Agency for Toxic Substances and Disease Registry
Case Studies in Environmental Medicine (CSEM)
Asbestos Toxicity

Course: **WB/CB 1093**
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Key Concepts	• Although asbestos is no longer used in many products, it will remain a public health concern well into the 21st century. • Intact asbestos sources in the home release few fibers and should be left undisturbed. Damaged or crumbling materials should be repaired or removed only by certified asbestos-removal professionals. • Asbestos exposure is associated with parenchymal asbestosis, asbestos-related pleural abnormalities, mesothelioma, and lung cancer, and it may be associated with cancer at some extra thoracic sites.
About This and Other Case Studies in Environmental Medicine	This educational case study document is one in a series of self-instructional publications designed to increase the primary care provider's knowledge of hazardous substances in the environment and to promote the adoption of medical practices that aid in the evaluation *and care of* potentially exposed patients. The complete series of *Case Studies in Environmental Medicine* is located on the ATSDR Web site at URL: www.atsdr.cdc.gov/csem/. This educational series and other environmental medicine materials are also available on CD-ROM for those who have limited high-speed Internet access.

How to Apply for and Receive Continuing Education Credit	See Internet address www2.cdc.gov/atsdrce/ for more information about continuing medical education credits, continuing nursing education credits, and other continuing education units.
Acknowledgments	We gratefully acknowledge the work that the medical writers, editors, and reviewers have provided to produce this educational resource. Listed below are those who have contributed to development of this version of the *Case Study in Environmental Medicine*. **Please Note:** Each content expert for this case study has indicated that there is no conflict of interest to disclose that would bias the case study content. **ATSDR Authors**: Pamela Tucker, MD **ATSDR Planners**: Valerie J. Curry, MS; John R. Doyle, MPA; Jill, J. Dyken, Ph.D.; Bruce J. Fowler, Ph.D.; Kimberly Gehle, MD, Sharon L. Hall, PH.D.; Michael Hatcher, DrPH;, Kimberly Jenkins, BA; Ronald T. Jolly; Vikas Kapil, MD; Karen Larson, PH.D; Delene Roberts, MSA; Oscar Tarrago, MD; Brian Tencza, MS; Pamela Tucker, MD. **ATSDR Commenters**: Jill J. Dyken, Ph.D.; John Wheeler, Ph.D.; Karen Larson, Ph.D.; Vikas Kapil, MD; Bruce J. Fowler, Ph.D; Kimberly Gehle, MD; Malcolm Williams, Ph.D. **Peer Reviewers**: Dina G. Markowitz, Ph.D.; William S. Beckett, MD, M.P.H.; Arthur L. Frank, MD, Ph.D.; John Wheeler, Ph.D.; Malcolm Williams, Ph.D.
Disclaimer	The state of knowledge regarding the treatment of patients potentially exposed to hazardous substances in the environment is constantly evolving and is often uncertain. In this educational monograph, ATSDR has made diligent effort to ensure the accuracy and currency of the information presented, but makes no claim that the document comprehensively addresses all possible situations related to this substance. This monograph is intended as an educational resource for physicians and other health professionals in assessing the condition and managing the treatment of patients potentially exposed to hazardous substances. It is not, however, a substitute for the professional judgment of a health care provider. The document must be interpreted in light of specific information regarding the patient and in conjunction with other sources of authority. Use of trade names and commercial sources is for identification only and does not imply endorsement by the Agency for Toxic Substances and Disease Registry or the U.S. Department of

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Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
Environmental Medicine and Educational Services Branch

How to Use This Course

Introduction	The goal of Case Studies in Environmental Medicine (CSEM) is to increase the primary care provider's knowledge of hazardous substances in the environment and to help in evaluating and treating potentially exposed patients. This CSEM focuses on asbestos toxicity.
Available Versions	Two versions of the Asbestos Toxicity CSEM are available • the CD version provides content in an electronic, printable format, especially for those who may lack adequate Internet service. • the online version (http://www.atsdr.cdc.gov/csem/asbestos/) provides the same content through the Internet. Both versions, when accessed using a computer, offer interactive exercises and prescriptive feedback to the user.
Instructions	To make the most effective use of this course, we recommend that you • take the initial check to assess your current knowledge about asbestos toxicity • read the title, learning objectives, text, and key points in each section • complete the progress check exercises at the end of each section and check your answers • complete and submit your Assessment and Posttest responses online if you wish to obtain continuing education credit. Continuing education certificates can be printed immediately upon completion
Instructional Format	This course is designed to help you learn efficiently. Topics are clearly labeled so that you can skip sections or quickly scan sections you are already familiar with. This labeling will also allow you to use this training material as a handy reference. To help you identify and absorb important content quickly, each section is structured as follows:

Section Element	Purpose
Title	Serves as a "focus question" that you should be able to answer after completing the section
Learning Objectives	Describes specific content addressed in each section and focuses your attention on important points
Text	Provides the information you need to answer the focus question(s) and achieve the learning objectives
Key Points	Highlights important issues and helps you review
Progress Check exercises	Enables you to test yourself to determine whether you have mastered the learning objectives
Progress Check answers	Provides feedback to ensure you understand the content and can locate information in the text

Learning Objectives Upon completion of the Asbestos Toxicity CSEM, you should be able to

Topic	Objectives
What Is Asbestos?	• Explain what asbestos is.
Where Is Asbestos Found?	• Identify where asbestos exists in the United States. • Describe how asbestos is released into the air.
How Are People Exposed to Asbestos?	• Identify the most important route of exposure to asbestos.
Who Is At Risk of exposure to Asbestos?	• Name the populations most heavily exposed to asbestos. • Describe Who Is At Risk of domestic exposure to asbestos.
What Are the U.S. Standards for Asbestos Levels?	• Explain the Occupational Safety and Health Administration (OSHA) permissible exposure level (PEL) for asbestos. • Explain the Environmental Protection Agency's (EPA) maximum contaminant level (MCL) for asbestos in drinking water.
What Is the Biologic Fate of Asbestos?	• Identify where asbestos fibers are most likely to be retained in the body.
How Does Asbestos Induce Pathogenic Changes?	• Describe the three mechanisms by which scientists hypothesize asbestos induces pathogenic changes in the lungs.

What Respiratory Conditions Are Associated with Asbestos?	• Describe the four respiratory diseases associated with asbestos.
What other health conditions can be associated with Asbestos?	• Identify nonrespiratory conditions that might be associated with exposure to asbestos.
How Should Patients Exposed to Asbestos Be Evaluated?	• Identify the primary focuses of the exposure history and medical history. • Describe the most typical findings on patient examination.
What tests can assist with diagnosis of asbestos-related diseases?	• Describe pulmonary function test findings associated with parenchymal asbestosis. • Describe chest radiograph findings associated with other asbestos associated diseases.
How Should Patients Exposed to Asbestos Be Managed and Treated?	• Identify two primary strategies for managing asbestos-associated diseases. • Describe specific strategies for managing parenchymal asbestosis.
What Instructions Should Be Given to Patients?	• List four instructions for patient self care and two instructions for clinical follow up.

Initial Check

Instructions	This Initial Check will help you assess your current knowledge and skill level about asbestos toxicity. To take the Initial Check, read the case below, answer the questions that follow, and then compare your answers with the answers provided.
Case	A 66-year-old retired male presents with dyspnea on exertion. He first noticed the shortness of breath several months ago but was not concerned because it seemed so minor; he attributed it to aging. During the past few months, however, the dyspnea on exertion has gradually worsened. The patient has no other symptoms of respiratory or cardiac disease. His medical history is unremarkable except for • an old back injury (compression fracture of L4) sustained while working as an electrician at a local shipbuilding facility and • a 25 pack-year history of smoking, though the patient quit smoking 5 years ago. On physical examination, the patient is in no apparent distress. Auscultation reveals bibasilar end inspiratory rales. There are no signs of cyanosis, no clubbing of the fingers, and no peripheral edema. Heart sounds are normal, as are the results of the rest of the physical examination.
Initial Check Questions	1. What further workup is required for this patient? 2. The exposure history indicates a 15-year history of exposure to asbestos at the shipyard, beginning 35 years ago and ending 20 years ago. The patient does not know the exposure levels but notes that he used a respirator during the last 5 years at the shipyard. In addition, when he was 21 years old, he swept floors at a vermiculite handling facility for a summer. He notes that the vermiculite plant was extremely dusty, but he was told it was just "nuisance dust." Are the patient's symptoms likely to be related to asbestos exposure? Why or why not? 3. The radiologist (a certified "B reader") finds small, irregular opacities in both lung bases consistent with early-stage parenchymal asbestosis. The pulmonary function tests reveal a mostly restrictive pattern of deficits, with decreased carbon monoxide diffusing capacity (DLco). You refer the patient to a pulmonologist. The pulmonologist diagnoses parenchymal asbestosis on the basis of the patient's exposure history, latency of symptoms (occurring 45 years after first exposure), chest x-ray findings, and

spirometry results. How will you manage the patient's condition?

4. Is the patient at risk for other asbestos-associated diseases? Why or why not?
5. Are the patient's family members at risk for asbestos-associated disease?
6. The patient has been married for 46 years and has four children. He notes that his wife laundered all his clothes from work, including his clothes from the summer job at the vermiculite plant and those from his job at the shipbuilding facility. His children had only incidental exposure from hugging him after work. The patient's wife, a two-pack-a-day smoker, has recently lost weight and developed sharp pains in her lower chest.

   Could the wife's recent weight loss and chest pain be related to her husband's occupational exposure to Asbestos? What work-up do you suggest for the patient's wife?

7. The patient asks if his children are at risk of asbestos-associated disease. How do you answer?

Initial Check Answers

1. The exertional dyspnea and bibasilar end inspiratory rales are suggestive of some type of interstitial pneumonitis. Because of the patient's history of work at a shipbuilding facility, a detailed exposure history is warranted. You should ask the patient about

   - possible exposures (especially to asbestos) at the shipbuilding facility
   - other jobs at which the patient may have been exposed directly or indirectly to asbestos
   - the source, intensity, frequency, and duration of any exposure
   - the time elapsed since first exposure
   - workplace dust measurements or cumulative fiber dose, if extant
   - use of personal protective equipment
   - other sources of exposure, including paraoccupational exposures to or from family members and other household contacts
   - sources of environmental exposure, such as a residence near a source of naturally occurring asbestos or hobbies or recreational activities that involve materials contaminated with asbestos (*e.g.*, home repairs or auto maintenance).

In addition to taking a detailed exposure history, it is prudent to order chest X-ray and pulmonary function tests.

The information for this answer comes from section How should patients exposed to asbestos be evaluated?

2. Yes, the patient's condition is likely to be related to asbestos exposure. Diagnoses to consider include

   - parenchymal asbestosis
   - idiopathic pulmonary fibrosis
   - other pneumoconiosis
   - hypersensitivity pneumonitis
   - sarcoidosis and other interstitial pulmonary diseases

   Several aspects of the patient's case point to parenchymal asbestosis as a likely diagnosis:

   - history of exposure to asbestos in the shipbuilding facility and vermiculite handling plant
   - onset of symptoms many years after the exposures (consistent with a long latency period)
   - insidious onset of dyspnea on exertion, and
   - bibasilar end inspiratory rales on auscultation.

   The results of the chest X-ray (which should be read by a certified "B reader") and pulmonary function tests will help with the differential diagnosis.

   The information for this answer comes from section How Should Patients Exposed to Asbestos Be Evaluated?

3. To manage this patient's condition, you will

   - advise the patient to avoid any further exposure to asbestos, smoke, and other respiratory irritants as practical
   - provide regular pneumococcal and annual influenza vaccines
   - advise the patient to contact you at any sign of respiratory infection
   - aggressively treat any respiratory infections that develop in the patient
   - advise the patient to contact you at any sign of other health changes, particularly changes that might be early

signs of neoplasia (*e.g.*, hoarseness, sores in the mouth, blood in urine or stool)

- perform colon cancer screening in accordance with American Cancer Society guidelines
- schedule regular follow-up visits to monitor progression of the parenchymal asbestosis and possible development of other asbestos-associated diseases.
- document any impairments related to work-related asbestos exposure
- notify the patient that he has an occupational disease. In states where occupational lung diseases are reportable conditions, report this case of asbestosis to the health department

The information for this answer comes from section How Should Patients Exposed to Asbestos Be Managed and Treated?

4. Yes, the patient is at risk of other asbestos-associated diseases. The patient's past exposures to asbestos were significant enough to have led to the development of parenchymal asbestosis. These exposures can also lead to the development of other asbestos-associated diseases such as asbestos-related pleural abnormalities, lung carcinoma, and pleural or peritoneal mesothelioma.

   The information for this answer comes from section What Other Health Conditions Are Associated with Asbestos?

5. Possibly. While taking the exposure history, it is important to ask about possible paraoccupational exposures to family members and other household contacts. These can include inhalation of asbestos fibers from

   - the worker's skin, hair, and clothing (if PPE was not used)
   - air and dust from local vermiculite- or asbestos-handling facilities.
   - air and dust from local mining operations or other blasting/disruption of asbestos-bearing rock.

You should also ask about other possible exposure sources such as

- materials used for hobbies and recreation
- outdoor activities that could involve exposure to naturally occurring asbestos particularly if the patient

lives near a geologic source

- vermiculite attic insulation contaminated with asbestos.

These types of exposures could place family members and other household contacts at risk of asbestos-associated disease.

The information for this answer comes from section Who Is At Risk of Exposure to Asbestos?

