in these patients. It may be difficult or impossible to limit the amount of nitrogen that a patient receives each day yet still provide adequate nutritional support. Branched-chain amino acids are metabolized by skeletal muscle and serve as an energy source during periods of stress. These amino acids are available enterally or parenterally to decrease the levels of aromatic amino acids and, therefore, the severity of encephalopathy; however, their efficacy has not been proved (*J Parenter Enteral Nutr* 14:225, 1990).
5. **Cachexia and cancer** are associated with lean muscle wasting. More than two-thirds of patients with cancer experience significant weight loss during their illness, and malnutrition is a contributing cause of mortality in 20–40% of these individuals. Reasons for this development include decreased nutrient intake and impaired nutrient use. Antineoplastic therapies, such as chemotherapy, radiation therapy, or operative extirpation, can worsen preexisting malnutrition. Although the addition of TPN to these modalities in clinical studies has shown improvement in weight, nitrogen balance, and biochemical markers, there is little evidence to suggest better response rates or survival. Use of specialized formulas supplemented with various substrates (arginine, glutamine, nucleic acids, and omega-3 fatty acids) may reduce morbidity and length of hospital stay, but ongoing studies need to be done before these formulas are routinely recommended.
6. **Short-bowel syndrome** commonly occurs in patients with less than 200 cm of functional jejunum. It may result from mesenteric ischemia, Crohn's disease, or necrotizing enterocolitis. It is characterized by nutrient malabsorption, electrolyte imbalance, diarrhea, and dehydration. Most of these patients require intravenous nutrition for life, at costs of more than $100,000 per year, with frequent hospitalizations for conditions such as catheter sepsis, progressive organ dysfunction, and osteoporosis. The estimated length of small bowel that is required for adult patients to become independent of TPN is greater than 120 cm without colon or greater than 60 cm with some colonic continuity. Salvage of the ileocecal valve improves outcome. Intestinal adaptation may occur in some patients, thereby allowing for the transition from intravenous to enteral feeding. Uniquely formulated diets (supplemented with glutamine and growth hormone) show promise for accelerating this process (*Curr Probl Surg* 34:393, 1997).
7. **Patients with AIDS** develop PCM and lose weight. Malnourished AIDS patients require 35–40 kcal and 2.0–2.5 g protein/kg per day. In addition to the required electrolytes, vitamins, and minerals, they should receive glutamine, arginine, nucleotides, omega-3 polyunsaturated fats, branched-chain amino acids, and trace metal supplements. Those with normal gut function should be given a high-protein, high-calorie, low-fat, lactose-free oral diet. Patients with compromised gut function require an enteral (amino acid, polypeptide, or immuno enriched) diet or TPN.

3 Life Support

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Introduction

The **time** from cardiopulmonary arrest to the initiation of **basic life support (BLS)** and **advanced cardiac life support (ACLS)** is critical to the ultimate outcome. The following guidelines were developed by the American Heart Association to standardize treatment for most adult patients [*Circulation* 102(Suppl I), 2000]. These guidelines do not preclude specific interventions based on an individual patient's characteristics.

Life Support and Arrest Algorithms

I. BLS. The ABCs of BLS—*a*irway, *b*reathing, and *c*irculation—are critical to successful resuscitative efforts for both respiratory and cardiac arrest. This algorithm has been recently updated to include BLC and ACLS in one format and can be represented in either simplified (not shown) or detailed forms (Fig. 3-1 and Table 3-1). After a person collapses, the following procedures are recommended:

Fig. 3-1. Comprehensive emergency cardiovascular care algorithm for the evaluation and management of persons after collapse. BLS, basic life support; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia. [Adapted from A guide to the international ACLS algorithms. *Circulation* 2000;102(Suppl I):I-142–I-157.]

