

# Introduction to Dosage Calculations

There is  
no such thing as a problem  
without a gift for you  
in its hands.

You seek problems  
because you need  
their gifts.

—Richard Bach. *Illusions: Confessions of a Reluctant Messiah*. New York:  
Bantam Dell Publishing Group; 1977.

## Exhibit 1-1

This text begins with simple mathematical problems and creates a bridge from the known to the unknown. Each chapter builds on information from previous chapters. Look ahead through the work. Do not be intimidated by the advanced problems. Master the objectives, taking one step at a time toward completion.

This text will prepare the reader to calculate correct doses of medications. Mathematical skills are necessary to master the material. These include simple skills of addition, subtraction, multiplication, and division. Slightly more complex skills include factoring and use of whole numbers, mixed numbers, decimal numbers, negative numbers, and fractions. They also include converting from one unit (such as hours) to another (such as minutes). The ability to solve simple ratio equations to determine one unknown factor is also necessary.

Many calculations in this text can be easily derived intuitively, in one's thoughts, without setting up an equation. There are problems with using this shortcut of intuitive deduction. The text will progressively build from simple and easily solved problems to more complex problems. Complex problems will require equations for their solution. Practice with the early,

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simple problems will prepare the clinician to set up and solve later, more complex ones. Solving problems intuitively is good practice. Go ahead and get an intuitive answer. Then set up an equation to solve for the same answer and check the calculations.

Most problems presented in this text represent doses of actual medications. They are usually American Heart Association–Advanced Cardiac Life Support medications and doses.

The text has attempted as much as possible to avoid gender-specific pronouns. However, whenever syntax made it necessary, the masculine pronouns *his* or *he* are used to simplify grammatical structure. This is a standard grammatical convention and in no way is intended to slight female patients, physicians, or clinicians.

That is the beginning of Knowledge,  
the discovery of something  
we do not understand.

—Frank Herbert. *Dune*. Randor, PA: Children Book Company; 1965.

### Exhibit 1-2

## OBJECTIVES

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Upon completion of this chapter the clinician should be able to:

1. Discuss patient rights in receiving medication
2. Discuss patient rights to privacy as provided by the HIPAA Privacy Rule
3. Discuss the health care professional's responsibilities in administering medication
4. Identify regulating agencies and legislation regarding medication
5. Discuss origins and major classifications of medication
6. Identify how medication is supplied, including pills, tablets, capsules, prefilled syringes, ampules, vials, etc.
7. Discuss factors influencing dosage, such as patient weight, age, sex, allergies, medical history, pregnancy, and concomitant medications
8. Discuss untoward effects of medication, including dependence, side effects, tolerance, and idiosyncratic reactions
9. Differentiate between parenteral and nonparenteral routes of administration and related rates of adsorption into the body systems

10. Discuss the therapeutic envelope, including subtherapeutic doses and toxic doses
11. Discuss the risk of transmission of infectious diseases associated with administering medication and techniques with which the clinician may reduce risk

## KEY TERMS

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acquired tolerance	hallucinogen
addiction	hypersensitivity
affect	hypnotic
allergy	informed consent
ampule	inotropic
anaphylactic reaction	inscription
antibiotic	intracardiac
antidepressant	intraocular
antidysrhythmic	intradermal
antihistamine	intramuscular
antihypertensive	intraosseous
antihypoglycemic	intravenous
barbiturate	MedicAlert
behavioral toxicity	medicine
cardiotonic	mineral origin
chemical name	mucosa
chemotherapy	narcotic
chronotropic	nonparenteral
concomitant	organic
confidentiality	overdose
dependence	parenteral
depressant	PDR
diuretic	percutaneous
dose	potentiation
effect	rate
elixir	recombinant DNA therapy
endotracheal instillation	serum
ethics	side effect
FDA	sign
first pass effect	signature
generic name	solution
habituation	stimulant
	subcutaneous

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sublingual	tolerance
subscription	toxic
superscription	trade name
suppository	tranquilizer
synergism	untoward effect
synthetic origin	vaccine
syringe	vasopressor
therapeutic	vial
therapeutic envelope	withdrawal

### CASE STUDY

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The fire department lieutenant received the call while he was on duty. There were no emergencies at the moment, so he called in a replacement to cover his position. The call was that his teenage daughter, who had been sick with a cold, had developed a fever, so his wife took her to the emergency department of the local hospital to be examined and medicated. There was no urgency or rush, but the lieutenant wanted to stop by and make sure his daughter was OK. It took about an hour for his replacement to arrive. As he left the office, the phone was ringing, but he didn't stop because he knew his replacement could handle whatever was coming in. He forgot his cell phone in his hurry to get to the hospital. He didn't speed. He arrived and entered the emergency department. People he knew and worked with every day were quiet. No one made eye contact with him. A chaplain met him and asked him to join him in the church chapel. This alerted him that something was seriously wrong. He asked, "Where's my wife? How is my daughter?" "She's in the chapel," the chaplain replied, "and your daughter is what we need to talk about." In the chapel his wife was crying quietly. Minutes later he learned his daughter was dead. The tragedy of her death stunned him and his wife. They couldn't understand why she had died from a cold. Was this some kind of rare virus? Did they miss something about her illness? Did they contribute to her death by not insisting she go to the doctor sooner? All the staff could tell them was that they gave her an antibiotic for her illness, and she seized and went into cardiac arrest with **signs of anaphylactic reaction**. Their words were guarded, and they would not say more than the very basics of what had happened. He asked what antibiotic they had given her. The answer chilled his heart. The hospital staff had given his daughter a medication to which she was acutely allergic. The joy of his life was now dead because somebody prescribed and somebody else gave a medication without reading the patient's chart or asking the sick but very alert teenager

about her allergies. She would never graduate, never marry, never have children, and never come home again.

## INTRODUCTION

This is a true case study with slight modifications! As you study this text, try to imagine how the clinician who gave that medication feels about the mistake, and remember your responsibilities when you calculate and give a dose.

Any text that proposes to deal with the topic of dosage calculations is obligated to address more than the mathematical calculations required to derive the correct **dose**. Many other issues—such as the patient’s rights, the clinician’s responsibilities, the **effects** of drugs, how the drugs work, and how they are administered—are included. The concept of rights and responsibilities is a primary one to the act of administering medications and serves here as the introduction to this book.

## PATIENT RIGHTS

Every mentally competent adult living in a democratic society has the right to refuse or discontinue medical treatment at any time. This concept dates to one of the earliest human rights documents—the Magna Carta, signed by King John in 1215—which stated:

No freeman shall be taken, or imprisoned, or outlawed, or exiled, or in any way harmed, nor will we go upon him nor will we send upon him, except by the legal judgment of his peers or by the law of the land.<sup>1</sup>

A patient receiving a medication must give **informed consent** to be treated before receiving the medication. Case law defining a patient’s right to refuse treatment dates to 1767. Justice Corderzo ruled in a case involving New York Hospital in 1914:

Every human being of adult years and sound mind has a right to determine what should be done with his own body; and a surgeon who performs an operation without his patient’s consent commits an assault for which he is liable in damages.<sup>2</sup>

The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research identified in its Belmont Report three

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<sup>1</sup> Magna Carta (1215).

<sup>2</sup> New York Circuit Court Ruling (1914). Justice Corderzo.

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conditions for consent to be “informed.” These include information, comprehension, and voluntariness as paraphrased here:

The patient should be given accurate information, in simple language about the treatment, its potential risks and benefits, and alternatives. The patient must comprehend the information given. Informed consent may only be granted by a competent adult who understands the information provided. This condition may not be properly met if the information is presented in too technical a manner, a language in which the patient is not fluent, or to a patient who is emotionally or mentally impaired by alcohol, drug abuse, or health disabilities.<sup>3</sup>

Voluntariness means the consent must be made without coercion. There should be no excessive pressure or reward for the patient’s consent.

Clinical human research has been recognized as an important method of obtaining information about disease and treatment. The rights of patients to be informed of and participate in an experiment must also be protected. The Nuremberg Code and the Declaration of Helsinki define conditions for human research. The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research reinforces this concept.

Patients also have a right to **confidentiality** (privacy) regarding their medical care. Health care providers may discuss a patient’s medical information with other providers. In fact, they have a responsibility to do so. However, a patient’s medical information should not be discussed with persons not involved in the patient’s care. Clinicians should not discuss a patient where they may be overheard. This is a violation of the patient’s right to confidentiality.

Some states define situations in which a patient does not have a right to confidentiality. These usually include gunshot wounds and child abuse. Child abuse is excepted from confidentiality on the basis that the victim is not a competent adult and can only be protected if the abuse is reported. Gunshot wounds are usually excepted because assault with a deadly weapon is a felony and requires being reported by law.

The U.S. Department of Health and Human Services issued the Privacy Rule to implement federal legislation passed in 1996. That legislation was the Health Insurance Portability and Accountability Act (HIPAA). HIPAA caused a stir in the health community workplace as providers took steps to

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<sup>3</sup> Spivery, W. H. (1989, July). Informed consent for clinical research in the emergency department. *Annals of Emergency Medicine*. 18(7).

ensure the privacy of patient records and to inform patients of their privacy rights. (It is beyond the scope of this text to provide a legal definition of the act. The act can be accessed at <http://www.hhs.gov/ocr/hipaa>. The information presented here is a simplified overview and should not be used as a guideline for policy development.)

HIPAA identifies protected health information (PHI) that agencies governed by the act must keep confidential for patients. Those agencies are called “covered entities.” Covered entities may include hospitals, emergency medical service providers, physical therapy centers, medical insurance plans (including private, government, and charitable plans), and others. PHI includes any individually identifiable health information held or transmitted by a covered entity or its business associate, in any form or media, whether electronic, paper, or oral.

Most employing agencies that are covered entities now have organizational policies in place to ensure that employees comply with HIPAA. A clinician who has questions should refer to both the act and his employer, to understand the employer’s interpretation of the act. Nothing in the act prohibits disclosing information to the individual patient.

HIPAA permits disclosure of protected information to law enforcement under six circumstances:

Covered entities may disclose protected health information to law enforcement officials for law enforcement purposes under the following six circumstances, and subject to specified conditions: (1) as required by law (including court orders, court-ordered warrants, subpoenas) and administrative requests; (2) to identify or locate a suspect, fugitive, material witness, or missing person; (3) in response to a law enforcement official’s request for information about a victim or suspected victim of a crime; (4) to alert law enforcement of a person’s death, if the covered entity suspects that criminal activity caused the death; (5) when a covered entity believes that protected health information is evidence of a crime that occurred on its premises; and (6) by a covered health care provider in a medical emergency not occurring on its premises, when necessary to inform law enforcement about the commission and nature of a crime, the location of the crime or crime victims, and the perpetrator of the crime.<sup>4</sup>

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<sup>4</sup> U.S. Department of Health and Human Services, Office of Civil Rights. *HIP-PAHIPAA: Medical Privacy National Standards to Protect the Privacy of Personal Health Information*. Retrieved July 24, 2008, from <http://www.hhs.gov/ocr/privacysummary.pdf>.

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HIPAA provides a criminal penalty: “A person who knowingly obtains or discloses individually identifiable health information in violation of HIPAA faces a fine of \$50,000 and up to one-year imprisonment.”<sup>5</sup>

Violating a patient’s rights is not usually a criminal act. A violation of criminal law is either a misdemeanor or a felony. Violation of a person’s rights is a tort. To remedy a tort, restitution is sought in a civil court, rather than with police officers and a criminal court.

Medical ethics are an important consideration for any clinician who gives medication. **Ethics** is the study of right and wrong. There are no clearly defined absolutes of what a clinician should do. Ethical decisions about health care may be guided by civil law but usually result from individual decisions. General Robert E. Lee summed it up when he said, “Do your duty in all things. You cannot do more, you should never wish to do less.”<sup>6</sup>

One guide to medical ethics is the Oath of Geneva (Exhibit 1-3), developed by the World Health Organization in 1948.

I solemnly pledge myself to consecrate my life to the service of humanity; I will give to my teachers the respect and gratitude which is their due; I will practice my profession with consciency and dignity; the health of my patient will be my first consideration; I will respect the secrets which are confided in me; I will maintain by all the means in my power the honor and noble traditions of the medical profession; my colleagues will be my brothers; I will not permit considerations of religion, nationality, race, party politics, or social standing to intervene between my duty and my patient; I will maintain the utmost respect for human life from the time of conception; even under threat, I will not make use of my medical knowledge contrary to the laws of humanity. I make these promises solemnly, freely, and upon my honor.

—Adopted by the General Assembly of the World Medical Association, Geneva, Switzerland (1948, September). Amended by the 22nd World Medical Assembly, Sydney, Australia (1968, August).

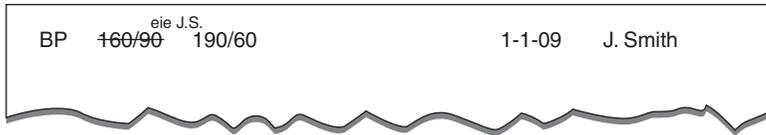
Exhibit 1-3 Oath of Geneva

## THE CLINICIAN’S RESPONSIBILITIES

All medication doses should be recorded in the patient’s chart or report. This chart or report is a legal document and medication administration record. Legal documents are admissible as evidence in a court of law.

<sup>5</sup> Ibid.

<sup>6</sup> Custis Lee, G. W. (1852, April 5). Letter to his son. Published in *The New York Sun* on November 26, 1864. Also inscribed beneath his bust in the Hall of Fame on the former New York University campus in New York City.



**Figure 1-1** Sample Chart

There are standard accepted practices in medical charting. Violation of these practices will work to the charting clinician's disadvantage in a malpractice legal action. The clinician will have to explain why the chart was not completed properly. An opposing attorney may imply there are only two valid reasons: incompetence or dishonesty.

Charting practices are based on common sense and are intended to standardize charts' contents. Nothing should be erased, whited out, obscured, or added at a later date to change a chart unless the change is clearly documented.

When changes are required, the clinician should mark through any error with a single line. He should not completely obscure the error. The correction should then be made. The chart should also be marked with the notation EIE (for "entered in error") (Figure 1-1) or the indication "error" and the initials of the person making the correction. It is not acceptable to write over an error, thereby correcting it, such as in changing a 7 to a 9. Writing over an entry may raise doubts about which number was correct and why a correction was not made in the standard way. Additions should be made in the same manner and should include a date indicating the notation is an addition.

Medications given in a dose that is less than a whole number should be recorded with a zero before the decimal to avoid error.

*For example:* A patient receives two pills of 0.5 g of medication in each pill. The chart would read "gave 1 g in two pills of 0.5 g each" of whatever medication is administered.

The written record of medication given to a patient should always be initialed by the person giving the medication. The first initial and the last name is the most appropriate chart entry in this case. The time, date, and reaction (or absence of one) to the **medicine** should also be recorded whenever possible.

## REGULATION AND STANDARDIZATION OF MEDICINE

The federal Food and Drug Administration, known as the **FDA**, is a division of the U.S. Department of Health and Human Services. The FDA was established by the federal Food, Drug, and Cosmetic Act of 1938 and subsequent, related legislation.

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The FDA periodically visits, inspects, and collects samples from drug-manufacturing and storage facilities. The samples then are analyzed at one of the FDA's 19 district laboratories for quality, purity, and correct labeling.

The FDA must approve any new products offered for sale or interstate traffic in the United States. New medications and medications from other countries must meet a thorough approval process before being marketed in the United States.

The Harrison Narcotic Act of 1914 set up regulation for narcotics and other controlled substances. It was amended, to increase the list of controlled substances and to increase penalties for illegal trafficking, in 1956 by the Narcotic Control Act.

The Bureau of Narcotics and Dangerous Drugs was an agency of the Department of Justice that kept a registry of physicians who were permitted to give out or prescribe controlled substances. It was replaced by the Drug Enforcement Agency (DEA) in the Controlled Substances Act of 1970. The DEA issues a registration number to each physician who is licensed to dispense controlled medications.

### Parts of a Prescription

A prescription is an order written by a physician, dentist, or practitioner licensed to prescribe medication. It authorizes a pharmacist to dispense medications regulated and controlled by the FDA under the federal Food, Drug, and Cosmetic Act.

A prescription has four format components: the inscription, the subscription, the superscription, and the signature.

- The **inscription** is the body of the prescription. It contains the name of the medication, its concentration, the form of the drug (pill, liquid, etc.), and the dose.
- The **subscription** is directions to the pharmacist about preparation of the medication.
- The **superscription** is the “Rx” symbol. It literally translates as “take thou.”
- The **signature** includes the physician's signature and instructions to the patient. It also includes general information, such as the physician's address and narcotic registry number, the date, and whether the prescription may be refilled.

### Standards of Medications

The *Physician's Desk Reference*, also known as the **PDR**, is an unofficial reference text published annually. It is a compilation of information

concerning drugs, including indications, dosages, precautions, **side effects**, contraindications, etc. The information is essentially the same as that included in the package insert required by the FDA in prescription medications.

The standards for drugs are published in the *United States Pharmacopeia* (USP) every five years. It has included the National Formulary since 1975. The USP is the authorized source of information on drugs, their chemical composition, quality tests, storage requirements, and their preparation. The USP is prepared under supervision of a national committee of pharmacists, pharmacologists, physicians, chemists, biologists, and other scientific and allied personnel. The *United States Pharmacopeia* was adopted as standard in 1906.

## ORIGINS OF MEDICATIONS

There are five origins of medication: animal, vegetable, mineral, synthetic, and electrical. Electrical energy is more correctly a therapy rather than a medication. It is addressed here because electrical therapies have doses of energy that must be calculated.

Animal origin includes all medicines, serums, and vaccines developed from human or animal origin. Insulin is an example of a medication once made only from pig and cow pancreases. It is now synthetically produced. Most medications of animal origin are either vaccines or serums.

**Vaccines** are **solutions** containing infectious agents. The intent is to administer an infectious agent to the patient to stimulate the patient's own immune system to generate antibodies to combat future infections. The infectious agents used as vaccines are deliberately weakened before injection to avoid giving the patient the disease. Vaccines are used prophylactically to prevent infection.

**Serums** are made by vaccinating lab animals, such as horses or human volunteers, with less-than-fatal doses of a disease organism. This allows the animal to create antibodies. Blood with the desired antibodies is then removed from the animal, processed, and used as a serum to treat others who have contracted or been exposed to the disease. Antivenin for the treatment of snakebites is an example of a serum.

Vegetable origin includes all medications derived from plants and plant products. For many years it was known that a tea made from the foxglove plant helped patients with chest pain. Modern research discovered the active ingredient of the foxglove was digitalis. Digitalis is now one of the most prescribed medications for cardiac patients.

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Many other medications have been derived from plant products. Penicillin was discovered as a mold growing on bread. Aspirin, opium, quinine, reserpine, and ergot are other plant products.

The Amazon River basin has contributed many medications. Many environmentalists believe there may be thousands of undiscovered medically beneficial plants in the Amazon River basin alone.

**Mineral origin** includes necessary vitamins and minerals, such as calcium, iron, and potassium. Boric acid, Epsom salts, and iodine are other medications of mineral origin.

**Synthetic origin** drugs are manufactured in a laboratory. These include medications created by chemical reactions or by gene-splicing techniques.

**Recombinant DNA therapy** origin is the name given to gene-splicing techniques that create new organisms. Scientists have been able to introduce genes into some bacteria or yeast to make them produce something new. Human insulin is now being created by recombinant DNA therapy. Eli Lilly and Company has the trademark Humulin, which is an insulin product “structurally identical to the insulin produced by your body’s pancreas.”<sup>7</sup>

The advantage to this is that a more pure product with fewer side effects can be manufactured. There is a lower incidence of allergic sensitivity. As a synthesized product, it can be produced in a non-disease-producing laboratory without the risk of using blood serums that have undetected blood-borne disease.

Recombivax is a trademark medication of Merck & Co. It is a vaccine of recombinant DNA therapy against hepatitis B. Older forms of the anti-hepatitis B vaccine were made from the blood serum of professional blood donors, whose profit motive may have encouraged inaccurate reporting of health risk factors. With the advent of human immunodeficiency virus (HIV) and its associated disease, acquired immunodeficiency syndrome (AIDS), health care providers were concerned about the possibility of undetected disease in the blood serums. The development of synthetic medication eliminates the possibility of an undetected infection being present in donor blood.

As mentioned earlier, electrical origin is not actually a medication. It is more correctly a therapy. Electrical energy is measured in doses and may interact

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<sup>7</sup> Eli Lilly and Company. *Information for the Patient: Humulin N (NPH Human Insulin)*. Retrieved July 24, 2008, from <http://pi.lilly.com/us/humulin-n-ppi.pdf>.

with other medications, especially digitalis, so it will be addressed in this text. Electrical energy is used to control abnormal heart rhythms (dysrhythmias) by shocking the heart to regulate its rate or to convert the rhythm to a more normal one.

## CLASSIFICATIONS OF MEDICATION

Medications are commonly classified in many ways. Two of the most common are by their actions or by their composition.

In the United States, medications are either controlled and available only by prescription or less stringently controlled and available over-the-counter without a prescription. Any medication or drug may be abused. Abuse is use of a medicine in a manner other than required for therapeutic management of an illness or injury.

**Antibiotics** are medications used to counter infections by bacterial microorganisms.

**Antidepressants** are used to counter emotional depression. These usually produce central nervous system depression.

**Antidysrhythmics** regulate or improve heart rhythm. These may be prescribed prophylactically, to prevent abnormal rhythms, or reactively, to treat existing abnormal rhythms.

**Antihistamines** counter histamine actions. These are used by persons suffering from some gastric ailments, allergies, and hay fever. Many antihistamines are sold over-the-counter.

**Antihypertensives** are a group of medications that counter high blood pressure (hypertension).

**Antihypoglycemics** are medications that stimulate insulin secretion in patients with Type II diabetes.

**Barbiturates** are **organic** compounds derived from barbituric acid. These are central nervous system **depressants** and highly addictive. They are used to induce sleep, relieve pain, and control seizure activity.

**Cardiotonics** are medications that improve the contractility (or rate) of the heart.

**Chronotropics** are medications that affect the heart rate.

**Diuretics** are medications that stimulate the production of urine. These are used in patients with diseases, such as congestive heart failure, that result in too much fluid in the body.

**Hallucinogens** induce hallucinations. Hallucinations are false sensory perceptions, such as seeing visions, hearing voices, feeling something, etc. Hallucinogens are frequently abused for recreational use. Lysergic acid

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diethylamide (LSD) was a popular hallucinogen in the 1960s. It is still an abused drug but is less popular now.

**Hypnotics** are sedatives that induce sleep. Some hypnotics are also barbiturates. *Hypnotic* refers to the medication's actions, while *barbiturate* refers to its composition.

**Inotropic** medications are cardiotonics that increase the contractility of the heart.

**Narcotics** depress the central nervous system. They relieve pain, induce sleep, and in excessive doses, produce coma and death. Narcotics are addictive, controlled medications. Heroin is an addictive narcotic derived from morphine. Its importation, sale, and use in the United States are illegal. Medical scientists agree its pharmacokinetic actions can be accomplished by other, less addictive drugs.

**Stimulants** are medications that increase the target organ's activity. Amphetamines are central nervous system stimulants that are sometimes prescribed as diet pills. They are commonly abused and illegally purchased from uncontrolled sources. Cocaine is another highly popular, dangerous, addictive stimulant of abuse.

**Tranquilizers** reduce anxiety and mental tension. This may have the indirect effect of enabling the anxious patient to sleep. Tranquilizers are psychologically and physically addicting. They are frequently unintentionally abused. It is difficult to achieve the appropriate level of relaxation without side effects of drowsiness, slowed reactions, and occasionally emotional depression.

**Vasopressors** are medications that cause the contraction of the capillaries and raise resistance to the flow of blood. This causes an increase in blood pressure.

Other major categories of medications include analgesic, anesthetic, antiepileptic, antifungal, antipyretic, antispasmodic, antitussive, bronchodilator, cathartic, cholinergic, and many more.

## HOW MEDICATION IS IDENTIFIED

Every legal medication in the United States is labeled. The medication label provides important information, including trade name, generic name, strength or concentration, number or amount of medication units, expiration date, usual dosage, special precautions, and manufacturer's name.

The **trade name** is given to a medication by its manufacturer. This is marked by a small *R* enclosed by a circle (®). This symbol means the name

is a registered trademark. The first letter of a trade name is capitalized. Different pharmaceutical companies may give different trade names to the same medication.

The **generic name** is given to the medication by the first manufacturer or discoverer. It is usually related to the drug's chemical structure. (This text will use the generic name for medications.) The **chemical name** reflects the drug's chemical structure. This name is derived with firmly established scientific guidelines. It reflects the exact chemical makeup of the medication.

The *United States Pharmacopeia* is the authorized treatise on drugs in the United States.

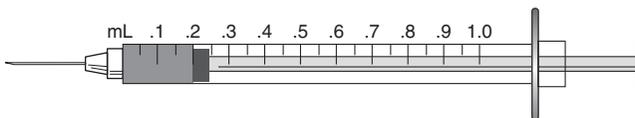
**Exhibit 1-4** *United States Pharmacopeia*

## HOW MEDICATIONS ARE SUPPLIED

Oral medications may be supplied as round tablets (such as aspirin), elongated tablets, or capsules. Occasionally, a tablet is coated to facilitate its adsorption or cause a time-released effect. Capsules are cylindrical-shaped gelatin containers that enclose a single dose of medication, sometimes a liquid or suspension. The purpose of the capsule is to protect the patient from an unpleasant taste while taking the medicine.

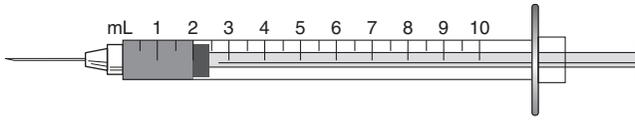
Injectable medications may be supplied as prefilled single-dose **syringes**, **ampules**, or multiple dose **vials**. Prefilled syringes have the advantage of being quickly and easily administered (Figure 1-2 and Figure 1-3). These usually do not require dosage calculations. They have the disadvantage of being expensive. If less than the premeasured dose is given, the balance of the syringe must be wasted because a used syringe is inappropriate for storage or reuse with another patient (Figure 1-4).

Ampules are small, single-dose containers with a breakable glass top. They are opened by breaking the glass top off. The clinician then inserts a



**Figure 1-2** 1 ml Syringe

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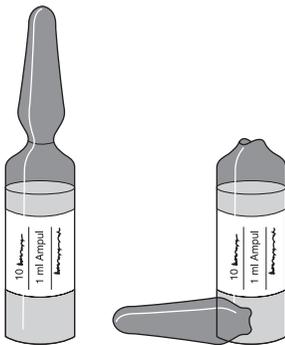


**Figure 1-3** 10 ml Syringe

sterile syringe and withdraws the medication. Ampules have the advantage of being single-dose units, which are relatively inexpensive and easy to store. The disadvantage of an ampule is that it must be handled carefully by the clinician to avoid minor self-inflicted lacerations.

Vials are glass containers with a rubber stopper (Figure 1-5). These may be single-dose containers or may allow multiple doses to be safely withdrawn when needed. The rubber stopper protects the contents from spilling and allows sterile technique to be used while the clinician withdraws medication. Each dose is drawn from the vial with a new sterile syringe. Vials are relatively inexpensive and allow a large range of doses. The disadvantage is that a large vial that is used infrequently may exceed its shelf life and become outdated.

A few medications are supplied as powders. These may be injected or orally administered. If the medication is injected, it must first be mixed with a liquid to form a solution. Medications that are supplied as a powder usually have a very short shelf life when in solution. They are supplied in a powder so they may be stored, without becoming impotent, until use.



**Figure 1-4** Ampule



**Figure 1-5** Vial

## FACTORS INFLUENCING DOSAGE

### Underlying Medical Conditions

Underlying medical conditions or pregnancy may **affect** the manner and dose of the medication administered.

Porphyria is an example of an underlying medical condition. It is a group of diseases in which patients must avoid barbiturates and alcohol. Another example is patients with chronic obstructive pulmonary disease (COPD), who may be dependent on catecholamines and should not receive beta-blocking medications, like propranolol or atenolol. Patients with liver diseases, such as cirrhosis, are unable to metabolize (break down) medications normally. Such people must be treated cautiously with any medication normally metabolized by the liver, such as lidocaine. Pregnancy creates special problems because many medications have undesired effects on the unborn fetus.

Patients with chronic medical conditions often take medication for their ailments. These medications and the possibility of interaction must be considered when giving other medications.

### Age

Infants and children present special dosage problems. They are not simply small adults. Their chemistry is affected by adolescence, body proportion, and an inability to metabolize medications as effectively as adults.

Senior citizens also present special problems. They frequently have hydration problems, such as overhydration from congestive heart failure or moderate dehydration. They also may not metabolize medications as effectively as the typical adult.

### Gender

A patient's gender has several influences on doses of medication. Males and females have body chemistry differences other than their sexual hormones. A female's hematocrit (concentration of red blood cells per unit of volume) and hemoglobin (amount of hemoglobin per unit of volume) measurements are lower than a male's. Men have a lower proportion of subcutaneous body fat than women. Men and women also have differences in the proportion of water volume per unit of body weight.

A woman's ability to receive medication is affected by pregnancy and considerations of how medication may affect the unborn fetus. The use of some medications by pregnant women may cause birth defects in their children.

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The two sexual systems have specific disorders for which medication may be given.

### Weight

Many medications have an effect on the body only within a specific concentration. To achieve a concentration of medication per unit of body water, the patient's body weight frequently serves as a guide to dosage determinations. Some medications are based on actual body weight. Others are based on the patient's ideal body weight. It is important to know which body weight is to be used to make the determination.

Medication is measured in metric units. Calculations related to body weight require body weight measurements in metric units also. It may be necessary to convert the patient's weight from pounds to kilograms.

### Risk-Benefit Analysis

The administration of medication presents difficult choices. The possibility of **untoward effects**, **allergy**, and toxicity must be balanced against the patient's need for medication.

Cancer **chemotherapy** is a well-known example of risk-benefit analysis. One could question the wisdom of taking medication that causes violent vomiting, diarrhea, and hair loss. The benefit of chemotherapy is a desired cure for a disease that would otherwise cause death. In this example the risks are outweighed by the benefit.

The focal point of risk-benefit analysis is "Which presents a greater threat to the patient: the illness or injury or the potential negative effects of the medication?"

Which presents a greater threat to the patient: the illness, the injury, or the potential negative effects of treatment?

**Exhibit 1-5** Risk-Benefit Question

Risk-benefit analysis depends on a thorough knowledge of pharmacokinetics and dosages. The USP and the PDR publish information about adverse reactions, interactions, etc. for this reason.

### Tolerance

**Tolerance** is an individual's capacity to endure medication. Patients with high tolerance require higher doses of medication to achieve a therapeutic effect.

Patients with low tolerance require smaller doses to achieve a therapeutic effect. Patients with very low tolerance may suffer side effects, **hypersensitivity**, an allergic reaction, or **overdose** effects.

Tolerance may be acquired. **Acquired tolerance** develops as a result of the body adapting to the medication. As a patient adapts to a medication, larger doses are required to achieve the desired effect. Acquired tolerance is the first step toward **habituation**, the act of becoming accustomed to medication from frequent use.

A habituated drug user may be dependent or addicted. **Dependence** is a condition in which the user depends on the medication for his psychological well-being but is not physically addicted.

**Addiction**, by contrast, is a condition in which the user has physically adapted to the use of the medication and has acquired tolerance. Continued use of the medication is required to maintain physical well-being. Without continued doses of the drug, **withdrawal** symptoms will occur as the body systems adapt to the absence of the drug. Sudden cessation of drug use, known to some as “quitting cold turkey,” may result in death. Rapidly acquired tolerance is a warning sign of potential addiction.

Drug potentiation can be a major factor in administration of medications. **Potentiation** is a dramatic increase in effect when two or more medications are used at the same time (**concomitantly**) by a patient. The increase in effect is greater than the sum of the medications’ individual effects, if taken separately.

Potentiation can be beneficial by allowing two or more medications to be given concomitantly to achieve a desired effect. The same effect would normally require a larger dose of either medication given individually.

Potentiation can be damaging. The effect of multiple medications may increase beyond expected levels and become **toxic** or lead to behavioral toxicity. A common example is using alcohol while taking medication. Alcohol is a central-nervous-system-depressing drug. It should not be used with other central-nervous-system-depressing drugs, such as tranquilizers, sleeping medications, and some muscle relaxants.

The effects of combining medication(s) and alcohol can be dangerous.

#### Exhibit 1-6 Behavioral Toxicity

**Synergism** is related to potentiation. It is the harmonious action of two agents, not necessarily two medications. One of the agents may be an organ or system or even electricity. Together these agents produce an effect greater than or different from the added effects of both agents taken separately.

Synergy means behavior of whole systems unpredicted by the behavior of their parts.

—Richard Buckminster Fuller.

### Exhibit 1-7 Synergy

**Behavioral toxicity** describes behavior that is detrimental to the patient's well-being. A patient under the influence of an hallucinogen may believe he can fly and jump from a tall building, a toxic behavior, because of that belief.

## ROUTE OF ADMINISTRATION

### Parenteral

A route of administration for medication by any means other than the gastrointestinal tract is a **parenteral** route. These include all forms of injection and adsorption.

### Subcutaneous Injection

A **subcutaneous** injection is an injection given into the fat or connective tissue just beneath the skin. The **rate** of adsorption from this tissue into central circulation is slow. It is the most common route for medications that must be adsorbed over a period of time. Subcutaneous injections are usually limited to a volume of 1 ml or less. Common sites for subcutaneous injection include the superficial deltoid region of the arm and the abdominal area. Tetanus toxoid, epinephrine, allergy desensitization medication, and insulin are all commonly given as subcutaneous medications.

### Intradermal

**Intradermal** (or intracutaneous) injections are given into a layer of the skin. This is commonly used to test for reactions, such as with the tuberculosis skin test or in allergy sensitivity testing. Common sites include the skin of the back or arms.

### Intramuscular Injection

An **intramuscular** injection is an injection into the muscle. The rate of adsorption of medication from a muscle into the central circulation may vary from minutes to hours. Intramuscular medication is adsorbed more quickly

than subcutaneous medication, but it is not as fast acting as an intravenous injection.

An intramuscular injection may be up to 5 ml of solution. The deltoid and the upper outer quadrant of the gluteus maximus are the most common sites for intramuscular injection. The anterior thigh is a common intramuscular injection site in children.

### **Intravenous Injection or Infusion**

The **intravenous (IV)** route of injection or infusion uses direct access to the venous bloodstream. It has several advantages over other injection routes.

The rate of adsorption into central circulation is almost immediate. To be absorbed, intramuscular and subcutaneous injections depend on adequate perfusion. If perfusion is poor, they will not be effectively adsorbed until perfusion is restored.

The intravenous route may be used to replace fluid or blood volume. It may also be used to continuously administer medication over an extended period of time, with great control over the rate of administration.

Adsorption of medication by intramuscular and subcutaneous routes cannot be as effectively controlled as the IV route. These routes are also limited in the amount of medication that can be given.

### **Intraosseous Infusion**

**Intraosseous** infusion is a technique of infusing medication directly into the bone marrow of a patient's long bone. This technique provides rapid vascular access in a critically injured infant or child. It is not considered a replacement for intravenous access but is reserved for emergencies. Medications that are commonly infused via the intraosseous route include atropine, dextrose, epinephrine, lidocaine, Ringer's lactate, and saline. There are no known medications that are absolutely contraindicated for intraosseous use at this time, but hypertonic solutions should be avoided because of the increased risk of osteomyelitis.

### **Intracardiac Injection**

An **intracardiac** injection is an injection of medication directly into a chamber of the heart. This route of administration has no advantages over intravenous or endotracheal instillation. Intracardiac injection has several risks. These risks include injection into the muscle wall instead of into the chamber of the heart, laceration of a coronary artery, puncture of a lung, and interruption of

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cardiopulmonary resuscitation. For these reasons, it is no longer a popular route of administration.

### Topical

Topical adsorption through the skin (**percutaneous**) or mucus membranes is a common route of administration. Some medications and many toxins can be adsorbed directly through the skin. Nitroglycerine paste or pads are examples of topical administration.

### Mucosal

A mucus membrane frequently used is the area under the tongue. This is the **sublingual** route. It is used to administer nitroglycerine. It results in rapid adsorption directly into the circulatory system. Another mucus area is the eyes. Eyedrops are adsorbed through the **mucosa** of the eyes. Nose drops and nasal aerosols are also adsorbed through mucus membranes.

### Inhalation

Inhalation is used for aerosol medications given to patients with lung disease or difficulty breathing. The most commonly administered medication, oxygen, is administered by inhalation.

### Endotracheal Instillation

**Endotracheal instillation** is a technique of administering medication through an endotracheal tube into the mucosal membrane of a patient's lungs. An endotracheal tube is a sterile tube introduced into the mouth that reaches down the trachea into the main bronchus of the lungs. Medication administered by this route is rapidly adsorbed by the mucosa of the bronchi. This route is used in cardiac arrest emergencies when intravenous access is delayed. A popular mnemonic—NAVEL—is a reminder of five medications commonly administered through this route. It stands for naloxone (Narcan<sup>®</sup>), atropine, Valium, epinephrine, and lidocaine.

### Nonparenteral

**Nonparenteral** routes of administration are through the alimentary canal. The alimentary canal is the digestive tract, which begins at the mouth and ends at the rectum. Nonparenteral medications are taken orally or rectally. These include suppositories, pills, caplets, gel caps, **elixirs**, and liquids, such as cough medicine or nose sprays.

Rectal **suppositories**, or rectal administration by soft catheter, are given for patients with active vomiting or rectal or lower gastrointestinal ailments, such as acute constipation. They are also given to pediatric patients who will not accept oral medication. Suppositories are commonly prescribed for patients who are vomiting and are unable to take or keep down oral medication. Some suppositories may be administered vaginally.

Medications given through the digestive tract are painlessly and easily taken. These medications are commonly prescribed for patients to take at home. A disadvantage of oral medicines is the first pass effect.

## FIRST PASS EFFECT

The **first pass effect** is one of several ways the body metabolizes medication. The digestive tract has a circulatory pathway, or portal circulation, of blood from the digestive organs into the liver. The liver metabolizes foreign substances in the bloodstream. The cleaned-up blood passes out of the liver through the hepatic vein into the inferior vena cava. Orally administered medications are partially metabolized by the liver in the first pass through the portal circulation, before they pass through the rest of the body. This reduces, but does not completely eliminate, medications' effectiveness. The first pass effect must be considered when determining doses of oral medicines.

Additional disadvantages to accurate dosing occur when liver (hepatic) function is impaired. A normal dose, usually reduced by the first pass effect, may unexpectedly be excessive. Medication may not metabolize, as normally expected, by the first pass effect through the portal circulation because of a patient's liver failure. The medication builds up in the blood stream and may quickly approach overdose concentration.

## BLOOD BRAIN BARRIER

The blood brain barrier, also known as the "hematoencephalic barrier," is a delicate membrane lining blood vessels in the brain. It separates nerve tissue of the brain from the circulatory system. It partially insulates the brain from damaging chemicals in the blood and helps control body regulatory mechanisms. Some medications diffuse across this barrier.

Antihistamines, for example, may be taken for sinus congestion and headaches. Most antihistamines cross the blood brain barrier and induce drowsiness. If drowsiness is not desired (an untoward effect), an antihistamine that doesn't cross the barrier would be more effective.

## DOSAGE

A dose of medication is the quantity to be administered at one time. A **therapeutic** dose is an amount that will produce the effects for which it is given. A quantity too small to produce the desired effect is subtherapeutic, or below therapeutic levels. A quantity that is too large and produces undesired effects is suprathereapeutic and is an overdose. Overdoses that produce deleterious effects are toxic. A lethal overdose results in death.

A loading dose is an initial dose intended to establish therapeutic levels of medication. Maintenance doses maintain the therapeutic level but are generally smaller than the loading dose. A therapeutic hiatus is a drop in the medication level to a concentration below a therapeutic level. This occurs when a loading dose is not properly followed with maintenance doses.

## THERAPEUTIC ENVELOPE

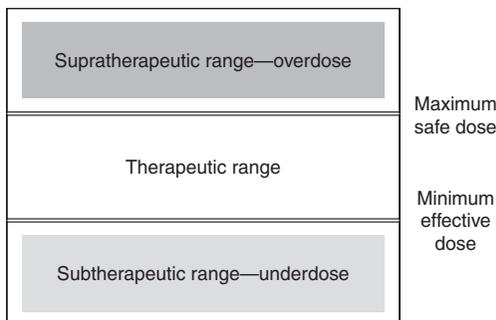
The **therapeutic envelope** is a range of dosages, from the smallest effective dose to the strongest effective dose, within which a medication has a beneficial effect on the patient (Figure 1-6).

## INFECTIOUS DISEASES

Infectious diseases may be transmitted between health care provider and patient. The risk of contracting an infectious disease is manageable and may be reduced to a very minimal risk.

The disease of greatest concern may be acquired immunodeficiency syndrome (AIDS). This disease is caused by the human immunodeficiency virus (HIV). Other diseases, such as tuberculosis, are also dangerous and opportunistic infections. Many AIDS patients have asymptomatic tuberculosis.

HIV is transmitted through sexual contact, exposure to infected blood or blood components, and perinatally from mother to neonate. HIV has been



**Figure 1-6** Therapeutic Envelope

isolated from blood, semen, vaginal secretions, saliva, tears, breast milk, cerebrospinal fluid, amniotic fluid, and urine and is likely to be isolated from other body fluids, secretions, and excretions. However, epidemiologic evidence has implicated only blood, semen, vaginal secretions, and possibly breast milk in transmission.<sup>8</sup>

The U.S. Department of Health and Human Services has a division entitled the Centers for Disease Control and Prevention. The Centers for Disease Control and Prevention is frequently called the CDC.

The CDC has published in the *Morbidity and Mortality Weekly Report* “Recommendations for the Prevention of HIV Transmission in Health Care Settings.”<sup>9</sup> Compliance with these recommendations will protect the provider against all other infectious diseases transmitted through body fluids. (Please refer to Exhibit 1-8.)

Health care workers are continually exposed to patients with infectious diseases. An exposure with a high probability of causing infection is a significant exposure.