6. Yes, the wife's symptoms could be related to her husband's occupational exposures to asbestos. Given that she laundered her husband's work clothes when he had two jobs involving asbestos, she could have received significant paraoccupational exposures to asbestos. To determine whether these exposures led to an asbestos-associated disease, you recommend that the patient's wife:

   - come in for an office visit
   - receive chest X-rays
   - undergo pulmonary function tests

   The wife's chest X-rays show a pleural thickening associated with a slight pleural effusion on the lower right lung field. You refer the wife to a pulmonologist, who performs a computed tomography (CT) scan and a biopsy of the pleural mass. The pulmonologist diagnoses pleural mesothelioma, refers her to a cancer center, and provides the family with a referral for psychosocial support.

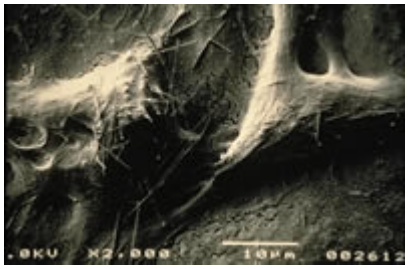
   The information for this answer comes from section How Should Patients Exposed to Asbestos Be Evaluated?

7. You explain that the risk of asbestos-associated diseases, especially parenchymal asbestosis, is generally dose-related and that asbestosis develops in approximately 50% of adults with heavy industrial exposures. The children received paraoccupational exposure to asbestos from dust and residue carried home on their father's skin and clothing, so their risk of asbestos-associated disease is less than the occupational risk. You note that asbestos-associated disease, particularly mesothelioma, can occur with paraoccupational and even background exposures to asbestos but at background levels, the risk is low.

   The information for this answer comes from section What Respiratory Conditions Are Associated with Asbestos?

What Is Asbestos?

Learning Objective	Upon completion of this section, you should be able to • explain what asbestos is.
Definition	Asbestos is the name given to a group of six naturally occurring fibrous silicate minerals that have been widely used in commercial products. Asbestos is composed of silicate chains bonded with magnesium, iron, calcium, aluminum, and sodium or trace elements to form long, thin, separable fibers. These fibers are often arranged in parallel or matted masses. Asbestos occurs naturally, but much of its presence in the environment stems from mining and commercial uses.
Classes	Asbestos fibers are classified by mineral structure as serpentine or amphibole.

Serpentine	**Amphibole**
	
Long, flexible fibers	Brittle with a rod or needle shape
Member: chrysotile	Members: crocidolite, amosite, anthophyllite, tremolite, actinolite, winchite, richterite
Accounts for 93% of world's commercial, purposeful use of asbestos	Accounts for 7% of commercial, purposeful use of asbestos

Properties	Asbestos was widely used commercially because of its • high tensile strength • resistance to acids and alkalis • resistance to heat and flame • flexibility These properties make asbestos commercially useful but also stable in the environment. Asbestos is nonbiodegradable. Once released to the environment, asbestos tends to persist.

Key Points	• Asbestos is a group of fibrous silicate minerals. • There are two classes of asbestos: serpentine and amphibole. • Asbestos was once used more widely for commercial purposes. • Asbestos is stable and persists in the environment.

Progress Check

1. Asbestos is a
   A. group of fibrous mineral silicates
   B. naturally occurring substance
   C. commercially used substance
   D. all of the above

To review relevant content, see Definition in this section.

2. Asbestos is useful commercially, but also persists in the environment, because it is
   A. reactive with water, acids, alkalis, and other chemicals
   B. strong and stable
   C. rigid and inflexible
   D. all of the above

To review relevant content, see Properties in this section.

Where Is Asbestos Found?

Learning Objective	Upon completion of this section, you should be able to • identify where asbestos still exists in the United States. • describe how asbestos is released into the air.
Introduction	Asbestos was widely used commercially until the 1970s, when health concerns led to some uses being banned and some voluntary phase outs (Seidman and Selikoff, 1990). Mining and milling of the raw material and production of asbestos has declined since the early 1970s, but asbestos is still used in some construction materials. Some asbestos-containing products, such as amphibole-contaminated vermiculite insulation, remain in many homes in the United States. Asbestos fibers are released into the air and dust when asbestos-containing materials are loose, crumbling, or disturbed. In addition to being at risk for exposure from the commercial uses of asbestos, people in some areas of the world are at risk because of geological deposits of asbestos near the surface which release asbestos if disturbed.
Current Commercial Uses	Today, most asbestos used in the United States is imported. Asbestos is still used in • brake pads • automobile clutches • roofing materials • vinyl tile • and, imported cement pipe and corrugated sheeting (American Thoracic Society 2004).
Former Commercial Uses	Until the 1970s, asbestos was widely used in the construction, shipbuilding, and automotive industries, among others. For example, asbestos was formerly used in the following items • boilers and heating vessels • cement pipe • clutch, brake, and transmission components • conduits for electrical wire • corrosive chemical containers • electric motor components • heat-protective pads • laboratory furniture • paper products • pipe covering

	• roofing products • sealants and coatings • insulation products, • textiles (including curtains) These materials remain in many buildings, ships, and automobiles built before 1975 (Seidman and Selikoff, 1990)
Contaminated Commercial Products	Asbestos has been a contaminant in other products such as • vermiculite in potting soil • vermiculite home insulation Vermiculite contaminated with amphibole asbestos was produced as late as 1990 from a mine near Libby, Montana. The mined ore was processed at more than 200 sites around the country, and contaminated vermiculite products were distributed nationally (ATSDR 2001a). Although all the new vermiculite in potting soil is amphibole free, pre-1990 products from that source may contain amphiboles, and many homes may still have vermiculite insulation in their attics. For more information on amphibole asbestos and vermiculite insulation, please refer to the ATSDR website on asbestos.
Homes and Buildings	Some home-attic insulating materials produced before 1975 contained asbestos. Of particular concern is vermiculite insulation contaminated with amphibole asbestos, because this is a loose material that can easily be disturbed, causing asbestos fibers to be released into the air. Asbestos in friable (easily pulverized or crumbled) material is also a concern. Asbestos embedded in solid materials (such as wallboards) is less easily disturbed and therefore less likely to be released into the air unless it is cut, drilled, or sanded. Many other home and building materials produced before 1975 contained asbestos including the following • duct and home insulation • fire protection panels • fireplace artificial logs or ashes • fuse box liners • gypsum wallboard

- hair dryers
- toasters
- heater register tape and insulation
- joint compounds
- patching and spackling compounds
- pipe or boiler insulation
- pot holders and ironing board pads
- sheet vinyl or floor tiles
- shingles
- textured acoustical ceiling
- textured paints
- underlayment for flooring and carpets

The Natural Environment

Because of widespread human use of asbestos, its fibers are found in many or most parts of the environment. These background levels are extremely low, about 0.0001 fibers/cc of air (Holland and Smith 2003).

Asbestos is also present in the environment naturally, primarily in underground rock. In most areas, the rock is too deep to be disturbed easily, so asbestos fibers are not released into the air. In some areas, such as parts of California, Virginia and New Jersey (and across the globe in Turkey and Corsica), asbestos-bearing rock is close enough to the surface that construction and other human activities can disturb it, leading to release of high concentrations of asbestos fibers into the air and dust (ATSDR 2001a; Hasanoglu *et al*. 2003; Luo *et al*. 2003). For a map of sites in the United States where naturally occurring asbestos outcroppings, please see:

http://www.atsdr.cdc.gov/asbestos/sites/national_map/

The table below shows examples of sources of asbestos in the environment.

Asbestos Source	Environmental Contamination
Mining, milling, and weathering of asbestos-bearing rock	Outdoor air and dust
Release of fibers from disturbed building materials (*e.g.*, vermiculite insulation)	Indoor air
Manufacture, wear, and disposal of asbestos-containing products	Outdoor and indoor air and dust

Release of fibers from brake linings or crushed asbestos-containing rock used in road construction	Street dust
Erosion of natural land sources, discarded mine and mill tailings, asbestos cement pipe, disintegration of other asbestos-containing materials transported by rain	Drinking water

Key Points

- Until the 1970s, asbestos was widely used in the construction, shipbuilding, and automotive industries.
- Asbestos-contaminated vermiculite materials were produced until 1990.
- Some home insulation and other building materials produced before 1975 contain asbestos.
- Asbestos fibers are mainly released into the air and dust when asbestos-containing materials are loose, crumbling, or disturbed.
- In a few areas, asbestos-bearing rock close to the earth's surface can be disturbed and release high concentrations of asbestos fibers into the air and dust.

Progress Check

3. Asbestos currently in the environment comes from
   A. current production of commercial products and building mater
   B. past production of commercial products and building materials
   C. natural release of asbestos fibers from weathered rock
   D. all of the above

   To review relevant content, see Natural Environment in this section.

4. Asbestos fibers are released into the air mainly when

   1. asbestos-containing materials are loose, crumbling, or disturbed
   2. asbestos is fixed in solid materials such as wallboard
   3. asbestos-bearing rock lays unexposed deep underground
   4. all of the above

To review relevant content, see Introduction in this section.

How Are People Exposed to Asbestos?

Learning Objectives	Upon completion of this section, you should be able to • identify the most important route of exposure to asbestos
Introduction	Exposure to asbestos can occur when asbestos-containing material (manmade or natural) is loose, crumbling, or disturbed, releasing asbestos fibers into the air and dust. Asbestos that is embedded or contained in undisturbed solid materials presents a negligible risk of exposure. The primary route of asbestos entry into the body is inhalation of air or dust that contains asbestos fibers. Asbestos can also enter the body via ingestion. With dermal exposure, asbestos fibers may lodge in the skin.
Inhalation	The air pathway is the most important route of exposure to asbestos, and the route that most commonly leads to illness. Exposure scenarios include inhalation of contaminated air and dust • during work with asbestos • during work in the same space as others working with asbestos • on worker's skin, hair, and clothing • in areas surrounding a mining operation • in areas of the world where construction or other human activity (such as gardening) results in disturbance of natural outcrops of asbestos-bearing rock • in homes and buildings where renovations or demolitions disturb asbestos-containing building materials The first four scenarios were common until the 1970s, when the Environmental Protection Agency (EPA) began to regulate the industrial uses of asbestos and the Occupational Safety Health Administration (OSHA) developed workplace exposure standards (Seidman and Selikoff, 1990). Today, the last two scenarios are the more common because of declining use of asbestos in developed countries (British Thoracic Society 2001).
Ingestion	Ingestion—a minor pathway of exposure—occurs through • swallowing material removed from the lungs via tracheociliary clearance by a person who has inhaled asbestos fibers into the lungs • drinking water contaminated with asbestos for example, from erosion of natural land sources, discarded mine and mill tailings, asbestos cement pipe, or disintegration of other asbestos-containing materials transported by rain Asbestos levels in most water supplies are well below the EPA maximum contaminant level (MCL), so significant exposure by

	drinking water is uncommon.
Skin	Today, with the advent of personal protective equipment, dermal contact is rarely a significant exposure pathway. In the past, handling asbestos could result in heavy dermal contact and exposure. Asbestos fibers could become lodged in the skin, producing a callus or corn, but not more serious health effects.
Key Points	• The air pathway (inhalation of contaminated air or dust) is the most important route of exposure to asbestos, the route that most commonly leads to illness. • Ingestion is a minor exposure pathway, but exposure can occur after swallowing of material cleared from the lungs. • Heavy dermal contact is unusual, but it can lead to calluses or corns.

Progress Check

5. The most important route of exposure to asbestos is

   A. inhalation
   B. ingestion
   C. dermal contact
   D. all are equally important

To review relevant content, see Inhalation in this section.

Who Is at Risk of Exposure to Asbestos?

Learning Objectives

Upon completion of this section, you should be able to

- Name the populations most heavily exposed to asbestos.
- Describe who is at risk of domestic exposure to asbestos.

Introduction

In the past, asbestos exposure was associated mainly with mining and milling of the raw material and with workers engaged in construction and product manufacture or use of end products. In the industrialized west, these heavy asbestos exposures peaked during the 1960s and 1970s and then it declined as worker protection regulations were put in place and later as industrial use of asbestos decreased. Because of long latency periods (10–40 years), workers exposed to asbestos in the 1960s and 1970s are now manifesting asbestos-associated diseases. Indeed, the incidence of asbestos-associated diseases among people occupationally exposed is beginning to peak and will likely begin to decline some time in the next 2 decades. National statistics that illustrate this trend are available at

www.cdc.gov/niosh/topics/surveillance/ords/NationalStatistics.html.

Today in the United States, most occupational exposures occur during repair, renovation, removal, or maintenance of asbestos that was installed years ago. People can also be exposed at home, both to old sources of asbestos as a result of activities such as home renovation or to new sources of asbestos as a result of certain types of recreational activities and hobbies such as auto repairs or gardening, which may disturb natural outcroppings of asbestos in the environment.

Past Occupational Exposure

In the past, many occupations entailed exposures to asbestos (see table below). Studies have documented the scale of the problem.

- In the United States, an estimated 27 million workers were exposed to aerosolized asbestos fibers between 1940 and 1979 (Nicholson *et al*. 1982).

Occupations	Businesses where workers may be exposed to asbestos
• Auto mechanics • Boiler makers • Bricklayers • Building inspectors • Carpenters • Demolition workers • Drywallers • Electricians	• Asbestos product manufacturing (insulation, roofing, building materials) • Automotive repair shops (especially those that involve repair of brakes, clutches) • Construction companies • Maritime companies • Mining companies • Offshore rust removal businesses • Oil refineries • Power plants • Railroads

- Floor covering workers
- Furnace workers
- Glazers
- Grinders
- Hod carriers
- Insulators
- Iron workers
- Laborers
- Libby vermiculite exfoliation plant workers
- Longshoremen
- Maintenance workers
- Merchant marines
- Millwrights
- Operating engineers
- Painters
- Pipe fitters
- Plasterers
- Plumbers
- Roofers
- Refinery workers
- Sheet metal workers
- Shipyard workers
- Steam fitters
- Tile setters
- U.S. Navy personnel
- Welders
- Manufacturers of sand or abrasives
- Shipbuilders, ship lines, and ship yards
- Steel manufacturers
- Tile cutters

Source: NIOSH, 2001

Past Secondary Occupational Exposure	Secondary exposure occurred when people who did not work directly with asbestos were nevertheless exposed to fibers as a result of sharing workspace where others handled asbestos. For example, electricians who worked in shipyards were exposed because asbestos was being used to coat the ships' pipes and hulls (Pan *et al*. 2005).
Past Para-occupational Exposures	In the past, because of a lack of proper industrial hygiene, asbestos workers went home covered in asbestos dust. The workers' families and other household contacts were then exposed via inhalation of asbestos dust

	• from workers' skin, hair, and clothing, and • during laundering of contaminated work clothes. A mortality study of 878 household contacts of asbestos workers revealed that 4 out of 115 total deaths were from pleural mesothelioma and that the rate of deaths from all types of cancer was doubled (Joubert *et al*. 1991) In addition, asbestos was released into the air and soil around facilities such as refineries, power plants, factories handling asbestos, shipyards, steel mills, vermiculite mines, and building demolitions. People living around these facilities were also exposed to asbestos.
Current Occupational Exposures	Currently, the people most heavily exposed to asbestos in the United States are those in construction trades. This population includes an estimated 1.3 million construction workers as well as workers in building and equipment maintenance (American Thoracic Society 2004). Because most asbestos was used in construction, and two-thirds of asbestos produced is still used in this trade, risk to these workers can be considerable if the hazard is not recognized and OSHA standards are not enforced.
Direct Domestic Exposures	As noted previously, some home attic insulation and many other home and building materials produced before 1975 contain asbestos. People who live in homes with these materials are at risk of exposure if the materials are loose, crumbling, or disturbed by household activities or renovations. In such cases, the asbestos materials should be removed or encapsulated by a trained and certified asbestos contractor. For information on where to find certified asbestos contractors in your state, contact your local health department. On the other hand, asbestos contained in intact solid material poses a negligible risk of exposure. A 1992 study of indoor air in homes and schools with asbestos-containing materials found an average concentration of 0.0001 fibers/cc (Lee *et al*. 1992). There are many ways that people can also be exposed to asbestos through hobbies and recreational activities that entail contact with materials containing asbestos; some examples are such activities as home renovation, auto repair, and urban spelunking. In places where naturally occurring asbestos is close to the earth's surface, activities such as gardening and dirt biking can cause exposures if asbestos-bearing rock is disturbed.
Exposure at School	Measurable asbestos levels in schools are usually 100 to 1,000 times below OSHA's permissible exposure limit of 0.1 fibers/cc

of air for asbestos (Holland and Smith 2003). However, ATSDR does not use occupational standards when considering the risks to health of the general population from asbestos in the general environment. A specific environmental health risk assessment process is used.

Over time, public concern led to widespread removal and abatement programs. Some facilities have higher levels of airborne asbestos after removal than before, highlighting the importance of proper encapsulation or removal by trained and certified contractors.

Background Exposures

No known truly unexposed group exists in the world. The cumulative risk of background exposures is probably minor, however, and these concentrations cannot be reduced (Hillerdahl 1999). Any source of pollution that releases significant amounts of asbestos fibers should be eliminated, using proper equipment and techniques, as soon as it is discovered.

The Libby Vermiculite Example

Most vermiculite used today contains low or non-detectable levels of asbestos. However, the vermiculite mined in Libby, Montana, from the turn of the 20th century to 1990 was contaminated with various fibrous amphiboles, including tremolite asbestos, and constituted 95% of the vermiculite used in the United States during that time. The vermiculite operations in Libby, Montana, are a good example of the many ways people can be at risk of asbestos exposure. In this example, mining of the asbestos- contaminated vermiculite ore in Libby resulted in asbestos exposures to

- miners
- household contacts of miners and other Libby asbestos workers
- children playing in piles of vermiculite in the area
- residents of nearby towns (where the air was contaminated by industrial activities involving asbestos)
- workers who handled the vermiculite in vermiculite exfoliation and handling sites throughout the United States after it was shipped there from Libby
- people who live in homes with vermiculite home insulation

This vermiculite was also used in potting soil, but EPA concluded that consumers "face only a minimal health risk from occasionally using vermiculite products at home or in their gardens" (EPA 2000).

For more information about amphibole-contaminated vermiculite, see

	• an ATSDR map of 28 priority vermiculite exfoliating sites at http://www.atsdr.cdc.gov/asbestos/sites/national_map/ • an EPA fact sheet about how to recognize and avoid exposure to vermiculite insulation in homes at http://www.epa.gov/asbestos/pubs/insulation.html • an EPA fact sheet about how to avoid asbestos exposures while using potting soils at http://www.epa.gov/asbestos/pubs/vermfacts.pdf
Key Points	• Today, the populations most heavily exposed to asbestos are those in construction trades. • In the past, pipe fitters, shipyard workers, military workers, automobile mechanics, and people in many other occupations were also exposed. • In the past, household contacts of asbestos workers were exposed to asbestos dust on workers' skin and clothing. • People in homes and buildings with loose, crumbling, or disturbed asbestos materials can be exposed to asbestos. • During renovations or abatement, asbestos materials should be encapsulated or removed by trained and certified asbestos contractors. • Asbestos embedded in intact solid materials poses little risk of exposure as long as it remains intact and undisturbed.

Progress Check

6. In the past, occupations that entailed exposure to asbestos included which of the following?

   A. construction workers, carpenters, sheet metal workers, and pipefitters
   B. utility workers, boiler makers, and electricians
   C. shipyard workers and automobile mechanics
   D. all of the above

To review relevant content, see Past Occupational Exposure in this section.

7. Of the following, who is most likely to be at risk of asbestos exposure?

   A. a child attending a school with asbestos-containing tile flooring
   B. an adult who uses vermiculite potting soil while gardening
   C. a person who resided with an asbestos worker in the 1940s
   D. a family living in a home with intact, solid asbestos-containing materials

To review relevant content, see Direct Domestic Exposure and Exposure at School in this section.

What Are the U.S. Standards for Asbestos Levels?

Learning Objectives

Upon completion of this section, you should be able to

- explain the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for asbestos.
- explain the Environmental Protection Agency's (EPA) maximum contaminant level (MCL) for asbestos in drinking water.

Introduction

The earliest evidence of asbestos-associated disease in workers was found in the 1930s by British studies (Lee and Selikoff, 1979). We now know that the toxic effects of asbestos depend on the nature and extent of exposure, particularly on the

- concentration of asbestos fibers involved in the exposure
- duration of exposure
- frequency of exposure
- type of asbestos fibers involved in the exposure
- dimensions and durability of the asbestos fibers

United States government agencies (OSHA and Centers for Disease Control's center National Institute for Occupational Safety and Health (NIOSH)) began establishing standards for asbestos in the 1970s. US regulatory agencies such as EPA and OSHA recognize six asbestos minerals (chrysotile, actinolite, tremolite, anthophyllite, amosite, crocidolite) as legally regulated forms of asbestos out of the group of asbestiform minerals. Asbestiform minerals are defined as crystal aggregates displaying these characteristics groups of separable, long, thin, strong, and flexible fibers arranged in parallel or in matted masses (ATSDR, 2001a).

Other regulations focus primarily on the concentration of asbestos fibers in air. Currently, we have

- a standard for asbestos in the workplace
- a standard for asbestos in drinking water
- regulatory requirements for school boards regarding asbestos in schools

Occupational Standards

In 1986, OSHA established the current permissible exposure limit (PEL) for asbestos in the workplace: 0.1 fibers/cc of air). PELs are an allowable exposure level in workplace air that are averaged over an 8-hour shift of a 40 hour workweek.

OSHA requires employers of all workers who are exposed to asbestos (regardless of exposure level) to

- provide training in the proper use of personal protective equipment (PPE)

- train workers in safety

In addition, OSHA requires workers who are exposed to asbestos above the PEL and who are employed in certain asbestos industries to

- use PPE
- to undergo medical surveillance in order to identify those with signs of asbestos-associated disease, remove them from further exposure, and
- provide documentation for work-related injury claims.

Components of the required medical surveillance include

- a standard questionnaire
- a physical examination
- a spirometric test
- a chest X-ray.

For further information about OSHA requirements, you can visit

http://www.osha.gov/SLTC/asbestos/standards.html.

For further information about protection guidelines, contact NIOSH at 1-800-35-NIOSH or visit the website at

http://www.cdc.gov/niosh.

Environmental Standards

ATSDR does not consider the use of OSHA's PEL for workplace exposures to be appropriate for environmentally exposed populations since residential and/or environmental exposures are 24 hours a day year round exposure rather than 8 hour day 40 hour week exposures. Children and the elderly are also not exposed in the workplace.

EPA has established a maximum contaminant level (MCL) for asbestos in drinking water: 7 MFL (million fibers per liter) in drinking water.

In addition, EPA has

- banned spraying of asbestos in building interiors (for fireproofing and ceilings)
- regulated uses of asbestos in industrial products and construction
- developed guidelines for proper treatment of in-place asbestos in old buildings
- recommended "no visible emissions" of asbestos

For more information on EPA rules and regulations regarding asbestos, visit the website at

	http://www.epa.gov/oppt/asbestos.
Schools	The Asbestos in Schools Identification and Notification Act of 1982 requires that local education agencies • inspect schools for friable material. • analyze these materials for asbestos content. • post results and notify parents and employees if asbestos is found. • maintain appropriate records. EPA also warned school authorities that power buffing and power stripping of asbestos-tile floors in schools produces significant airborne asbestos levels. Floor maintenance must be performed by hand to prevent release of asbestos fibers.
Key Points	• OSHA's PEL for asbestos in the workplace is 0.1 fibers/cc of air (8-hour TWA). • OSHA requires asbestos workers in certain industries to be trained in PPE; they must undergo medical surveillance if exposed above the PEL. • EPA's MCL for asbestos in drinking water is 7 MFL (million fibers per liter) of drinking water. • Local education agencies must inspect schools and analyze friable material for asbestos content, communicate results, and maintain records.

Progress Check

8. OSHA's PEL for asbestos in the workplace is which of the following?

   A. 10 fibers/cc of air (8-hour TWA)
   B. 1 fiber/cc of air (8-hour TWA)
   C. 0.1 fibers/cc of air (8-hour TWA)
   D. 0.01 fibers/cc of air (8-hour TWA).

To review relevant content, see Occupational Standards in this section.

9. EPA's MCL for asbestos in drinking water is which of the following?

   A. 0.07 fibers per liter of drinking water
   B. 7 million fibers per liter of drinking water
   C. 700 fibers per liter of drinking water
   D. 70,000 fibers per liter of drinking water.

To review relevant content, see Environmental Standards in this section.

What Is the Biologic Fate of Asbestos?

Learning Objective Upon completion of this section, you should be able to

- identify where asbestos fibers are most likely to be retained in the body

Introduction

Inhaled asbestos fibers enter the upper and lower respiratory tracts. The durability of the fibers in lung tissue may lead to a risk of disease.

Penetration of Lungs

Some of the inhaled asbestos fibers are deposited on the surface of the larger airways where some of them are cleared by mucociliary transport and swallowing. Other fibers are deposited further in the lung, especially in the bifurcations of the tracheobronchial tree and, eventually, in the alveolar sacs (Broaddus 2001).

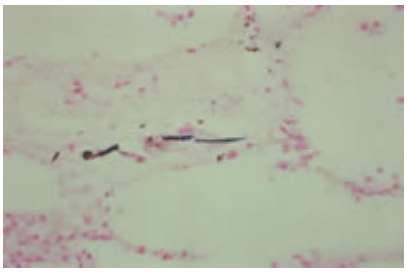
The dimensions of the asbestos fiber determines how easily and how far it penetrates the lungs and how quickly it is cleared. Wide fibers (diameter greater than 2 to 5 microns) tend to be deposited in the upper respiratory tract and cleared. Long thin asbestos fibers reach the lower airways and alveoli and tend to be retained in the lungs. However, it is important to remember that asbestos fibers of all lengths can induce pathological changes and cannot be excluded as contributors to asbestos-related diseases (Dodson *et al*. 2003).

Fate in Lungs

In the lungs, asbestos fibers are subject to several lung defenses.

- Mucociliary transport of the larger airways. This cleared material is usually swallowed and eliminated.
- Dissolution by alveolar macrophages.
- Attempted phagocytosis, resulting in fragmentation and splitting of fibers.
- Encapsulation by proteins and deposition in ferrous material in a drumstick configuration called a ferruginous or asbestos body.

The lymphatic system also clears fibers from the lungs (Dodson *et al*. 2003). Although some asbestos fibers are cleared from the lungs, most are retained in lung tissue for many years. The total burden of fibers in the lungs depends not only the size of the fiber but the amount of fibers inhaled from the environment (Dodson *et al*. 2003).



Movement Out of Lungs	From the lungs, some asbestos fibers (mainly short fibers) can migrate to pleural and peritoneal spaces, especially following patterns of lymphatic drainage (Broaddus 2001). Their presence in the peritoneum is more likely if there is a high fiber burden in the lungs.
Half-Life in the Lungs	How rapidly the body's defenses can clear asbestos fibers from the lungs depends in part on the type of asbestos. Amphibole fibers are retained longer than serpentine fibers of the same dimensions (Hillerdal 1999). Even so, all types of fibers are retained for many years in the lungs (2001a).
Fate of Ingested Asbestos	Most ingested asbestos fibers pass through the gastrointestinal tract unchanged and are cleared in the feces. A few ingested fibers pass through the walls of the gastrointestinal tract. Some of these fibers stay in the peritoneal cavity. Other of these fibers move into the bloodstream and into the kidneys, where some are eliminated unchanged in the urine.
Key Points	• Some inhaled asbestos fibers reach the lungs, where they become lodged in lung tissue, especially in the lower lung fields. • Some fibers are encapsulated in asbestos bodies. Some fibers move to pleural or peritoneal spaces or the mesothelium. • The half-lives of fibers vary, but they are retained for many years. • Ingested asbestos fibers are usually eliminated from the body.

Progress Check

10. Some inhaled asbestos fibers that reach the lungs
    A. become lodged and are retained in lung tissue
    B. migrate to other spaces
    C. are eliminated via phagocytosis
    D. all of the above

To review relevant content, see Fate in Lungs and Movement Out of the Lungs and Fate of Ingested Asbestos in this section.

How Does Asbestos Induce Pathogenic Changes?

Learning Objective

Upon completion of this section, you should be able to

- describe the three mechanisms by which scientists hypothesize asbestos induces pathogenic changes in the lungs.

Introduction

The three main determinants of asbestos toxicity are

- fiber size,
- durability, and
- iron content.

The presence of asbestos fibers in the lungs sets off a variety of responses leading to inflammation, cell and tissue damage, which can lead to disease related to fibrosis, or malignancy.

The mechanisms by which asbestos causes disease are not fully understood. Currently, there are three hypotheses to account for asbestos's pathogenicity

- direct interaction with cellular macromolecules,
- generation of reactive oxygen species, and
- other cell-mediated mechanisms (especially inflammation)

Asbestos is genotoxic and carcinogenic.

Interaction with Cellular Macromolecules

Because of their surface charge, asbestos fibers can adsorb to cellular macromolecules (proteins, DNA, RNA) and cell surface proteins. Binding of asbestos fibers to these cellular components is believed to induce changes in macromolecular conformation, thereby affecting protein function.

Long asbestos fibers have been shown to interfere physically the mitotic spindle and cause chromosomal damage, especially deletions (Broaddus, 2001; ATSDR 2001; National Academy of Sciences, 2006).

Release of Reactive Oxygen Species

The presence of asbestos fibers in lung and pleural tissue is also believed to cause the formation and release of reactive oxygen species (ROS). That is, when alveolar macrophages attempt to engulf and digest an asbestos fiber, they release ROS: hydrogen peroxide (H_20_2), and the super oxide radical anion (O^{2-}) (Kamp and Weitzman 1999, 1997). (H202), and the super oxide radical anion (O^{2-}) (Kamp and Weitzman 1999, 1997). Through the Haber-Weiss (or Fenton) reaction, these ROS react with each other to produce hydroxyl radicals, which are even more potent oxidizers. This reaction is believed to be catalyzed by iron present on the surface of the asbestos fibers (Broaddus 2001; ATSDR 2001).

Other Cell-Mediated Mechanisms	The presence of asbestos fibers also causes alveolar macrophages, lung cells, and pleural cells to release cellular factors (such as leukotrienes, prostaglandins, TNF-α) that lead to multiple cellular processes such as • inflammation • macrophage recruitment • cell and DNA damage • cell proliferation • apoptosis The exact role of all these cellular processes in the formation of fibrosis and malignancy is still being defined (Broaddus 2001; Kamp *et al*. 2002).
Primary Sites Affected	All types of asbestos fibers tend to lodge in the lung at the bronchiolar-alveolar duct bifurcations, and some proceed to the smaller airways and alveolar sacs. From the lung, some fibers can migrate into the pleural space by unknown mechanisms (National Academy of Sciences, 2006). The length of time needed for migration and the number of fibers that successfully migrate may explain why asbestos-induced fibrosis occurs earlier in the lung than the more slowly developing pleural mesothelioma (Broaddus 2001).
Carcinogenicity	Asbestos has been designated a known human carcinogen as shown in the following table. All types of asbestos are carcinogenic, but some scientists believe that the amphibole type is more potent in causing mesotheliomas than the serpentine type (chrysotile). However, both types can cause mesotheliomas and are believed to be equally potent in causing lung cancer (ATSDR 2001).

Agency	Carcinogenicity Classification	Description
International Agency for Research on Cancer (IARC)	1	Known human carcinogen
U.S. Environmental Protection Agency (EPA)	Group A	Known human carcinogen

Key Points	• The three processes hypothesized to account for asbestos's pathogenicity are
	  o direct interaction with cellular macromolecules
	  o generation of reactive oxygen species (ROS)
	  o other cell-mediated mechanisms (especially inflammation)
	• Asbestos induces pathological changes leading to such outcomes as fibrosis and malignancy.
	• Asbestos is genotoxic and carcinogenic.

Progress Check

11. Asbestos induces pathogenic changes in lung tissue via:

    A. direct interaction with cellular macromolecules
    B. generation of active oxygen species
    C. cell-mediated inflammatory mechanisms
    D. all of the above

    To review relevant content, see Introduction in this section.

12. As a result of its pathogenic actions, asbestos

    A. induces fibrotic changes in lung tissue
    B. is genotoxic
    C. is carcinogenic
    D. all of the above

    To review relevant content, see Introduction and Carcinogenicity in this section.

What Respiratory Conditions Are Associated with Asbestos?

Learning Objective Upon completion of this section, you should be able to

- describe the four respiratory conditions associated with asbestos exposure.

Introduction

According to the American Thoracic Society (2004), "asbestos has been the largest cause of occupational cancer in the United States and a significant cause of disease and disability from nonmalignant disease." It has been estimated that the cumulative total number of asbestos-associated deaths in the United States may exceed 200,000 by the year 2030 (Nicholson *et al*. 1982).

Depending on the level of exposure, inhalation of asbestos fibers can cause different diseases such as

- parenchymal asbestosis
- asbestos-related pleural abnormalities
- lung carcinoma
- pleural mesothelioma

Any combination of these syndromes (or all four of them) can be present in a single patient. Clinically, it is important to distinguish nonmalignant conditions from malignant diseases; differential diagnosis will be discussed further in later sections of this document.

Parenchymal Asbestosis

Parenchymal asbestosis is a diffuse interstitial fibrosis resulting from inhalation of asbestos fibers. Asbestos fibers inhaled deep into the lung parenchyma become lodged in the tissue, resulting in diffuse alveolar and interstitial fibrosis. The fibrosis first occurs in the respiratory bronchioles, particularly the subpleural portions of the lower lobes. The fibrosis can progress to include the alveolar walls. Fibrosis tends to progress even after exposure ceases (Khan *et al*. 2004). This fibrosis can lead to

- reduced lung volumes
- decreased compliance
- impaired gas exchange
- restrictive pattern of disease
- obstructive features due to small airway disease
- progressive exertional dyspnea with an insidious onset

Parenchymal asbestosis is characterized by the following radiographic changes: fine, irregular opacities in both lung fields (especially in the bases) and septal lines that progress to honeycombing and sometimes, in more severe disease, obscuration of the heart border and hemi-diaphragm, the so-

called shaggy heart sign (Khan *et al*. 2004). Radiographic changes depend on the duration, frequency, and intensity of exposure, however.

Patients with parenchymal asbestosis may have elevated levels of antinuclear antibody and rheumatoid factors and a progressive decrease in total lymphocyte count with advancing fibrosis.

Parenchymal asbestosis has no unique pathognomonic signs or symptoms, but diagnosis is made by the constellation of clinical, functional, and radiographic findings as outlined by the American Thoracic Society (American Thoracic Society 2004). These criteria include

- sufficient history of exposure to asbestos
- appearance of disease with a consistent time interval from first exposure
- clinical picture such as insidious onset of dyspnea on exertion, bibasilar end-inspiratory crackles not cleared by coughing
- functional tests showing restrictive (occasionally obstructive) pattern with reduced diffusing capacity
- characteristic X-ray appearance
- exclusion of other causes of interstitial fibrosis or obstructive disease such as usual interstitial pneumonia, connective tissue disease, drug-related fibrosis (American Thoracic Society 2004; Khan *et al*. 2004)

The table below describes the natural history associated with parenchymal asbestosis.

Parameter	Typical Findings
Sufficient exposures	Usually associated with high-level occupational exposures (Khan *et al*., 2004).
Latency periods	Radiographic changes: <20 years. Clinical manifestations: 20-40 years. Asbestosis appears earliest in those with the highest exposure levels (American Thoracic Society 2004)
Risk of asbestosis	Asbestosis develops in 49-52% of adults with occupational levels of asbestos exposure (Khan *et al*. 2004).
Co-morbid	Increased risk for lung cancer and mesothelioma, though both can occur without parenchymal asbestosis (Weiss 1999;

conditions	Hillerdal 1999)
Mortality and Morbidity	Severe asbestosis may lead to respiratory failure over 12-24 years. Many patients with asbestosis die of other causes such as asbestos-associated lung cancer (38%), mesothelioma (9%), and other causes (32%) (Rosenberg 1997, Kamp and Weitzman 1997)
Asbestos-Related Pleural Abnormalities	Asbestos-related pleural abnormalities (also called pleural asbestosis) encompass four types of pleural changes • Pleural plaques • Benign asbestos pleural effusions • Diffuse pleural thickening • Rounded atelectasis (folded lung) The pleura are more sensitive to asbestos than the lung parenchyma, so the effects of asbestos exposure show here first and occur at much lower doses than the fibrotic changes in the lung (Peacock *et al*. 2000; Khan *et al*. 2004).  *Pleural plaques* are well-circumscribed areas of thickening, usually located bilaterally on the parietal pleura. They are usually asymptomatic, though they can cause small reductions in lung function (American Thoracic Society 2004). Pleural plaques are the most common manifestations of asbestos exposure; the highest rate (58%) is found in insulation workers (American Thoracic Society 2004; Peacock *et al*. 2000). The presence of pleural plaques in the general environmentally exposed population in developed societies is in the range of 0.5%-8% (Khan *et al*., 2004). Indeed, they are considered a biomarker of asbestos exposure, depending on length from first exposure, rather than a threshold dose like asbestosis (Peacock *et al*. 2000). Pleural plaques can also form following exposure to: • talc • silica • ceramic fibers • titanium • zeolite (Chapman *et al*. 2003; Rockoff and Robin 2002).

Benign asbestos pleural effusions are small unilateral effusions, often occurring as blood-stained exudates with various types of blood cells and mesothelial cells (Khan *et al*., 2004). These effusions are among the earliest manifestations of asbestos exposure; they can occur within 10 years of exposure (Chapman *et al*., 2003). They are usually asymptomatic. Rarely, they can cause pain, fever, and dyspnea. These effusions typically last for months, and may occasionally recur. Their presence can precede the occurrence of diffuse pleural thickening (Chapman *et al*. 2003).

Diffuse pleural thickening is a noncircumscribed fibrous thickening of the visceral pleura with areas of adherence to the parietal pleura and obliteration of the pleural space. It can be associated with more extensive asbestos exposure than diffuse pleural plaques (Chapman *et al*. 2003). And, diffuse pleural thickening, in fact, has been reported to occur in 10% of patients with asbestosis (Khan *et al*. 2004). Diffuse pleural thickening can occur after benign pleural effusions. The fibrotic areas are ill-defined, involving costophrenic angles, apices, lung bases, and interlobar fissures. Diffuse pleural thickening can be associated with mild (or, rarely, moderate to severe) restrictive pulmonary function deficits such as decreased ventilatory capacity. When this occurs, the patient may experience progressive dyspnea and chest pain (Chapman *et al*. 2003; Rockoff *et al*. 2002).

Rounded atelectasis (or folded lung) occurs when blebs of lung tissue are caught in bands of fibrous pleural tissue with in-drawing of the bronchi and vessels (Khan *et al*. 2004). This produces a distinctive X-ray appearance: a rounded pleural mass with bands of lung tissue radiating outwards. This condition is usually asymptomatic, though some patients develop dyspnea or dry cough. The course is usually stable or slowly progressive. Folded lung is the least common asbestos-related benign pleural disease, and it is not only associated with asbestosis exposure but can occur following other exposures and medical conditions. However, asbestos exposure is the leading cause of rounded atelectasis, accounting for 29%-86% of cases. It can rarely also co-occur with lung cancer (Stathopoulos *et al*. 2005).

The differential causes of rounded atelectasis includes

- exposure to mineral dusts such as asbestos, and occupational exposures to silica and mixed mineral dusts
- exudative pleural effusions such as empyema, tuberculous effusions, hemothorax, post-cardiac surgery, chronic hemodialysis
- other medical conditions such as *Legionella pneumophilia* pneumonia, histoplasmosis, end-stage renal disease,

pneumothorax, childhood cancer (Stathopoulos *et al*., 2005)

The table below shows typical findings and natural history associated with asbestos-related pleural abnormalities.

Parameter	Pleural Plaques	Pleural Effusions	Diffuse Pleural Thickening	Rounded Atelectasis
Typical exposures	Can occur with short low level exposures or high level occupational exposures. The incidence in the population will increase as exposure increases.		Usually associated with moderate- to high-level exposures. Less specific for asbestos exposure than for pleural plaques	May occur with occupational level and environmental exposures. Has other causes besides asbestos exposure.
Average latency periods	20–30 years	10 years	15 years	N/A
Co-morbid conditions	Since the presence of these plaques is an indicator of asbestos exposure, there is an increased incidence of asbestos related diseases associated with them.	Other asbestos related diseases	Other asbestos related diseases. Can follow benign pleural effusions.	Follows benign pleural effusions; can co-exist with other asbestos-related diseases or its other causes.
Mortality and Morbidity	Not fatal/usually asymptomatic; incidental finding.	Not fatal. Clinical presentation ranges from asymptomatic to pleuritic chest pain and fever.	Not fatal. If severe, can cause dyspnea.	Not fatal. Usually asymptomatic; if severe, chest pain, dyspnea, and cough. Usually no functional impairment unless accompanied by other asbestos-related disease.

Source: American Thoracic Society 2004; Chapman *et al*., 2003; Khan *et al*. 2004; Stathopoulos *et al*. 2005)

Lung Carcinoma

Most lung cancers are associated with exposure to tobacco smoke. Smokers have a 13-fold higher risk than nonsmokers for lung cancer, and people with long-term passive exposure to tobacco smoke are at 1.5 times higher risk for lung cancer than are people who are never exposed to tobacco smoke. Lung cancer currently accounts for 28% of all cancer deaths in the United States (Minna 2005).

Exposure to asbestos is associated with all major histological types of lung carcinoma (adenocarcinoma, squamous cell carcinoma, and oat-cell carcinoma). It is estimated that 4%-12% of lung cancers are related to occupational levels of exposure to asbestos (Henderson *et al*. 2004). It is estimated that 20%-25% of heavily exposed asbestos workers will develop bronchogenic carcinomas (Khan *et al.*, 2004). Whether asbestos exposure will lead to lung cancer depends on several factors

- level, duration, and frequency of asbestos exposure (cumulative exposure) (Henderson *et al*. 2004)
- time elapsed since exposure occurred
- age when exposure occurred,
- history of tobacco use
- individual susceptibility factors not yet determined

Most asbestos-related lung cancers reflect the dual influence of asbestos exposure and smoking (Henderson *et al*. 2004). Smoking and asbestos exposure have a multiplicative effect on the risk of lung cancer (Lee 2001; Henderson *et al*. 2004; ATSDR 2001). Asbestos as the sole contributing factor for an individual patient can be difficult to prove especially when the patient has other risk factors for lung cancer. The presence of parenchymal asbestosis is an indicator of high-level asbestos exposure, but lung cancer can occur without asbestosis.

One of the best known sets of criteria to guide the clinician regarding whether asbestos contributed to lung cancer in an asbestos-exposed individual is the Helsinki criteria. For these criteria, some of the markers for attributing asbestos exposure as a contributing factor to lung cancer are

- the presence of asbestosis – serves as marker for significant exposures to asbestos
- 5,000 to 15,000 asbestos bodies per gram dry lung tissue (if lung biopsy indicated)
- estimated cumulative exposure history of 25 fiber-years

to asbestos (if known)

- by history, 1 year of heavy occupational exposure or 5-10 years of moderate exposure
- lag time of 10 years since the first exposure

The table below shows typical findings associated with lung carcinoma.

Parameter	Typical Findings
Typical exposures	Large cumulative exposure (short-term, high-level exposures or long-term, moderate-level exposures).
Latency periods	20–30 years
Clinical presentation	Only 5%-15% of patients are asymptomatic when diagnosed. Most present with cough, hemoptysis, wheeze, dyspnea (Minna, 2005).
Co morbid conditions	Asbestosis, other asbestos-related diseases. Paraneoplastic syndromes associated with lung cancer.
Mortality	Same as lung carcinoma with other causes - 14% five year survival rate (British Thoracic Society 2001).

Pleural Mesothelioma

Diffuse malignant mesothelioma is a tumor arising from the thin serosal membrane of the body cavities, arising from the pleura, peritoneum, tunica vaginalis testis, and ovaries. It is a rare neoplasm, accounting for less than 5% of pleural malignancies. There are three histological types of malignant mesothelioma: epithelial, mixed, and sarcomatous. Of malignant mesotheliomas, 80% affect the pleura, and 20% of all malignant mesotheliomas affect the peritoneum (Khan *et al*. 2004). Peritoneal mesothelioma is discussed in the next section.

In most cases, the tumor is rapidly invasive locally (Lee *et al*. 2000). Patients with malignant pleural mesothelioma can have sudden onset of pleural effusion or thickening, dyspnea, and chest pain. By the time symptoms appear, the disease is most often rapidly fatal (British Thoracic Society 2001).

Pleural mesothelioma is a signal tumor for asbestos exposure; other causes are uncommon. The risk of mesothelioma does depend on the amount of asbestos exposure (Weill *et al*. 2004). All types of asbestos can cause mesothelioma, but some researchers believe that the amphibole form is more likely to induce mesothelioma than the serpentine form (ATSDR 2001a).

In 2000, about 3,000 people in the United States died of mesothelioma (Lee *et al*. 2000; Khan *et al*. 2004) According to the National Cancer Institute's SEER data, there was an increase in the incidence of mesothelioma in the United States from the early 1970s to the mid-1990s, as disease developed in people exposed during peak asbestos exposure years (1940–1970). Mesothelioma incidence has probably started to decline in the United States, although it may still be increasing in Europe and Australia because of more abundant and prolonged use of asbestos in these countries than in the United States (Weill *et al*. 2004).

The table below shows typical findings associated with pleural mesothelioma.

Parameter	Typical Findings
Typical exposures	Short-term, high-level exposures or chronic low-level exposures, especially to amphibole asbestos; incidence increases in dose-related manner (Hillerdal 1999).
Latency periods	10–57 years (30–40 years typical).
Clinical presentation	Frequently presents with chest pain accompanied by pleural mass or pleural effusion on chest X-ray (British Thoracic Society 2001).
Mortality	High . The typical 1-year survival rate is <30%. Average survival time is 8–14 months after diagnosis (British Thoracic Society 2001).
Key Points	• Parenchymal asbestosis is a interstitial pulmonary fibrosis resulting from inhalation of asbestos fibers. It produces a restrictive pattern of disease and progressive exertional dyspnea. • Asbestos-related pleural abnormalities include pleural plaques, benign pleural effusions, diffuse pleural thickening, and rounded atelectasis. They are relatively benign conditions, though pleural thickening can cause restrictive deficits. • Lung carcinoma caused by asbestos exposure is histologically similar to lung cancer from other causes. • Malignant pleural mesothelioma is a rare tumor arising from the pleural mesothelium. It is a signal tumor for asbestos exposure. • Asbestos-associated respiratory diseases have long latency periods: 10 to 40 years or more, depending on the disease and exposure factors.

Progress Check

13. Diffuse interstitial fibrosis resulting from inhalation of asbestos fibers and producing restrictive lung disease and progressive exertional dyspnea is termed

    A. lung carcinoma
    B. pleural mesothelioma
    C. parenchymal asbestosis
    D. asbestos-related pleural abnormalities

To review relevant content, see Parenchymal Asbestosis in this section.

14. Asbestos-related pleural abnormalities include which of the following?

    A. pleural plaques
    B. benign pleural effusions and diffuse pleural thickening
    C. rounded atelectasis
    D. all of the above

To review relevant content, see Asbestos-Related Pleural Abnormalities in this section.

What Other Health Conditions Are Associated with Asbestos?

Learning Objective Upon completion of this section, you should be able to

- identify nonrespiratory conditions that might be associated with exposure to asbestos.

Introduction

Evidence suggests that exposure to asbestos might lead to conditions outside the respiratory system, including

- peritoneal mesothelioma
- other extrathoracic cancers
- cardiovascular conditions secondary to pulmonary fibrosis

Peritoneal Mesothelioma

Peritoneal mesothelioma is similar to pleural mesothelioma except that it arises in peritoneal membranes. Like pleural mesothelioma, this tumor is rapidly locally invasive and often rapidly fatal after it is diagnosed. It is frequently asymptomatic, though it can often be detected by abdominal palpation as an expanding "doughy" feeling.

Peritoneal mesothelioma is rare. In men, 90% of all mesotheliomas are pleural (Weill *et al*. 2004). In addition, the sex difference in incidence is smaller with peritoneal mesothelioma than for pleural mesothelioma (Hillerdal 1999).

The table below shows male to female incidence ratios for the two different types of mesothelioma.

Type of Mesothelioma	Male/Female Incidence Ratio
Pleural	5:1
Peritoneal	1.5:1

Source: Hillerdal 1999

Other Extrathoracic Cancers

Researchers and regulators have not been able to reach a consensus on the effects of asbestos on extrathoracic cancers. To address this concern, the National Academy of Sciences charged the Institute of Medicine (IOM) to review the state of the evidence regarding the role of asbestos in causing selected extrathoracic cancers. The results of this panel are presented below.

Type of cancer	Evidence for causality by asbestos
Laryngeal	Sufficient
Pharyngeal	Suggestive but not sufficient
Stomach	Suggestive but not sufficient
Colorectal	Suggestive but not sufficient
Esophageal	Inadequate

Source: (National Academy of Sciences, 2006)

	Nevertheless, ATSDR and the National Toxicology Program (NTP) concur that it is prudent to consider increased risk of gastrointestinal cancer a possible effect of asbestos exposure (ATSDR 2001a; American Thoracic Society 2004). Screening for colon cancer is recommended for everyone over the age of 50, but on the basis of current evidence, screening for other extrathoracic cancers in people exposed to asbestos is not currently recommended (American Thoracic Society 2004; Griffith and Maloney 2003).
Cardiovascular Conditions	Cor pulmonale occurs in many forms of far advanced lung disease when fibrosis of the lungs leads to increased resistance to blood flow through the capillary bed. This condition is most commonly seen in patients with severe parenchymal asbestosis, though it can also occur with less severe fibrotic disease, especially if chronic obstructive pulmonary disease is simultaneously present, as is often the case with asbestos workers who smoke cigarettes. Constrictive pericarditis rarely occurs secondary to asbestos-induced severe fibrosis or calcification of the pericardium.
Key Points	• Peritoneal mesothelioma is a rare, rapidly invasive tumor associated with asbestos exposure. • Asbestos exposure might be associated with extrathoracic cancers, especially colon cancer. This association is controversial. • Cor pulmonale can occur secondary to pulmonary fibrosis, mainly in patients with severe parenchymal asbestosis. • Rarely, constrictive pericarditis can occur secondary to asbestos-associated disease.

Progress Check

15. Exposure to asbestos is associated with

    A. peritoneal mesothelioma
    B. gastrointestinal cancer
    C. other extrathoracic cancers
    D. all of the above

To review relevant content, see Peritoneal Mesothelioma in this section.

16. The cardiovascular condition most likely to occur secondary to pulmonary fibrosis is:

    A. endocarditis
    B. constrictive pericarditis
    C. cor pulmonale
    D. all of the above

To review relevant content, see Cardiovascular Conditions in this section.

How Should Patients Exposed to Asbestos Be Evaluated?

Learning Objectives

Upon completion of this section, you should be able to

- identify the primary focuses of the exposure history and medical history
- describe the most typical finding on patient examination

Introduction

Patients who have been exposed to asbestos should undergo a thorough medical evaluation. Early and accurate diagnosis is important to your choosing the most appropriate care strategies, even if the patient is not exhibiting symptoms. In cases of asbestos exposure, medical evaluation should include

- an assessment of clinical presentation
- an exposure history (See ATSDR Case Study in Environmental Medicine: Taking an Exposure History)
- a medical history
- a physical examination
- a chest radiograph and pulmonary function tests

This section focuses on the first four items, which are typically conducted during the patient's visit to your office. Recommended tests are discussed in the next section.

Clinical Presentation

Many people with occupational exposure to asbestos never have serious asbestos-related diseases. However, asbestos-associated diseases typically have long latency periods, so many patients exposed to asbestos are asymptomatic for years before asbestos-related any disease develops. If and when asbestos-associated disease does manifest clinically, the patient's symptoms depend on the type and stage of disease(s) involved (see table). A single patient can have any combination of asbestos-associated diseases.

Asbestos-Associated Disease	Clinical Presentation
Parenchymal asbestosis	Presenting Symptoms • Insidious onset of dyspnea on exertion • Fatigue Advanced Stages • Clubbing of the fingers • Cor pulmonale (rare)
Asbestos-related pleural abnormalities	Presenting Symptoms

	• Usually none Diffuse Pleural Thickening • Progressive dyspnea • Intermittent chest pain Rounded Atelectasis • Dyspnea • Dry cough
Lung cancer	Presenting Symptoms • Early in the course, usually none • Occasionally, dry cough Advanced Stages • Hemoptysis • Chest pain • Weight loss • Fatigue • Dyspnea with pleural effusion
Mesothelioma	Presenting Symptoms • Early in the course, can be asymptomatic • Frequently presents with chest pain and dyspnea Advanced Stages • Dyspnea • Severe and progressive chest pain • Pleuritic chest pain • Systemic signs of cancer such as weight loss and fatigue

Source: British Thoracic Society 2001; American Thoracic Society 2004

Exposure History	Taking a detailed exposure history is an important step in evaluating a patient who may be at risk for developing asbestos-associated diseases. In general, risk of asbestos-related disease increases with total dose (Khan *et al*. 2004). However, since asbestos accumulates in the body, even relatively minor exposures many years before could be important in diseases like mesothelioma. The exposure history should include the following information

- work history, including occupations in which the patient may have been exposed directly or indirectly
- source, intensity, frequency and duration of exposure
- time elapsed since first exposure
- if extant, workplace dust measurements or cumulative fiber dose (or exposure scenario, if levels cannot be determined)
- use of personal protective equipment
- other sources of exposure, including paraoccupational exposures from family members and other household contacts
- sources of environmental exposure including a residence near an area with naturally occurring asbestos deposits or hobbies or recreational activities that involve materials that are contaminated with asbestos)
- sources of other environmental contaminants such as environmental tobacco smoke

For more information on the exposure history, see the Taking an Exposure History CSEM at

http://www.atsdr.cdc.gov/csem/exphistory/ .

See the table below for typical exposures for each of the asbestos-associated diseases.

Asbestos-Related Disease	Typical Exposure History
Parenchymal asbestosis	Usually associated with high-level occupational exposures, not with paraoccupational or environmental exposures (Khan *et al*. 2004).
Asbestos-related pleural abnormalities	Pleural Plaques Presence depends on time from exposure, not a threshold dose. The incidence of this disorder in a population does increase with exposure. Occurs in 0.5% to 8% of environmentally exposed individuals to a high of 58% in insulation workers (Peacock *et al*. 2000).
Lung cancer	Large cumulative exposure. It is believed to be dose-related.
Mesothelioma	Not as dose-related as other asbestos-related diseases, but the risk does increase with dose. Can be found in residents near asbestos mines and with paraoccupational exposure. The percent of patients with confirmed asbestosis will die of mesothelioma (British Thoracic Society 2001).
Medical History	Knowing the complete medical history of a patient who has been exposed to asbestos is important to making an accurate

diagnosis. It is especially important to ask about a history of smoking and exposure to second-hand smoke, because exposure to tobacco smoke, especially active smoking, can greatly increase a patient's risk of lung cancer and can worsen the effects of parenchymal asbestosis.

In addition, it is important to be aware of other respiratory and non-respiratory conditions that may have similar clinical presentations.

Physical Examination

Patients with a history of asbestos exposure should receive a full physical examination. In the case of early or mild disease, there will probably be no abnormal physical findings. The most common abnormal finding with significant asbestosis is bibasilar rales with end-inspiratory crackles on pulmonary auscultation. These are typically described as sounding like Velcro (Ross 2003).

Physical examination should also include

- abdominal palpitation, which is used to detect the expanding "doughy" feeling associated with peritoneal mesothelioma.
- digital exam for clubbing of the fingers and cyanosis (American Thoracic Society 2004).
- examination of the extremities for symmetrical dependent edema, one of the physical findings of cor pulmonale.

Differential Diagnosis

Several treatable conditions have symptoms similar to those of asbestos-associated diseases. For this reason, it is important to distinguish between these conditions and such disorders as parenchymal asbestosis (see table), which is not curable (treatment is supportive and symptomatic).

It is also important to distinguish between benign asbestos-associated conditions and malignant conditions such as lung cancer and mesothelioma. In cases that are not clear cut, a referral to a pulmonary specialist for further workup is indicated.

Asbestos-Related Conditions	Differential Diagnosis: Respiratory Conditions	Differential Diagnosis: Non-Respiratory Conditions
Parenchymal Asbestosis	• idiopathic pulmonary fibrosis • other pneumoconiosis: o talc o silica o titanium o zeolite • interstitial pulmonary fibrosis (IPF)	• rheumatoid arthritis • prior thoracic surgery/chest wall configuration • left ventricular failure (presents

	• hypersensitivity pneumonitis • sarcoidosis • chronic obstructive pulmonary disease (may produce rales similar to bibasilar rales) • drug-related fibrosis • other pulmonary diseases of this type	with dyspnea, rales, edema, restriction, and basilar markings on chest film)

Benign asbestos-related pleural disease	Single pleural plaques
	
	• malignant mesotheliomas and metastatic adenocarcinomas (Khan *et al*. 2004)
	
	Single calcified pleural plaques
	
	• tuberculosis
	• empyema
	• hemothorax (Khan *et al*. 2004)
	
	Bilateral calcified pleural plaques
	
	• Most commonly asbestos related but in rare cases
	  o radiation exposure
	  o hyperparathyroidism
	  o pulmonary infarction
	  o pancreatitis (Khan *et al*. 2004)
	
	Diffuse pleural thickening
	
	• post-exudative effusions such as parapneumonic effusions and those secondary to connective tissue disease
	• hemothorax
	• mesothelioma, (Khan *et al*. 2004)
	
	Rounded atelectasis (folded lung)
	
	• Lesions that are similar to in appearance to rounded atelectasis (*i.e.*. , solitary pulmonary mass) are
	  o Malignancies such as bronchogenic carcinoma, metastasis, lymphoma
	  o Benign neoplasms such	

	as hamartoma and adenoma o Vascular causes such as arteriovenous malformation, pulmonary infarct, hematoma o Infections such as tuberculosis, round pneumonia, fungal infections (Khan *et al*., 2004)	
Lung carcinoma	Other causes of a solitary pulmonary nodule • Folded lung • Metastatic lesion • Lymphoma • Benign neoplasms such as hamartoma or adenoma • Vascular lesion such as a arteriovenous malformation, pulmonary infarction or hematoma • Infectious lesions from tuberculosis, fungal infections (Khan *et al*. 2004)	
Malignant mesothelioma	• Diffuse pleural thickening • Metastatic adenocarcinoma (Khan *et al*. 2004; British Thoracic Society 2001)	

Key Points	• The exposure history focuses on finding information on exposures to asbestos. • The medical history focuses on smoking history and other respiratory conditions. • The most typical abnormal finding on examination of patients with a history of asbestos exposure is bibasilar end inspiratory rales on pulmonary auscultation. • Patients with parenchymal asbestosis present to the clinician with the chief complaint of fatigue, insidious onset of dyspnea on exertion. • Asbestos-related pleural abnormalities typically do not cause symptoms, although some patients experience progressive dyspnea and chest pain. • Lung cancer can be asymptomatic, but in the later stages patients experience fatigue, weight loss, chest pain, dyspnea, or hemoptysis. • Mesothelioma is typically asymptomatic until later stages, at which point patients have dyspnea and chest pain.

Progress Check

17. The most typical abnormal finding on physical examination of a patient with significant asbestosis is
    A. a "doughy" feeling in the abdomen
    B. bibasilar inspiratory rales on pulmonary auscultation
    C. clubbing of the fingers
    D. all of the above

To review relevant content, see Physical Examination in this section.

18. Why is it important to know a patient's exposure history?
    A. Asbestos-associated diseases have symptoms similar to those of treatable diseases, and the exposure history assists a differential diagnosis.
    B. Activities such as smoking can increase a patient's risk of asbestos-related diseases.
    C. Asbestos accumulates in the body and, for certain disorders, even minor exposures can be important.
    D. all of the above

To review relevant content, see Exposure History in this section.

What Tests Can Assist with the Diagnosis of Asbestos Toxicity?

Learning Objectives

Upon completion of this section, you should be able to

- describe pulmonary function test findings associated with parenchymal asbestosis
- describe chest radiograph findings associated with other asbestos-associated diseases.

Introduction

The two most important tests in diagnosing asbestos-associated disease are

- pulmonary function tests, and
- chest radiographs.

Other tests and procedures that are sometimes used to diagnose asbestos-associated diseases by specialists in cases that require further work-up are

- computed tomography (CT) or high-resolution computerized (axial) tomography (HRCT)
- bronchoalveolar lavage (BAL)
- lung biopsy
- blood studies
- colon cancer screening

Screening Pulmonary Function Tests

Screening pulmonary function tests are useful for finding restrictive deficits associated with parenchymal asbestosis (see table). Findings may include a reduction in forced vital capacity (FVC) with a normal Forced Expiratory Volume (FEV1)/FVC ratio. Some sources report abnormal pulmonary function tests in 50% to 60% of patients with asbestosis (Ross 2003).

In some cases, combined patterns of restrictive and obstructive disease may be seen. For further assessment of whether a patient has a restrictive abnormality and asbestosis, additional, more specialized tests may be required

- Carbon monoxide diffusion capacity (DLco), which is very sensitive to the ventilation-perfusion mismatch and gas exchange abnormalities characteristic of all types of diffuse interstitial pulmonary fibrosis and DLco is reduced in 70% to 90% of asbestosis cases (Ross 2003). Be aware however that, although fairly sensitive, the DLco is a non-specific finding and it can be reduced in far advanced stages of COPD as well as in other types of restrictive interstitial diseases.
- static lung volumes
- plethysmographic and helium dilution methods

Consider consulting a pulmonologist if the diagnosis is unclear, if there is a rapid decline in pulmonary function, or if there is a need for a tissue biopsy or BAL, such as in cases where lung cancer, mesothelioma, or an infection is suspected. The pulmonologist may recommend more extensive pulmonary function tests.

Asbestos-Associated Disease	Pulmonary Function Test Findings
Parenchymal asbestosis	• reduction in FVC, normal FEV1/FVC ratio. • a 25% to 74% reduction of forced expiratory rate • restrictive pattern with a decreased DLco • mixed obstructive/restrictive pattern (reduced FEV1/FVC associated with reduced FEV1) (American Thoracic Society 2004)
Asbestos-related pleural abnormalities	• reduced FVC can be associated with diffuse pleural thickening

Chest Radiograph

The chest radiograph is used primarily to

- find structural changes associated with asbestos-associated diseases such as asbestosis
- assess asbestos-associated parenchymal and pleural disease such as pleural plaques and mesothelioma.

Diagnosis of asbestosis should mostly but not totally be based on radiographic findings, per the diagnostic criterion of the American Thoracic Society. In 10% to 15% of cases, an asbestos-associated pulmonary function abnormality can occur without definite radiologic change (Ross 2003). The association of pleural thickening and calcification with interstitial changes enhances diagnostic accuracy of asbestosis. The American Thoracic Society includes radiographic findings as one of their criterion for making a diagnosis of asbestosis.

In 1980, the International Labour Organization (ILO) developed a system for radiographic classification of the pneumoconiosis. Persons certified to use this rating system are called "B readers." A current list of B readers can be found at http://www.cdc.gov/niosh/topics/chestradiography/breader-list.html. Detection of parenchymal asbestosis by chest radiography should be guided by the ILO system or other standard reading methods.

A list of typical chest radiograph findings for each of the asbestos-associated diseases is in the table below.

Pleural Plaques

Pleural Mesothelioma

Parenchymal asbestosis

Asbestos-Associated Disease	Typical Chest Radiograph Findings
Parenchymal asbestosis	• small, irregular opacities in one or both lung fields, with a pattern of irregular linear opacities • diffuse, bilateral interstitial fibrosis • with advanced disease, "ground-glass" appearance that blurs the heart border if there is combined interstitial and pleural involvement (also known as the "shaggy heart sign") • honeycombing and upper lobe involvement in advanced stages
Asbestos-related pleural abnormalities	*Pleural Plaques* • often multiple bilateral well-circumscribed areas of thickening found on the pleura, sometimes with calcification (10%-15%) (Khan *et al*. 2004) *Benign Pleural Effusions* • cloudy, milky appearance like other pleural effusions *Diffuse Pleural Thickening* • thickening of the parietal pleura on more than one quarter of the chest wall appears as a lobulated prominence of the pleura adjacent to the thoracic margin (Khan *et al*. 2004) • thickening of the visceral pleura (diffuse, may also appear as interlobar fissure pleural thickening) *Rounded Atelectasis* • appears as a rounded pleural mass with bands of lung tissue radiating outwards

Lung cancer	• radiological appearance same as that of lung cancers with other causes, (*i.e.*, solitary pulmonary mass with or without mediastinal lyphadenopathy)
Mesothelioma	May present as a • pleural effusion • pleural mass • a diffuse pleural thickening
CT and HRCT	In some cases, CT and HRCT scans can facilitate diagnosis of asbestos-associated diseases. Because they are associated with higher doses of radiation than conventional chest X-rays and their cost-effectiveness and efficiency as screening tools have not been established, CT scans should not be used for routine screening. They can be useful in further investigating abnormalities found on chest X-rays and in detecting abnormalities not seen on chest films of patients with dyspnea or pulmonary function abnormalities. CT and HRCT scans are more sensitive than chest radiographs. When B readers are not able to agree on the presence of asbestos-associated disease per the chest radiograph, CT and HRCT scans can be used (American Thoracic Society 2004). They are especially useful in detecting • early changes of parenchymal asbestosis. • pleural disease, such as plaques and rounded atelectasis • the difference between asbestos-associated pleural plaques and soft tissue densities • mesothelioma (British Thoracic Society 2001). ATSDR recommends low-dose CT scans for screening certain former vermiculite miners or vermiculite mill workers and their household contacts whose chest radiographs are indeterminate (Muravov *et al*. 2005). The utility of other imaging techniques such as ultrasound, gallium scanning, magnetic imaging, ventilation-perfusion studies, and positron emission tomography has not been established. New digital imaging techniques (*e.g.*, digital radiography) are under development as well.
BAL and Lung Biopsy	BAL (bronchoalveolar lavage) is sometimes used by specialists to identify other possible causes for lung pathology and it can be used to determine the level of exposure to asbestos by measuring the amount and type of asbestos bodies in the lung tissue and lavage fluid (Santorelli *et al*. 2001; American Thoracic Society 2004). Special laboratory facilities for quantitating asbestos fibers must be available.

	Lung biopsy is a definitive test used in the histopathical confirmation of asbestos-associated diseases. Lung biopsies are rarely used to diagnosis asbestosis or pleural plaques, because diagnosis of these conditions is usually based on findings from the medical evaluation and other tests. Appropriate referral to a specialist is indicated if lung cancer or mesothelioma is suspected, since a lung biopsy may be indicated under these conditions.
Blood Studies	Arterial blood gas (ABG) and pulse oximetry are sometimes used to detect decreases in oxygen in the blood associated with the respiratory changes associated with asbestos-related disease. Blood chemistry studies may occasionally be useful for ruling out other causes of restrictive lung disease (*e.g.*, rheumatoid lung disease, uremia, increased sedimentation rate).
Colon Cancer Screening	Some studies show that asbestos exposure increases a patient's risk for colon cancer. Therefore, colon cancer screening should be considered in accordance with the American Cancer Society's screening guidelines for colon cancer for people over age 50 American Thoracic Society 2004).
False Positives and False Negatives	It is important to know what other conditions bear radiographic similarities to changes associated with asbestos-related disease (see table).

Asbestos-Associated Disease	Similar Radiographic Appearance
Parenchymal asbestosis	• left ventricular failure • other treatable and non-treatable forms of pulmonary fibrosis, including other forms of pneumoconiosis
Asbestos-related pleural abnormalities	General differential diagnoses • acute pleuritis (due to conditions such as empyema and tuberculosis) • previous surgery or chest wall trauma • past empyema or infected pleural effusion Pleural plaques may be confused with • extra pleural fat • muscle or fat shadows • pleural thickening from old rib fractures Benign asbestos pleural effusions may be confused with • Malignant pleural effusion

	• Multiple other causes of pleural effusion, including tuberculosis, congestive heart failure Diffuse pleural thickening may be confused with • Mesothelioma • Healed empyema • Old chest trauma • Old chest surgery Rounded atelectasis • Bronchogenic carcinoma • Mesothelioma. • Pleural-based lung cancer or metastasis to the pleura
Lung cancer	Lung cancer not related to asbestos.
Mesothelioma	All other causes of unilateral pleural masses.
Attribution of Asbestos-Related Cause	To help attribute pulmonary fibrosis to asbestos exposure check for the diagnostic guidelines suggested by the American Thoracic Society • appropriate exposure history, • appropriate latency period between exposure and onset of symptoms • characteristic chest radiograph appearance when the ILO system of either parenchymal or pleural changes is used. Other findings that aid in attributing a disease to asbestos exposure include • asbestos bodies and uncoated fibers in the lungs found on BAL (if performed) • restrictive pattern and decrease in DLco on spirometry • ausculatory signs such as characteristic rales (Holland and Smith 2003; American Thoracic Society 2004). Bilateral calcified pleural plaques are usually attributed to asbestos exposure, but single-sided pleural plaques may not be and a search for other causes such as old tuberculosis, empyema, or hemithorax may be indicated. CT scanning can be used to make a definite diagnosis of rounded atelectasis, if there are any questions (Khan *et al*. 2004). As stated previously, sets of diagnostic criteria like the Helsinki criteria can help determine if a lung cancer has any causal relationship to asbestos exposure.

	Malignant mesotheliomas are, for all practical purposes, related to previous asbestos exposure.
Key Points	• Parenchymal asbestosis is associated with a reduction in FVC and restrictive patterns on spirometry. • Signs of parenchymal asbestosis on chest X-ray include irregular opacities, interstitial fibrosis, and the "shaggy heart sign." • On chest X-ray, pleural plaques appear as well-circumscribed areas of pleural thickening, sometimes with calcification. • On chest X-ray, pleural effusions have a cloudy or milky appearance. • On chest X-ray, diffuse pleural thickening appears as a lobulated prominence and interlobar fissure thickening. • On chest X-ray, findings associated with rounded atelectasis appear as a rounded pleural mass with radiating bands of lung tissue. • Asbestos-associated lung cancer has the same appearance as lung cancer from other causes. • Chest X-ray findings associated with mesothelioma include pleural effusions or a pleural mass. • CT and HRCT scans can be useful in diagnosing early changes associated with asbestosis, in helping clarify questionable pleural or parenchymal findings and in diagnosing mesothelioma. • Other tests that can be useful include BAL, lung biopsy, and colon cancer screening.

Progress Check

19. The two most important tests for diagnosing asbestos-associated diseases are

    A. BAL and lung biopsy
    B. CT and HRCT scans
    C. chest radiograph and pulmonary function tests
    D. blood studies and colon cancer screening.

To review relevant content, see Introduction in this section.

20. Diffuse, bilateral interstitial fibrosis and small, irregular opacities are characteristic X-ray findings with

    A. parenchymal asbestosis
    B. lung cancer
    C. mesothelioma
    D. all of the above

To review relevant content, see Chest Radiograph in this section.

How Should Patients Exposed to Asbestos Be Managed and Treated?

Learning Objectives

Upon completion of this section, you should be able to:

- identify two primary strategies for managing asbestos-associated diseases.
- describe specific strategies for managing parenchymal asbestosis.

Introduction

In general, asbestos-associated diseases such as asbestosis and pleural plaques are not treatable. Management focuses on prevention and amelioration of symptoms whether the patient is asymptomatic or already ill. Therefore, the primary goals are to

- remove the patient from the workplace or source of exposure (if possible) or provide proper respiratory protection according to OSHA standards
- in states, where asbestosis is a reportable disease, report new cases to the appropriate health authorities.
- monitor the patient to facilitate early diagnosis of any treatable respiratory conditions

Patients who are symptomatic may need documentation of impairments caused by asbestos-associated disease for the purpose of filing for worker compensation, social security disability, or other claims. Degree of disability should be stated in the terms required by the program to which the patient is applying. Recording these impairments is an important task and may require the assistance of a specialist. To locate a specialist, please refer to the Web resources listed under Where Can I Find More Information? at the end of this CSEM

The remainder of this section focuses on patient care.

All Exposed Patients

Care of patients who have been exposed to asbestos, whether or not they are symptomatic, involves routine follow up to facilitate early diagnosis and intervention. This includes

- taking exposure and medical histories and regular physical examinations
- periodic chest X-rays and pulmonary function tests to look for early signs of asbestos-associated disease
- gathering information on smoking cessation
- educating patients regarding the possible consequences of asbestos exposure

Information and Instructions for Patients

Parenchymal Asbestosis	Parenchymal asbestosis is irreversible, and the rate of disease progression varies (American Thoracic Society 2004). Currently, there is no effective treatment. Patients with advanced disease and hypoxemia at rest, during exercise, or during sleep will benefit from continuous home oxygen therapy, which can prevent or attenuate cor pulmonale. However, primary management strategies for parenchymal asbestosis are listed below • remove the patient from the source of exposure (if possible) or provide personal protective equipment to OSHA standards • notify employer of exposures to asbestos so that medical surveillance and personal protective equipment can be instituted (if occupational exposure). • in states, where asbestosis is reportable, notify the appropriate health authorities • assess the patient's level of disability • treat respiratory infections aggressively. • provide annual influenza and regular pneumococcal vaccines at intervals recommended by CDC • provide respiratory therapies and pulmonary rehabilitation as needed • counsel patients who smoke to quit. • follow the general strategies listed for all patients Patients should be monitored periodically (per doctor-patient consultation) for disease progression and closely observed for asbestos-associated malignancies such as lung cancer, mesothelioma, and gastrointestinal cancers (American Thoracic Society 2004).
Pleural Abnormalities	Pleural plaques are benign, but they can occasionally result in pulmonary impairment. In addition, patients with asbestos-related pleural abnormalities are likely to have or eventually get parenchymal asbestosis or asbestos related cancers. Therefore, management of asbestos-related pleural abnormalities involves monitoring for parenchymal asbestosis and the general strategies listed for all patients.
Mesothelioma	Diffuse malignant mesothelioma is almost always fatal. According to the British Thoracic Society, the mean life expectancy following diagnosis is 8 to 14 months (British Thoracic Society 2001). For more information about the diagnosis and treatment of mesothelioma, see: • British Thoracic Society's Standards of Care Committee, Statement on malignant mesothelioma in the United Kingdom (Thorax 2001; 56:250-265) • The National Cancer Institute's latest news on the treatment of mesothelioma at URL http://www.nci.nih.gov/cancertopics/types/malignantmesothelioma/

Lung Cancer	The treatment and management of asbestos-associated lung cancer is the same as that of lung cancer from other causes.

Key Points	• The two primary strategies for managing asbestos-associated diseases are
	  o Remove the patient from further exposure to asbestos (if possible) or provide of personal protective equipment up to OSHA standards.
	  o Monitoring the patient carefully to facilitate early diagnosis of treatable complications.
	• The primary strategies for managing parenchymal asbestosis are to stop exposure, stop smoking, avoid or aggressively treat respiratory infection, and assess the level of impairment.
	• Notify employer of exposure so that medical surveillance and appropriate PPE can be provided (if occupational exposures are over OSHA standards).

Progress Check

21. Primary strategies for managing asbestos-associated diseases in exposed patients or those already ill include

    A. smoking cessation
    B. periodic pulmonary function tests
    C. patient education
    D. all of the above

To review relevant content, see Introduction in this section.

22. Managing parenchymal asbestosis involves:

    A. smoking cessation
    B. regular influenza and pneumococcal vaccines
    C. respiratory therapies and pulmonary rehabilitation
    D. all of the above

To review relevant content, see Parenchymal Asbestosis in this section.

What Instructions Should Be Given to Patients?

Learning Objective Upon completion of this section, you should be able to

- list four instructions for patient self-care and two instructions for clinical follow-up.

Introduction

Patients with a history of asbestos exposure will vary widely in their clinical condition. Some will be asymptomatic and will continue to be so for life. Some will be beginning to show signs of asbestos-associated disease, and others will have more established disease. The care you provide will depend on the clinical status of the patient. All patients exposed to asbestos, however, need some basic guidance on

- self-care, so they can minimize further risks and avoid complications to the extent possible
- clinical follow up, so they understand when and why to return for further medical attention.

ATSDR has developed a patient education sheet on asbestos toxicity.

Self Care

Patients should be advised to avoid exposures and conditions that might further increase their risk of disease or worsen their existing condition (see table).

Advice	Rationale
If the patient smokes, advice them to stop smoking and provide advice on smoking cessation. All patients should avoid exposure to second-hand smoke.	Smoking decreases lung defenses, dramatically increases risk of lung cancer in case of asbestos exposure, and worsens effects of asbestosis.
Avoid exposure to respiratory irritants, such as air pollution, dusts, and fumes.	These irritants can worsen breathing problems.
Avoid exposure to respiratory infections.	Respiratory infections can be very serious in people with asbestos-associated respiratory conditions.

Clinical Follow Up

Patients should be advised to consult their physicians if they have

- any sign or symptom of respiratory infection
- signs or symptoms of other health changes (especially those possibly related to an asbestos-associated disease).

ATSDR's patient education sheet on asbestos toxicity has a more detailed checklist that you can use to determine which types of follow-up are relevant for a given patient.

Key Points	Counsel patients as follows: • if smoking, patients should stop • avoid other respiratory irritants • avoid exposure to respiratory infections • contact their physician if you have a respiratory infection or other health changes • use the patient education sheet and prescribed follow up check list on asbestos toxicity at http://www.atsdr.cdc.gov/csem/asbestos/pated_sheet2.html

Progress Check

23. Patients who were exposed to asbestos should

    A. stop smoking
    B. avoid exposure to other respiratory irritants
    C. avoid exposure to respiratory infections and contact their doctor if they
    D. develop signs of infection or other health changes
    all of the above

To review relevant content, see Introduction in this section.

Where Can I Find More Information?

For More Information	Please refer to the following Web resources for more information on the adverse effects of asbestos, the treatment of asbestos-associated diseases, and management of persons exposed to asbestos. You may also contact ATSDR (see URLs provided below), your state and local health departments, and university medical centers. Independent Medical Examiners: http://www.abime.org/ Association of Occupational and Environmental Clinics: http://www.aoec.org American College of Occupational and Environmental Medicine: http://www.acoem.org American College of Medical Toxicologists: http://www.acmt.net American College of Preventive Medicine: http://www.acpm.org NIOSH Certified B-Readers National Listing: http://origin.cdc.gov/niosh/topics/chestradiography/breader-list.html Occupational Safety and Health Administration: http://www.osha.gov ATSDR Information Center: http://www.atsdr.cdc.gov/icbkmark.html ATSDR Information Center Contact Information: http://www.atsdr.cdc.gov/contacts.html
Suggested Reading	For further information on asbestos-associated diseases, please refer to American Thoracic Society. 2004. Diagnosis and initial management of nonmalignant diseases related to asbestos. American Journal of Respiratory and Critical Care Medicine, 170: 691-715, 2004. British Thoracic Society Standards of Care Committee. 2001. Statement on malignant mesothelioma in the United Kingdom. Thorax 56: 250-265.

	Peipins LL, Campolucci S, Lybarger JA, *et al*. 2003. Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana. Environmental Health Perspectives Environ Health Perspect. 111(14):1753-9
Other CSEMs	*Case Studies in Environmental Medicine: Asbestos* is one educational case study in a series. To view Taking an Exposure History and other publications in this series, please go to http://www.atsdr.cdc.gov/csem/csem.html

Posttest Instructions

Introduction

ATSDR seeks feedback on this course so we can assess its usefulness and effectiveness. We ask you to complete the assessment questionnaire online for this purpose.

If you complete the Posttest online, you can receive continuing education credits as follows:

Accrediting Organization	Credits Offered
Accreditation Council for Continuing Medical Education (ACCME)	Up to 2.0 hours in category 1 credit toward the American Medical Association (AMA) Physician's Recognition Award
American Nurses Credentialing Center (ANCC), Commission on Accreditation	2.0 contact hours
National Commission for Health Education Credentialing, Inc. (NCHEC)	2.0 Certified Health Education Contact Hours (CECH)
International Association for Continuing Education and Training (IACET)	0.2 continuing education units (CEUs)

Instructions

To complete the Assessment and Posttest, go to http://www2.cdc.gov/atsdrce and follow the instructions on that page. You can immediately print your continuing education certificate from your personal transcript online. No fees are charged.

Posttest

1. What Is Asbestos?
    A. A group of naturally occurring fibrous silicate minerals.
    B. A fibrous substance used widely throughout the United States in the construction, shipbuilding, and automotive industries until the 1970s.
    C. A heat-stable substance commonly used in insulation, pipe coverings, boilers, brake pads, and many other products.
    D. all of the above.
2. Which asbestos exposure pathway most commonly leads to illness?
    A. Ingestion.
    B. Inhalation.
    C. Dermal contact.
    D. All are equally important.
3. Of the following, in the United States, the people in the general population most at risk of exposure to asbestos today is
    A. people who work in asbestos mining and milling.
    B. household contacts of workers engaged in the manufacture of asbestos-containing products.
    C. people working or living in homes and buildings with loose, crumbling, or disturbed asbestos materials.
    D. people who garden with vermiculite potting soil.
4. OSHA requires workers who are exposed to asbestos at levels higher than the PEL of 0.1 fibers/cc of air (8-hour TWA) to
    A. receive medical surveillance.
    B. be hospitalized immediately.
    C. file claims for work-related injuries.
    D. all of the above.
5. After inhalation, asbestos fibers
    A. are retained in the lungs, especially the lower lung fields.
    B. initiate responses that can lead to fibrosis of lung tissue.
    C. initiate responses that can lead to carcinogenesis.
    D. all of the above.
6. Of the four respiratory conditions associated with asbestos exposure, the condition that is not malignant but is associated with significant restrictive deficits is
    A. parenchymal asbestosis.
    B. asbestos-related pleural abnormalities.
    C. lung carcinoma.
    D. pleural mesothelioma.

7. Which condition is most likely to occur secondary to asbestos-associated pulmonary fibrosis?
    A. Peritoneal mesothelioma.
    B. Colon cancer.
    C. Cor Pulmonale.
    D. Constrictive pericarditis.
8. The most important risk factor for asbestos-associated diseases are
    A. genetic polymorphisms and exposure to air pollution.
    B. total exposure to asbestos and smoking.
    C. frequency of respiratory infections and coexistence of other fibrotic respiratory conditions.
    D. all are equally important.
9. A 64-year-old male who worked in shipyards in the United States in the 1960s and 1970s presents to his physician complaining of breathlessness, especially when he works or exercises. He says this symptom began several years ago but was so minor that he was not concerned. He also complains of a slight, nagging dry cough. Of the asbestos-associated diseases, the *most likely* culprit is
    A. parenchymal asbestosis.
    B. asbestos-related pleural abnormalities.
    C. lung carcinoma.
    D. pleural mesothelioma.
10. On auscultation of the patient described above, you are most likely to hear
    A. normal breath sounds.
    B. absent breath sounds.
    C. bibasilar end inspiratory rales.
    D. rhonchi.
11. As part of taking the exposure history, you should explore
    A. possible occupational exposures to asbestos.
    B. possible paraoccupational and secondary exposures to asbestos.
    C. use of personal protective equipment.
    D. all of the above.
12. Pulmonary function tests of a patient with parenchymal asbestosis are most likely to show
    A. normal results.
    B. low FVC.
    C. low FEV1.
    D. low FEV1/FVC.
13. On chest radiograph, small, irregular opacities in the bases of both lung fields is suggestive of
    A. parenchymal asbestosis.
    B. pleural plaques.
    C. benign asbestos pleural effusion.
    D. diffuse pleural thickening.

14. In caring for a patient who was exposed to asbestos, it is important to
    A. take steps to avoid further exposure to asbestos.
    B. counsel the patient to stop smoking.
    C. monitor the patient to facilitate early diagnosis.
    D. all of the above.
15. Patients diagnosed with an asbestos-associated disease should be instructed to
    A. continue working with asbestos as long as they use PPE.
    B. contact their doctor if they develop any sign of respiratory infection or other health change.
    C. receive influenza and pneumococcal vaccines only if they meet other criteria for being high risk.
    D. all of the above.
16. Asbestos fibers are released into the air mainly when
    A. asbestos-containing materials are loose, crumbling, or disturbed.
    B. asbestos is fixed in solid materials such as wallboard.
    C. asbestos-bearing rock lays unexposed deep underground.
    D. all of the above.
17. EPA's MCL for asbestos in drinking water is which of the following?
    A. 0.07 fibers per liter of drinking water.
    B. 7 million fibers per liter of drinking water.
    C. 700 fibers per liter of drinking water.
    D. 70,000 fibers per liter of drinking water.
18. Diffuse interstitial fibrosis resulting from inhalation of asbestos fibers and producing restrictive lung disease and progressive exertional dyspnea is termed
    A. lung carcinoma.
    B. pleural mesothelioma.
    C. parenchymal asbestosis.
    D. asbestos-related pleural abnormalities.
19. Asbestos-related pleural abnormalities include which of the following?
    A. Pleural plaques.
    B. Benign pleural effusions and diffuse pleural thickening.
    C. Rounded atelectasis.
    D. all of the above
20. The most typical abnormal finding on physical examination of a patient with significant asbestosis is
    A. a "doughy" feeling in the abdomen.
    B. bibasilar inspiratory rales on pulmonary auscultation.
    C. clubbing of the fingers.
    D. all of the above.

21. The two most important tests for diagnosing asbestos-associated diseases are
    A. BAL and lung biopsy.
    B. CT and HRCT scans.
    C. chest radiograph and pulmonary function tests.
    D. blood studies and colon cancer screening.
22. Managing parenchymal asbestosis involves
    A. smoking cessation.
    B. regular influenza and pneumococcal vaccines.
    C. respiratory therapies and pulmonary rehabilitation.
    D. all of the above.
23. Patients who were exposed to asbestos should
    A. stop smoking.
    B. avoid exposure to other respiratory irritants.
    C. avoid exposure to respiratory infections and contact their doctor if they get signs of infection or other health changes.
    D. all of the above

Relevant Content To review content relevant to the posttest questions, see:

Question	Location of Relevant Content
1	What Is Asbestos? Where Is Asbestos Found?
2	How Are People Exposed to Asbestos?
3	Who Is at Risk of Exposure to Asbestos?
4	What Are U.S. Standards for Asbestos Levels?
5	What Is the Biologic Fate of Asbestos? How Does Asbestos Induce Pathogenic Changes?
6	What Respiratory Diseases Are Associated with Asbestos?
7	What Other Diseases Are Associated with Asbestos?
8	How Should Patients Exposed to Asbestos Be Evaluated? What Instructions Should Be Given to Patients?
9	How Should Patients Exposed to Asbestos Be Evaluated?
10	How Should Patients Exposed to Asbestos Be Evaluated?
11	How Should Patients Exposed to Asbestos Be Evaluated?
12	What Tests Can Assist with Diagnosis of Asbestos Toxicity?
13	What Tests Can Assist with Diagnosis of Asbestos Toxicity?
14	How Should Patients Exposed to Asbestos Be Treated?
15	What Instructions Should Be Given to Patients?
16	Where Is Asbestos Found?
17	What Are U.S. Standards for Asbestos Levels?
18	What Respiratory Conditions Are Associated with Asbestos Exposure?
19	What Respiratory Conditions Are Associated with Asbestos Exposure?
20	How Should Patients Exposed to Asbestos Be Evaluated?
21	What Tests Can Assist with the Diagnosis of Asbestos-Related Diseases?
22	How Should Patients Exposed to Asbestos Be Managed and Treated?
23	What Instructions Should Be Given to Patients?

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Answers to Progress Check Questions

1. The correct answer is D. Asbestos is a group of fibrous silicate minerals; they are naturally occurring and used commercially.
2. The correct answer is B. Asbestos is strong and stable. It is relatively resistant to water, acids, alkalis, and other chemicals (and to heat and flame). It is also flexible.
3. The correct answer is D. Asbestos enters the US environment from current asbestos containing products such as brake linings, from past uses of asbestos-containing building materials in old building stock, and from weathering of exposed asbestos-contained rock in certain areas of the country.
4. The correct answer is A. Asbestos is released when materials such as building materials or asbestos-bearing rocks are disturbed. If asbestos is embedded and left undisturbed in either manufactured products or deep within the earth, no asbestos release occurs and therefore no subsequent human exposure.
5. The correct answer is A. The air pathway (inhalation of contaminated air or dust) is the most important route of exposure to asbestos, the route that most commonly leads to illness. Ingestion by swallowing inhaled asbestos from the nasopharynx and dermal contact are less important exposure pathways.
6. The correct answer is D. In the past, exposure to asbestos was a risk for people in many occupations, including construction workers, carpenters, utility workers, electricians, military personnel, pipe fitters, shipyard workers, steel mill workers, sheet metal workers, boiler makers, laborers, and automobile mechanics.
7. The correct answer is C. In the past, because of lack of proper industrial hygiene, household contacts of asbestos workers were exposed to asbestos dust on the worker's skin and clothing.
8. The correct answer is C. OSHA's PEL for asbestos in the workplace is 0.1 fibers/cc of air (8-hour TWA).
9. The correct answer is B. EPA's MCL for asbestos is 7 million fibers per liter of drinking water.
10. The correct answer is D. Some of the inhaled asbestos fibers that reach the lungs become lodged and are retained in lung tissue. Although they are subject to lung defenses and can move to pleural and peritoneal spaces and to the mesothelium, the fibers tend to remain in the lungs for many years.
11. The correct answer is D. Three processes are hypothesized to account for asbestos' pathogenicity: direct interaction with cellular macromolecules, generation of active oxygen species, and other cell-mediated mechanisms (inflammation).
12. The correct answer is D. As a consequence of its effects on cellular macromolecules and release of ROS and various cellular factors, asbestos induces fibrotic changes in lung tissue and is genotoxic and carcinogenic.
13. The correct answer is C. Parenchymal asbestosis is a diffuse interstitial fibrosis resulting from inhalation of asbestos fibers. It produces a restrictive pattern of disease and progressive exertional dyspnea.
14. The correct answer is D. Asbestos-related pleural abnormalities are a collective term for a range of pleural reactions, including pleural plaques, benign pleural effusions, diffuse pleural thickening, and rounded atelectasis.

These conditions are relatively benign, though diffuse pleural thickening can cause restrictive deficits.

15. The correct answer is A. Peritoneal mesothelioma is a rare, rapidly invasive tumor associated with asbestos exposure. Asbestos exposure might be associated with extrathoracic cancers, but this association is controversial.
16. The correct answer is C. In people exposed to asbestos, cor pulmonale can occur secondary to pulmonary fibrosis, especially in patients with severe parenchymal asbestosis.
17. The correct answer is B. Bibasilar inspiratory rales on pulmonary auscultation are the most typical finding on physical examination of patients with significant asbestosis. A "doughy" feeling in the abdomen is associated with peritoneal mesothelioma (which is rare). Clubbing of the fingers secondary to asbestosis is a less common finding.
18. The correct answer is D. It is important to take a comprehensive medical and exposure history because 1) asbestos-associated diseases have symptoms similar to those of treatable diseases, 2) activities such as smoking can increase a patient's risk of developing symptoms, and 3) asbestos accumulates in the body (making even minor exposures important).
19. The correct answer is C. The two most important tests for diagnosing asbestos-associated diseases are chest radiograph and pulmonary function tests.
20. The correct answer is A. Diffuse bilateral interstitial fibrosis and small, irregular opacities are signs of parenchymal asbestosis on chest X-ray.
21. The correct answer is D. Primary strategies for managing asbestos-associated diseases in exposed patients or those already ill include smoking cessation, periodic pulmonary function tests, and patient education.
22. The correct answer is D. Managing parenchymal asbestosis involves smoking cessation, regular influenza and pneumococcal vaccines, and respiratory therapies and pulmonary rehabilitation. Removal of the patient from the source of exposure (if possible) or provision of personal protective equipment up to OSHA standards, impairment assessment, and aggressive treatment of respiratory infections are also strategies for managing parenchymal asbestosis.
23. The correct answer is D. Patients exposed to asbestos should stop smoking, avoid all respiratory irritants, avoid exposure to respiratory infections, and contact their physician if they notice signs of infection or other health changes.