Table 3-1 Primary ABCD Survey

A. **Determine unresponsiveness** by gently tapping or shaking the victim and asking, “Are you okay?” **Do not shake the victim's head or neck** unless trauma to these areas has been excluded.
B. **Call for help if there is no response.** In the field, activate the emergency medical service system by calling the local emergency telephone number (e.g., 911). Call for a defibrillator.
C. **Airway**
   1. **Position the patient** supine on a firm, flat surface. While the patient is being moved, his or her head and neck should remain in the same plane as the torso, and his or her body should be moved as a unit.
   2. **Open the airway.** If there is no evidence of head or neck trauma, the head-tilt, chin-lift maneuver is used: The rescuer should place the palm of one hand on the patient's forehead and apply firm pressure to tilt the head backward. At the same time, the rescuer places the index and middle fingers of the other hand under the patient's chin and displaces the mandible anteriorly, raising the tongue away from the posterior pharynx. For the patient with a suspected neck injury, the neck tilt should be avoided, and the modified jaw thrust should be used. This is performed by grasping the angles of the patient's mandible with the fingers of both hands and moving the mandible anteriorly.
D. **Breathing**
   1. **Assess for the presence of spontaneous respiration** with the patient's airway open. The rescuer should listen and feel for airflow while observing for movement of the patient's chest. Maintenance of an open airway may suffice for spontaneous respiration to resume.
   2. **Perform rescue breathing** if spontaneous respiration is not present. Gently occlude the patient's nose, making a tight seal over the patient's mouth, and ventilate twice with slow, full breaths (1–2 seconds each, with a 2-second pause between breaths). Adequate ventilation is indicated by observing the chest rise and fall and hearing and feeling the air escape during exhalation. Rapid and high-pressure breaths might result in gastric distention. Health care professionals should be proficient in the use of the pocket mask to help prevent the transmission of infection during BLS. Proper technique involves holding the mask in place with the middle and ring fingers of the hands at the angle of the patient's mandible while executing the head-tilt maneuver. Because it is difficult to maintain a leak-proof seal, only well-trained and experienced personnel should use a bag-valve device with a mask. If the patient cannot be ventilated, his or her head should be repositioned, and ventilation should be attempted again. If these attempts are still unsuccessful, the foreign body–airway obstruction maneuver should be performed (see section **I.F**).
E. **Circulation**
   1. **Assess for the presence of a pulse** by palpating the carotid artery. If a carotid pulse is present, rescue breathing should be continued at a rate of 10–12 breaths per minute until spontaneous respiration resumes.
   2. In the absence of a carotid pulse, **deliver chest compressions** at a rate of 80–100 per minute. Chest compression is performed by placing the heel of one hand on the back of the other with the fingers extended or interlocked. With elbows locked and shoulders located directly above the hands, the rescuer's hands are placed 1 inch cephalad to the xiphoid process. The patient's sternum is then compressed 1.5–2.0 inches by thrusting with the heel of the hand directly toward the spine. Compressions should be smooth and regular, with an equal amount of time allowed for compression and release. Without moving the hands, pressure must be completely released from the chest after each compression. During **one-rescuer BLS**, 15 compressions are delivered before ventilating twice. For **two-rescuer BLS**, the compression-ventilation ratio is 5:1, and the rescuer responsible for airway management should assess the adequacy of compressions by palpating periodically for the carotid pulse. Once the patient is intubated, ventilation can be given at a rate of 12–15 breaths per minute without pausing for compressions.
   3. **BLS should be stopped** for 5 seconds after four cycles of compressions and ventilation and every 2–3 minutes thereafter to assess whether the patient has resumed spontaneous breathing or circulation. If a pulse is present, ventilation should be continued as needed. When the defibrillator is available, it should be attached. Otherwise, BLS should not be stopped for more than 5 seconds except to intubate or defibrillate.
F. **Foreign body–airway obstruction management.** If an unconscious patient cannot be ventilated after two attempts at repositioning the airway, abdominal thrusts (Heimlich maneuver) should be performed. The rescuer straddles the victim's thighs and places the heel of one hand against the victim's abdomen in the midline slightly cephalad to the umbilicus. The second hand is placed directly on top of the first, and thrusts are delivered by pressing posteriorly and cephalad. After 6–10 quick thrusts, the victim's mouth is opened, and a finger sweep is performed to remove any debris. Ventilation is then attempted, and if unsuccessful, the sequence of abdominal thrusts and the finger sweep are repeated. Cricothyrotomy and transtracheal ventilation should be performed if effective ventilation cannot be established.

II. ACLS. Properly performed BLS is critical to the successful performance of ACLS, which is a team effort that depends on effective supervision by a team leader. The leader should ensure that the following measures are taken: