Continuing Education Programs

Annual Meetings
San Francisco, California
October 10–15, 1992
Washington, DC
October 30–November 4, 1993

Spring Sessions
Chicago, Illinois
March 20–25, 1993

Continuing Medical Education Courses
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Washington, DC
June 19–21, 1992

Pediatrics for the Practitioner
Seattle, Washington
September 4–6, 1992

Advances in Pediatrics
Newport, Rhode Island
October 2–4, 1992

Pediatric Update II
Williamsburg, Virginia
December 11–13, 1992

Current Concepts in Pediatrics
Vail, Colorado
January 7–10, 1993

Pediatrics 1993
Maui, Hawaii
March 5–7, 1993

State-of-the-Art Pediatrics
New York, New York
May 14–16, 1993

Pediatric Advances
Hilton Head Island, South Carolina
May 28–30, 1993

To those enrolled in PREP (Pediatrics Review and Education Program), these programs feature subject matter coordinated with the PREP curriculum. Credits earned in these courses may be applied toward the PREP Education Award available to Fellows and Candidate Fellows of the Academy.

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Supplement to Pediatrics in Review
This guide has been prepared by the American Board of Pediatrics (ABP) as an integral part of the record review required for renewal of certification in general comprehensive pediatrics. Its purpose is to provide the pediatrician with criteria for assessing patient records dealing with specific problems. Important elements to be included in the record appear in bold-face type in the margins; other elements to be considered are printed in italics. Please note that these guides do not purport to articulate standards of care. They are designed solely to address record keeping issues.

The guides focus on the elements of the history and physical examination relevant to specific problems and are not meant to discourage a more thorough history and physical examination as appropriate for the patient and the particular circumstances.

The guides will be updated periodically. Because of rapid changes in knowledge about drugs and their availability, drugs and dosages included in these guides should be verified in current sources.

A table of international units is included in each guide.

The guides are planned, written, and reviewed by an ABP committee composed primarily of practicing pediatricians. Appropriate subject experts are consulted during the preparation of the guides.

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INTRODUCTION

Asthma is one of the most important chronic illnesses of childhood and one of the most frequent reasons why a child misses school. Approximately 10% of children may at some time have signs and symptoms of asthma. The disease may produce long-term morbidity and cause considerable psychosocial and financial stresses within a family. Early, aggressive therapy will often reduce the impact of the problem on the child and the family. Careful attention to and recording of detailed information about the child, family, and environment can provide important clues to the etiology, precipitating factors, and the efficacy of treatment. Although longitudinal studies suggest that approximately 50% of children with asthma will be relatively asymptomatic by adolescence, some go on to severe, intractable disease with permanent pulmonary disability. It is not possible to determine in advance which course a child’s asthma will follow, so the physician should counsel the patient and his or her family accordingly.

The basic abnormalities in asthma are hyperreactivity and inflammation, causing obstruction of airways; both the hyperreactivity and the inflammation are amenable to treatment, particularly early in the process. Because the pathophysiology and epidemiology of wheezing-associated respiratory illness tends to be different in infants, this discussion will relate only to asthma in children older than 3 years of age.

EPIDEMIOLOGY

Most children who have asthma have had their initial symptoms by 4 to 5 years of age. Before puberty, more boys than girls are affected; the incidence after puberty is similar in each gender. The incidence within families indicates that asthma may be inherited as a polygenic or multifactorial disorder, with allergy being an important component in many patients. Other known predisposing factors include chronic neonatal lung disease (bronchopulmonary dysplasia) and viral bronchiolitis, especially that caused by respiratory syncytial virus.

Asthma has been classified as immunologic (atopic or allergic; extrinsic) and nonimmunologic (intrinsic). Immunologic asthma often has an IgE-mediated mechanism, but in both types of asthma there is a complex chain of events, including release of chemical mediators from mast cells and basophils, as well as abnormalities of neurohormonal regulation. Many precipitating factors are responsible for individual exacerbations of asthma, the most frequent of which is an acute viral infection. In an allergic child, the inhalation of allergens, or occasionally the ingestion of an allergen such as a food or drug, may incite an attack. Some children regularly experience increased bronchospasm following exercise, or with emotional stress. Nonspecific environmental pollutants and irritants (tobacco, smoke, fumes) and changes in physical environment (humidity, barometric pressure, temperature) may also precipitate episodes of asthma. Gastroesophageal reflux may contribute to asthma by reflex mechanisms or by promoting aspiration of ingested material, but this relationship is complicated by the fact that the child with chronic obstructive pulmonary disease generates greater intraabdominal pressure during expiration or cough and is more likely to have reflux than unaffected children; it is sometimes difficult to determine which is the primary problem.
PATHOPHYSIOLOGY

Asthma is believed to be an inflammatory condition of the airways. Although the initial abnormality in an episode of asthma is often bronchospasm, edema and inflammation of the mucous membranes lining the airways quickly follow. The increased production of mucus and release of inflammatory mediators aggravate the airway obstruction. The result is inadequate air exchange, which may not be uniform throughout the lungs, particularly early in the attack. Hypoxemia follows, stimulating respiration. The resultant hyperventilation may lead to a reduction in arterial PCO₂ and respiratory alkalosis. As the obstructive process worsens, impaired ventilation ensues, causing retention of carbon dioxide and respiratory acidosis. Hypoxemia, dehydration, and inadequate intake of fluid and calories may result in a superimposed metabolic acidosis. When asthma is chronic, pulmonary hypertension and right ventricular strain or hypertrophy may supervene.

PATIENT IDENTIFICATION

Demographic data such as birth date and gender should be present on all charts. Any or all of these variables may be important factors in developing an appropriate differential diagnosis, interpreting laboratory and radiologic data, and determining the safety, efficacy, and appropriate dose of medications. An up-to-date record of immunizations should be a part of every child's medical record.

Because of the frequency of drug therapy in children with asthma, it is essential that any confirmed drug allergies be noted prominently on the chart so that inadvertent prescription of the drug can be avoided. However, the absence of such a notation does not relieve the physician of the responsibility for inquiring about drug sensitivity before prescribing any medication.

HISTORY

There are few diseases for which a careful, detailed, and continuing acquisition of historical information is more important. In some children, clinical wheezing may not have been recognized, but chronic or nocturnal cough or exercise intolerance indicates that bronchial hyperreactivity may be present. The classic symptoms are a tight cough, which is usually nonproductive early in the course of an attack, followed by wheezing, rapid respirations, and dyspnea. Abdominal pain and vomiting are also relatively common. Fever is an indication that infection may be present, and may suggest the need for antibacterial therapy if purulent rhinitis, sinusitis, pneumonia, or other possible bacterial infection is identified. Fever also indicates the need for additional fluid intake. The age of onset may give a clue to the etiology, as will a detailed personal and family history of atopic manifestations such as hay fever or eczema. The careful physician will always remember that "all that wheezes is not asthma"; an acute onset with coughing should raise the suspicion of inhalation of a foreign body, and recurrent pneumonia or other severe manifestations of pulmonary disease may indicate the presence of an immunologic defect, cystic fibrosis, or gastroesophageal reflux.
frequency and duration of the episodes should be noted; the number of hospitalizations and the number of school days missed are helpful indicators of severity, or of inadequacy of treatment. Frequent exposure to infection, as in a day-care setting or school, may cause additional acute episodes. The treatment given previously, its efficacy, and any side effects should be recorded, and may be very helpful in guiding future treatment or in identifying problems of compliance with therapy.

To determine the cause or precipitating factors of asthma in an individual patient, a history of other possible allergic manifestations should be sought. These include eczema, formula intolerance or food allergy, reactions to drugs, recurrent conjunctivitis, persistent or recurrent upper respiratory symptoms, and possibly otitis media. The environmental factors noted above should be reviewed to determine those that apparently predispose to or precipitate attacks. Important questions include exposure to tobacco smoke, molds and dusts, animals, plants and trees, farming or gardening, wood stoves or fireplaces, and toys or pillows stuffed with feathers or other materials. A delay in bronchial response may make it difficult to identify etiologic factors, but it is important to search for such relationships. A seasonal pattern of symptoms may give an important clue to the etiology of asthma, particularly if pollens or molds are significant allergens.

**PHYSICAL EXAMINATION**

Height and weight should be recorded regularly because chronic illness may have an unfavorable effect on growth, as may long-term treatment with corticosteroids. During the acute episode, the pulse rate provides important clues to hypoxia or to anxiety. The respiratory rate should be recorded as an indicator of severity, and as an important, objective measurement to evaluate the course during treatment. Blood pressure should be recorded because the presence of pulsus paradoxus is a clue to the severity of an acute episode, and many of the drugs used in treatment (adrenergic drugs, corticosteroids) may cause hypertension.

The temperature should be recorded because fever may indicate the presence of infection, although some patients may have fever on the basis of dehydration and the increased work of breathing. The eyes should be inspected for conjunctivitis and "allergic shiner." The presence of nasal mucosal edema, obstruction, serous secretions, or polyps may give a clue to the atopic nature of the disease, or there may be evidence of acute or chronic diseases of the upper respiratory tract such as sinusitis or serous otitis media. Clinical cyanosis is uncommon, but when it occurs a true emergency exists. The skin may also provide evidence of underlying atopic disease, such as eczema.
The diagnosis of asthma is dependent largely upon the physical examination and the demonstration of wheezing, but it must be remembered that wheezing may not occur at either end of the severity spectrum. For example, some children may have a persistent and nonproductive cough, especially at night or with exercise. On the other hand, in a child having a very severe acute episode, air exchange may be so compromised that an audible wheeze is not present. If crackles (rales) or evidence of consolidation is present, one should suspect a complication such as pneumonia or atelectasis. Grunting, retractions, and the use of the accessory muscles of respiration are also important clues to severity. The presence of an accentuated second pulmonic heart sound may indicate chronic obstructive pulmonary disease with pulmonary hypertension. The finding of a persistent barrel chest deformity indicates that the disease has been chronic and unremitting in character, and that aggressive prolonged treatment is necessary. Digital clubbing is uncommon but, if present, suggests complicating factors such as cystic fibrosis, infection with Aspergillus fumigatus, and resulting bronchiectasis.

**RADIOLOGIC AND LABORATORY STUDIES**

Although the diagnosis of asthma is largely dependent upon the history and physical examination, some laboratory or radiologic studies are indicated to rule out other diseases. X-ray studies of the chest should be considered to be certain that such diagnoses as a foreign body or chronic obstructive pulmonary disease are not missed. X-ray studies of the chest need not be done with each acute episode, but should be reserved for situations when complications such as pneumonia or atelectasis are suspected. X-ray studies of the upper airway may be needed to rule out other causes of noisy breathing. A barium esophagogram should be done if gastroesophageal reflux or a congenital vascular anomaly is suspected; esophageal pH monitoring may be necessary if reflux is a significant concern. X-ray studies of the sinuses may be helpful if there are clinical indications such as purulent rhinorrhea, posterior nasal secretions, or if a chronic focus of infection is suspected.

Peripheral eosinophilia is often present, but repeated blood counts are usually helpful only to rule out anemia, lymphopenia, and other disorders. A nasal smear for eosinophils may be useful in documenting the allergic nature of the disease if symptoms of rhinitis are present. The serum IgE concentration may be helpful in identifying the atopic individual; other serum immunoglobulin determinations are indicated in wheezing patients with recurrent severe otitis, pneumonia, or chronic sinusitis to rule out immunologic disorders. A sweat chloride determination should be done in all young children with persistent wheezing, or in older children with atypical courses, to rule out cystic fibrosis. Similarly, a tuberculin skin test (eg, PPD) should be done, particularly in high-risk populations, to avoid missing the diagnosis of tuberculosis in a child with persistent cough. In a child who is receiving continuous theophylline therapy, the serum theophylline concentration should be measured until appropriate dosage is established. If poor response to or non-compliance with therapy is a problem or if toxicity is suspected, additional determinations may be necessary.
Although it is not practical to perform detailed studies of pulmonary function in every child with asthma, and they are difficult to perform in children younger than 6 years of age, some measurement of the degree of obstruction to air flow is desirable. Measurement of peak flow is a useful assessment of the degree of obstruction and of its reversibility. The availability of inexpensive peak flow meters makes it practical to obtain such measurements on a regular outpatient basis for those patients able to cooperate. In patients with severe disease, a meter may be provided for home use so that the child and his or her family can monitor the disease. In patients with exercise-induced bronchospasm, the flow meter may provide documentation of the diagnosis, and of its relief by therapy.\textsuperscript{11} Other types of bronchial provocation tests (eg, methacholine, histamine) are probably not indicated in the usual child with asthma. Exercise commonly induces bronchospasm but may not be identified as a provocative factor by the patient or family; an exercise tolerance test can confirm this association. Although the test may be impractical in many office settings, the pediatrician should be aware that exercise often leads to airways obstruction. In general, this manifestation of asthma is easily preventable.

In the asthmatic child in whom atopy is suspected, skin tests are useful in identifying specific respiratory allergens. In young infants, in patients with extensive atopic dermatitis, or when only one or two food allergens are being considered as etiologic factors, the use of one of the specific IgE tests (eg, radioallergosorbent test [RAST], multiple allergosorbent test [MAST], enzyme-linked immunsorbent assay [ELISA]) may be indicated.\textsuperscript{12,13} All children with asthma do not have atopic disease, so it is not appropriate to subject every child to an extensive and expensive battery of skin tests.
MANAGEMENT OF ACUTE ASTHMA

The most urgent objective in the management of acute asthma is relief of hypoxemia if present. Pulse oximetry can be done quickly in an emergency room setting and serves as a reliable identifier of severe hypoxemia. In the office setting, the physician must usually rely on clinical signs. Death from asthma occurs in most instances as a result of hypoxemia; the possibility of this abnormality should be addressed immediately. Treatment of bronchospasm should then be initiated without delay. Two basic classes of drugs are helpful: the β-adrenergic drugs, which can be administered either by inhalation or subcutaneously, and the methylxanthines, which in the acute situation must be administered intravenously and may be less effective. β-adrenergic agonists increase pulmonary shunting and decrease the PaO₂. Therefore, adequate oxygenation is doubly important. For many years, subcutaneous administration of aqueous epinephrine was standard initial therapy for the child with acute asthma; up to three doses were given approximately 15 to 20 minutes apart. Other therapy was not generally considered until the efficacy of epinephrine had been determined. This regimen remains effective and acceptable, but it has the disadvantage of requiring one or more injections. Moreover, epinephrine has both α- and β-adrenergic effects, and troublesome side effects sometimes occur; these include tachycardia, pallor, and tremulousness. In addition, the duration of action is short, and a longer-acting form is needed after immediate relief has been obtained. Terbutaline has been used similarly, but in children it appears to have no definite advantage over epinephrine.

The introduction of more selective and longer-acting β₂-adrenergic drugs has allowed initial management of acute asthma with inhalation therapy via power-driven nebulizers. Older children can use metered dose inhalers, but preschool children have difficulty coordinating administration of the drug with inhalation. Several devices are now available which permit inhalation therapy in young children. These include powdered aerosols which are released into a moving airstream, and the incorporation of some type of spacer into the delivery system for aerosolized drugs. Most studies show that the use of spacers results in effective bronchodilation. The most effective aerosolized drugs are metaproterenol, albuterol, fenoterol, and terbutaline. It is essential that the child and parent(s) be instructed carefully in the proper use of whatever device is prescribed, and that their utilization of it be reevaluated periodically. The advantages of inhalation therapy are that it can be administered at home, and that response, when it occurs, is usually prompt. Overdosage has sometimes been a problem, but may be of less concern with the newer drugs. β-adrenergic therapy should not be relied upon as the only therapy when response is poor; other therapy should be instituted, as described below.

Aminophylline can be administered intravenously to the child with acute asthma. This should be done in a hospital outpatient or inpatient service rather than in an office or home setting. Because the mechanism of bronchodilation brought about by theophylline is somewhat different from that produced by the β-adrenergic drugs, the combination of the two drugs may be more effective than either alone, and should be considered in the child with severe asthma. In the child who is not regularly receiving theophylline orally, a loading dose of aminophylline must be administered to obtain therapeutic serum concentrations. To avoid toxicity, the child who has received theophylline orally within hours of the asthmatic attack should receive a lower loading dose, or a maintenance dose, until the serum theophylline concentration is known. Optimally, a serum theophylline concentration should be determined before aminophylline is administered.
The anti-inflammatory nature of corticosteroids is helpful in combating the delayed reaction of asthma. Although corticosteroid therapy is not indicated for mild to moderately severe episodes of asthma, such treatment should be instituted promptly when an episode is especially severe, when a lack of response to bronchodilator therapy becomes apparent, or when a child has a history of requiring corticosteroid therapy to treat previous episodes.\textsuperscript{19,20} Drugs such as methylprednisolone can be administered parenterally, or prednisone can be administered orally in the absence of vomiting. The therapeutic effects of corticosteroids are not immediate, so treatment should be instituted early if the course appears static or is progressive despite bronchodilator therapy.

Anticholinergic drug therapy is the oldest form of bronchodilator therapy. The development of ipratropium bromide has stimulated new interest in this type of therapy.\textsuperscript{21} The benefits of its use in day-to-day management of asthma in children have not been established.

Some investigators have reported that the newer non-sedating antihistamines have mild bronchodilator activity; there is now re-evaluation of this class of compounds in the therapy of asthma.\textsuperscript{22} The long-held concern that the antihistaminic drying effect may worsen asthma has not been verified, but bronchoconstriction may be aggravated in a few patients.\textsuperscript{22}

Antibiotic therapy is not indicated for most episodes of acute asthma because infection, when present, is most frequently of viral origin. When bacterial infection does occur, it will require antibiotic therapy. Of course, a careful history of drug allergy, particularly to the penicillins, should be obtained before administering an antibiotic to a child with asthma. In the child who is receiving theophylline therapy, erythromycin should be used with caution, and serum theophylline concentrations should be monitored because the drug interactions may result in an increase in the serum theophylline values to a toxic concentration.\textsuperscript{23}

Many children with asthma have vomiting, fever, and poor fluid intake. These factors, along with the increased work of breathing, may cause dehydration. Provision of an adequate fluid intake is therefore essential. However, fluid overload may contribute to pulmonary edema, an occasional consequence of severe asthma. Correction of fluid deficits and provision of fluids for maintenance and ongoing losses should proceed with careful monitoring in the child with impending respiratory failure. If vomiting continues to be a problem, parenteral therapy will be needed. Drugs that suppress the cough reflex should not be administered. The cautious physician will recognize that excessive anxiety may be a manifestation of hypoxia, and know that the administration of a sedative could be disastrous in such a patient.