The significance of an exposure depends on the manner in which the disease is communicated and the type of exposure. For example, a health care worker who has an immunity from a childhood exposure to chicken pox is exposed to a child with chicken pox. This exposure is not significant because the worker has a preexisting immunity to the disease.

Many serious diseases, including AIDS and hepatitis B, are blood borne. Blood-borne diseases require an exposure of body fluids—such as semen, vaginal secretions, breast milk, or blood—to contact a person’s body fluids or mucus membranes for the disease to be communicated. Blood-borne diseases may be transmitted sexually. Significant exposures to blood-borne diseases can occur as listed in Exhibit 1-9 on page 27. The risk of hepatitis B being contracted during exposure to a patient’s blood is high. This risk can be almost completely eliminated by administration of the antihepatitis B vaccine before potential exposure. Professional health care providers are unwise and may present a risk of infection to others if they fail to take advantage of this excellent vaccine.

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<sup>8</sup> U.S. Department of Health and Human Services, Centers for Disease Control. (1988, June 24). Update to Universal Precautions for Prevention of Transmission of Human Immunodeficiency Virus, Hepatitis B Virus, and Other Blood Borne Pathogens in Health Care Settings. *Morbidity and Mortality Weekly Report*, 37(24).

<sup>9</sup> U.S. Department of Health and Human Services, Centers for Disease Control. (1987, August 21). Recommendations for Prevention of HIV Transmission in Health Care Settings. *Morbidity and Mortality Weekly Report*, 36(2S).

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1. Take care to prevent injuries when using needles, scalpels, and other sharp instruments or devices; when handling sharp instruments after procedures; when cleaning used instruments; and when disposing of used needles. Do not recap used needles by hand; do not remove used needles from disposable syringes by hand; and do not bend, break, or otherwise manipulate used needles by hand. Place used disposable syringes and needles, scalpel blades, and other sharp items in puncture-resistant containers for disposal. Locate the puncture-resistant containers as close to the use area as is practical.
2. Use protective barriers to prevent exposure to blood, body fluids containing visible blood, and other fluids to which universal precautions apply. The type of protective barrier(s) should be appropriate for the procedure being performed and the type of exposure anticipated.
3. Immediately and thoroughly wash hands and other skin surfaces that are contaminated with blood, body fluids containing visible blood, or other body fluids to which universal precautions apply.

**Glove Use for Phlebotomy**

*Gloves should always be available to health care workers who wish to use them for phlebotomy. In addition, the following general guidelines apply:*

1. Use gloves for performing phlebotomy when the health-care worker has cuts, scratches, or other breaks in his/her skin.
2. Use gloves in situations where the health-care worker judges that hand contamination with blood may occur—for example, when performing phlebotomy on an uncooperative patient.
3. Use gloves for performing finger and/or heel sticks on infants and children.
4. Use gloves when persons are receiving training in phlebotomy.

*The following general guidelines are recommended for the selection of gloves:*

1. Use sterile gloves for procedures involving contact with normally sterile areas of the body.
2. Use examination gloves for procedures involving contact with mucous membranes, unless otherwise indicated, and for other patient care or diagnostic procedures that do not require the use of sterile gloves.
3. Change gloves between patient contacts.
4. Do not wash or disinfect surgical or examination gloves for reuse. Washing with surfactants may cause “wicking”—i.e., the enhanced penetration of liquids through undetected holes in the glove. Disinfecting agents may cause deterioration.
5. Use general-purpose utility gloves (e.g., rubber household gloves) for housekeeping chores involving potential blood contact and for instrument cleaning and decontamination procedures. Utility gloves may be decontaminated and reused but should be discarded if they are peeling, cracked, or discolored, or if they have punctures, tears, or other evidence of deterioration.

*Adapted from: U.S. Federal Health and Human Services, Centers for Disease Control. Morbidity and Mortality Weekly Report, June 24 and August 21, 1988.*

**Exhibit 1-8** Universal Precautions

Significant exposure varies depending on the substance to which the exposure is made. Chemicals and some diseases may be atmospherically spread or absorbed through the skin. For the purposes of blood-borne pathogens significant exposure is defined by the Centers for Disease Control and Prevention as:

An "exposure" that may place a Health Care Worker (HCW) at risk for Human Immunodeficiency Virus (HIV) infection and therefore requires consideration of PPE [Personal Protective Equipment] is defined as a percutaneous injury (e.g., a needle stick or cut with a sharp object), contact of mucous membrane or nonintact skin (e.g., when the exposed skin is chapped, abraded, or afflicted with dermatitis), or contact with intact skin when the duration of contact is prolonged (i.e., several minutes or more) or involves an extensive area with blood, tissue, or other body fluids. Body fluids include (a) semen, vaginal secretions, or other body fluids contaminated with visible blood that have been implicated in the transmission of HIV infection; and (b) cerebrospinal, synovial, pleural, peritoneal, pericardial, and amniotic fluids, which have an undetermined risk for transmitting HIV. In addition, any direct contact (i.e., without barrier protection) to concentrated HIV in a research laboratory or production facility is considered an "exposure" that requires clinical evaluation and consideration of the need for PPE.

*Source:* Florida Department of Health and Rehabilitative Services, Office of Emergency Medical Services. Program Letter 88–20, October 18, 1988.

#### Exhibit 1-9 More Universal Precautions

## MEDICALERT

Some patients wear a **MedicAlert** tag. MedicAlert is a private nonprofit organization that provides bracelets or pendants for sale to patients who have significant medical conditions. Wearing a MedicAlert tag provides important information about a patient's medical condition or allergy when he is unconscious or otherwise unable to communicate. Always check for MedicAlert tags before administering medication to an unconscious patient in an emergency setting. MedicAlert tags may be purchased at most pharmacies. The organization's Web site is <http://www.medicalert.org/home/Homegradient.aspx>.

Do not believe in anything simply because you have heard it. Do not believe in anything simply because it is spoken and rumored by many. Do not believe in anything simply because it is found written in your religious books. Do not believe in anything merely on the authority of your teachers and elders. Do not believe in traditions because they have been handed down for many generations. But after observation and analysis, when you find that anything agrees with reason and is conducive to the good and benefit of one and all, then accept it and live up to it.

—Buddha.

#### Exhibit 1-10