If the child’s asthma does not respond promptly to initial therapy such as that described, arterial blood gas measurements should be done, and admission to the hospital considered. The inpatient management of severe asthma will not be considered here.
LONG-TERM MANAGEMENT OF ASThma

When wheezing recurs frequently or persists, long-term bronchodilator therapy is indicated. Oral administration of theophylline has been used most widely in the United States despite its disadvantages. Dosage should be monitored periodically with determination of serum theophylline concentrations whenever the patient's clinical condition deteriorates, when there is a question that the serum concentration is not therapeutic, or when toxicity is suspected. Seizures have been reported with increased serum theophylline concentrations. Some children have undesirable behavioral side effects, such as irritability, sleeplessness, learning difficulties, or hyperactivity, especially when therapy is first instituted. Because children tend to metabolize the drug rapidly, it is often necessary to administer at least three doses per day, even of the long-acting preparations, to maintain adequate serum concentrations. Absorption of some preparations may be inconsistent, and influenced by the intake of foods. Drug metabolism may be delayed during intercurrent infections or by simultaneous treatment with antibiotics such as erythromycin. Nevertheless, theophylline is an effective drug for long-term bronchodilation; preparations that may further reduce the required number of doses are being tested.

The β-adrenergic drugs have not been tested as widely in children, but may be useful in some patients, either alone or as an adjunct to theophylline, especially as longer-acting formulations become available. As noted above for treatment of the acute episode, in the child with chronic asthma, these drugs may be administered intermittently in aerosol form, particularly for exacerbations of wheezing, or as a prophylactic measure before exercise or exposure to cold in children who experience bronchospasm under those circumstances.

Cromolyn sodium, which may be effective in the prevention of bronchospasm, has anti-inflammatory properties and will reduce airways reactivity through its action on mast cells, but has been used less in the United States than in Canada or Europe. It must be administered regularly, and by inhalation. Therapy should be initiated when the patient is relatively asymptomatic because effectiveness is not noted until several days after treatment is begun. With continued therapy, it may be possible to reduce the frequency of administration from three or four times a day to twice a day. The drug was initially available only as a powder for inhalation, but now can be administered via a nebulizer or metered dose inhaler. Administration of the powder may result in coughing, which can often be prevented by preliminary administration of an inhaled β-adrenergic drug. Despite its inconvenience, cromolyn sodium is a safe drug, and has the advantage of inhibiting both the early and late reactions of the airways that characterize asthma.

Corticosteroids have anti-inflammatory properties and may enhance responsiveness to β-agonists. They are effective in controlling the symptoms of asthma, but have many undesirable side effects such as growth retardation, hypertension, adrenal suppression, and perhaps immunologic suppression that might lead to other infections (eg, tuberculosis). As noted previously, brief courses (three to seven days) of corticosteroid therapy may be very useful in the management of acute exacerbations of asthma. The continuous, long-term administration and frequent repetition of short courses of corticosteroids for the management of chronic severe asthma should never be undertaken lightly. Consultation is desirable for patients who require extended oral corticosteroid therapy. The smallest effective dose should be administered for the shortest possible period of time; therapy should be administered on alternate days, if possible. Alternatively, corticosteroid therapy may be administered as an aerosol,
using drugs such as beclomethasone, flunisolide, or triamcinolone. Side effects are fewer than with chronic oral therapy, but adrenal suppression and oral candidiasis have been associated. As is recommended for the adrenergic drugs, the use of a spacer device makes aerosolized corticosteroid therapy feasible, even in the young child.

Immunotherapy may be considered in the atopic child in whom efforts at environmental control and drug therapy have not been entirely effective, and in whom specific inhalant allergens can be demonstrated. In general, immunotherapy has been a much more effective therapy for allergic rhinitis than for asthma. These patients may have other allergic manifestations, such as rhinitis or conjunctivitis; antihistamine or other specific therapy may relieve such symptoms.

Children with exercise-induced bronchospasm tend not to participate in sports or other physically stressful activities; the resultant inactivity almost insures lack of physical conditioning. Programs of graded exercise may be helpful in improving cardiac efficiency, gas exchange, and ventilation if used in conjunction with pulmonary therapy and appropriate drugs. Certainly, the child with asthma should not be disqualified if drugs such as theophylline are required to permit participation in sports. Cromolyn sodium has also been used prophylactically prior to exercise, and may be less objectionable than β-adrenergic drugs to those regulating formal, competitive sports, although prior inhalation of β-adrenergic drugs is very effective. Swimming may be a particularly useful and enjoyable activity for children with asthma, and does not appear to precipitate asthmatic attacks.

PATIENT AND FAMILY EDUCATION

Asthma is a chronic disease, and the physician should spend substantial time with the patient and the family in educating them about it. In general, self-reliance should be encouraged, and every effort made to minimize the concept that the child is disabled. Family interaction needs to be evaluated, so that the frustration and expense of caring for a chronically ill child do not begin to influence the parent/child relationship. It is especially important that the child does not utilize his or her disease to manipulate the parents. As with all chronic illnesses, compliance with the many instructions and medication regimens is frequently a problem. The importance of continuing the regimen of therapy should be routinely stressed.

Patients and parents should be alerted to the usual trigger mechanisms that increase the risk of an asthmatic episode, such as an acute viral infection, so that they can observe the child closely for the first signs of difficulty. Early medical attention during an exacerbation is recommended. Such early self-management will probably lead to fewer emergency room visits and hospitalizations. The importance of environmental controls, particularly in the child's bedroom, and of avoiding such obvious incitants as tobacco smoke, needs continued reemphasis. Patients and parents need to be aware of any foods or drugs that may exacerbate symptoms; aspirin, for example, may not be considered a "drug." The effect of acute illness and of erythromycin on serum theophylline concentrations should be communicated, and parents should know the early manifestations of drug toxicity. Patients who are being treated with inhalation therapy require frequent reminders about its appropriate use. Utilization of a peak flow meter is an objective way to monitor patient care. It can be used at home by children 5 years of age and older. Clear criteria should be established for using any drug and for notifying the physician of problems. Overall, time spent in the education of the child with asthma, and his or her family, may ultimately save a physician time in the management of the disease itself, and may prevent acute episodes and some long-term sequelae.
REFERENCES


18. American Academy of Allergy and Immunology, Committee on Drugs: Adverse effects and complications of treatment with beta-adrenergic agonist drugs. *J Allergy Clin Immunol* 75:443, 1985


22. American Academy of Allergy and Immunology, Committee on Drugs: The use of antihistamines in patients with asthma. *J Allergy Clin Immunol* 82:481, 1988


Recommended Reading

### Conversion Table to Standard International (SI) Units

#### I. Hematology
- **Hemoglobin** g/dL x 0.155 = mmol/L
- **Platelets/mm\(^3\)** = count/µL = 10\(^6\) cells/L
- **Leukocytes/mm\(^3\)** = count/µL = 10\(^6\) cells/L
- **Erythrocytes/mm\(^3\)** = count/µL = 10\(^6\) cells/L
- **Hematocrit % x 0.01** = vol RBC/vol whole blood
- **Reticulocytes % x 0.01** = (1)

#### II. Blood Pressure
- **mm Hg (torr) x 1.333** = mbar

#### III. Blood Gases
- **1 mm Hg = 133.322 Pa**
- **PCO\(_2\) mm Hg x 0.1333 = kPa**
- **PO\(_2\) mm Hg x 0.1333 = kPa**
- **pH value = same**

#### IV. Blood Chemistries
- **Acetone mg/dL x 0.1722 = mmol/L**
- **Acetaminophen µg/mL x 6.62 = µmol/L**
- **Albumin g/dL x 144.9 or g/L x 14.49 = µmol/L**
- **Aldosterone ng/dL x 0.0277 = nmol/L**
- **Ammonia mgN/dL x 0.714 = mmol/L**
- **Bicarbonate mEq/L = mmol/L**
- **Bilirubin mg/dL x 17.10 = µmol/L**
- **Blood urea nitrogen mg/dL x 0.357 = mmol urea/L**
- **Calcium mg/dL x 0.25 = mmol/L**
- **Carotene IU x 0.6 or µg/dL x 0.01863 = µg**
- **Ceruloplasmin mg/dL x 0.0662 = µmol/L**
- **Chloride mEq/L = mmol/L**
- **Cholesterol mg/dL x 0.0259 = mmol/L**
- **Complement component (C3) mg/dL x 0.01 = g/L**
- **Copper µg/dL x 0.157 = µmol/L**
- **Cortisol µg/dL x 27.59 = nmol/L**
- **Creatine mg/dL x 76.26 = µmol/L**
- **Creatinine mg/dL x 88.40 = µmol/L**
- **Digoxin ng/mL x 1.28 = nmol/L**
- **Enzymes**
  - **Alanine aminotransferase (ALT, SGPT) U/L = U/L**
  - **Aldolase**
  - **Sibley-Lehninger units/mL = U/L**
  - **Amylase**
  - **Somogyi units/dL = U/L**
  - **Aspartate aminotransferase (AST, SGOT) U/L = U/L**
  - **Creatine kinase (CK) U/L = U/L**
  - **Phosphatase**
  - **Bodansky units/dL = U/L**
  - **King-Armstrong units/dL = U/L**
Fatty acids mg/dL x 0.0354 = mmol/L
Ferritin ng/mL x 1 = µg/L
α-Fetoprotein ng/mL x 1 = µg/L
Fibrinogen mg/dL x 0.01 = g/L
Folic acid µg/dL x 22.65 = nmol/L
Glucose mg/dL x 0.0555 = mmol/L
Glycerol mg/dL x 0.1086 = mmol/L
Haptoglobin mg/dL x 0.01176 = µmol/L
17-Hydroxycorticosteroids mg/d x 2.759 = µmol/L
Insulin IU x 0.04167 = mg
or µU/mL x 1.0 = µU/L
Iodine µg/dL x 78.8 = nmol/L
Iron µg/dL x 0.1791 = µmol/L
Iron binding capacity µg/dL x 0.1791 = µmol/L
17-Ketosteroids mg/d x 3.467 = µmol/L
Lead µg/dL x 0.0483 = µmol/L
Lipoprotein mg/dL x 0.01 = g/L
Magnesium mg/dL x 0.14 = mmol/L
or mEq/L x 0.5 = mmol/L
Phosphorus mg/dL x 0.3229 = mmol/L
Potassium mEq/L = mmol/L
Prednisone mg x 2.79 = µmol
Protein g/dL x 10 = g/L
Salicylate mg/dL x 0.0724 = mmol/L
Sodium mEq/L = mmol/L
Theophylline µg/mL x 5.55 = µmol/L
Thyroid-stimulating hormone µU/mL x 1 = mU/L
Thyroxine µg/dL x 12.87 = nmol/L
Transferrin mg/dL x 0.01 = g/L
Triglycerides mg/dL x 0.01 = g/L
Triiodothyronine ng/dL x 0.0154 = nmol/L
Urea nitrogen mg/dL x 0.357 = mmol urea/L
Uric acid mg/dL x 59.48 = µmol/L
Vitamin A µg/dL x 0.0349 = µmol/L
Vitamin B₁₂ pg/dL x 0.738 = pmol/L
Vitamin C mg/dL x 56.78 = µmol/L
Vitamin E µg/dL x 2.322 = µmol/L
Xylose mg/dL x 0.0667 = mmol/L
Zinc µg/dL x 0.153 = µmol/L

V. Urine or Stool
Coproporphyrin µg x 1.53 = nmol
Epinephrine µg/d x 5.458 = nmol/d
Vanilmandelic acid mg/d x 5.046 = µmol/d
Homovanillic acid mg/d x 5.489 = µmol/d

VI. Energy
Kcal x 4.1868 = KJ (Kilojoule)
Rad x 0.01 = Gy (Gray) (joule/kg)

VII. Radionuclide Activity
Curie (Ci) x 37 = GGq (Gigabecquerel)