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Lung radiology in the tropics

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This article describes the radiologic findings of the more common conditions that affect the thorax in the tropics. Inevitably, the bulk of the discussion focuses on infectious diseases. The intention, however, is not simply to list salient imaging features out of context. There are other important dimensions to lung radiology in the tropics, and they are the physical, political, and economic settings. The first part of this article considers the broader issues of imaging services in the tropics; the second part concentrates on the radiology of infectious and other disease states.

Imaging services in the tropics

Radiologic evaluation is fundamental in the diagnosis of lung disease; a radiography unit is arguably as important as a stethoscope in the assessment of pulmonary pathology. In North America and elsewhere in the developed world, high-quality and timely imaging is taken for granted. Unfortunately, in the tropical health care system, modern, dependable imaging is a scarce luxury. The affluent areas in Europe and North America have generous budgets for radiologic equipment. Contrast this with the often-impoverished regions in the tropics, which lack resources, equipment, and personnel. (There is, for example, no resident radiologist in the 800-bed teaching hospital in Kumasi, Ghana's second largest city, which serves more than 1 million people.)

The differential is exacerbated by a hostile topography and climate. Many areas are remote and sparsely populated, such that in many tropical countries, resources are often concentrated in a few urbanized areas [1–4]. Clinicians who care for patients with pulmonary symptoms in the tropics frequently must accept suboptimal (or even no) imaging or send their patients long distances to receive services. In turn, the radiologist rarely has access to bronchoscopic or lavage findings. The opportunity for multidisciplinary meetings to review imaging with clinical and pathology experts, a keystone to lung radiology in many developed countries, is severely limited. How can tropical lung radiology services be optimized?

The key to delivering a workable lung radiology service within the tropics is to match provision to demand. Imaging should be geared for the investigation and treatment of infection (eg, percutaneous image-guided empyema drainage). Plain radiography and ultrasound must form the core of any realistic imaging service [2,4,5]. CT plays a limited role and is found only in major centers.

Whenever possible, equipment should be cheap and portable yet reliable and durable. Small machines may be used in field hospitals with rapid transmission of the images to large yet remote hospitals, where interpretation is possible. The quality of the images generated by these machines is good. Alternatively,

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the World Health Organization basic radiologic system often could be a suitable basis for a basic but not rudimentary imaging service in the tropics. With respect to ultrasonography, which is helpful in the diagnosis and treatment of pleural disease, there are several high-quality yet compact and affordable units

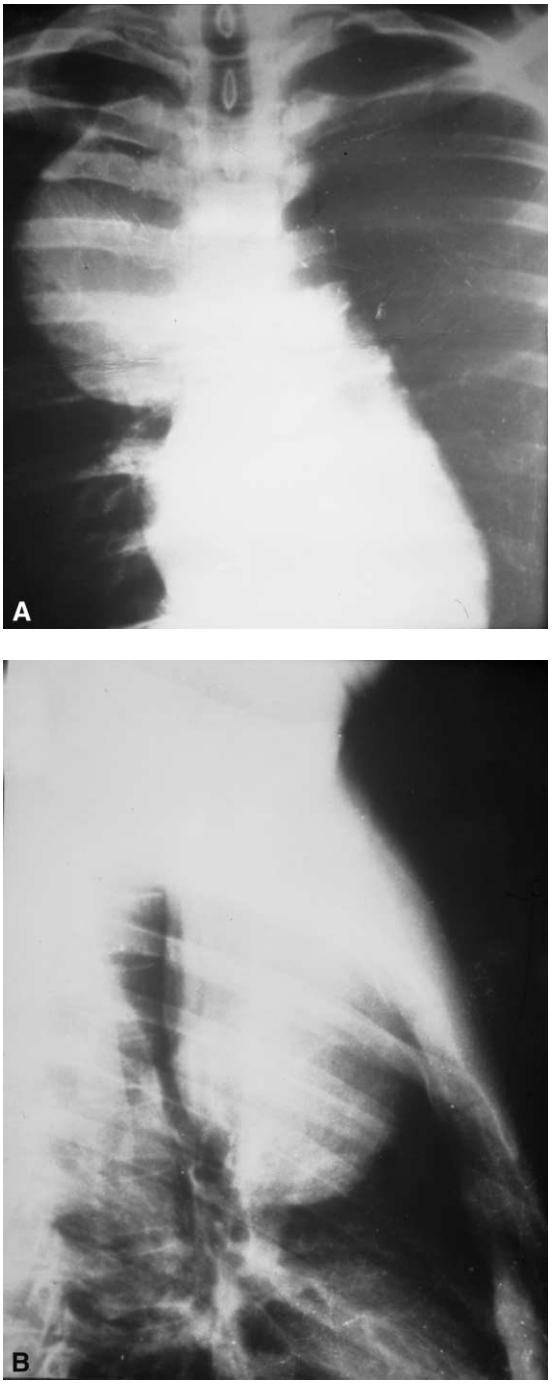

Fig. 1. Posteroanterior (A) and lateral (B) chest radiographs and CT scan (C) and ultrasound (D) of a huge bronchogenic cyst in the upper lobe of the right lung.

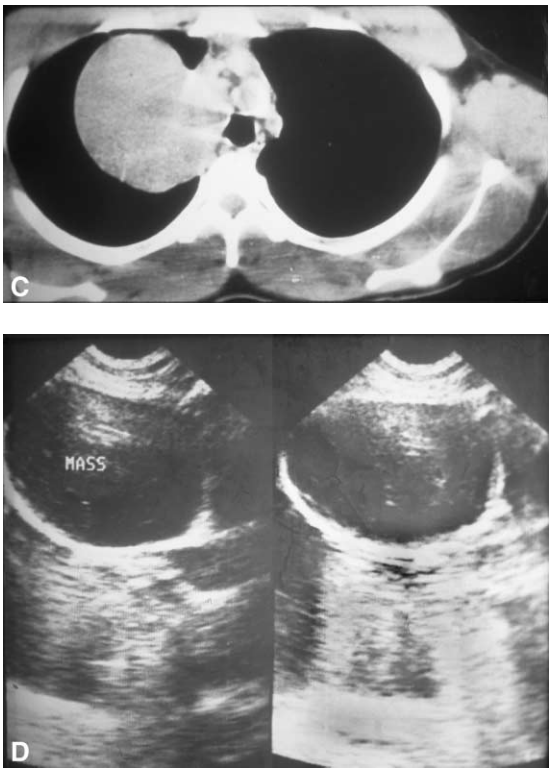

Fig. 1 (*continued*).

developed in the ironically high-tech world of North American intensive care units that would function admirably in the intensive environments experienced in a tropical hospital.

Image-guided fine-needle aspiration and biopsy may be crucially important in the management of patients in the tropics. Ultrasound provides a relatively cheap real-time method for guiding interventional procedures. Aspirates may provide samples from which organisms can be isolated so that valuable antibiotics can be husbanded and only used where appropriate. After all, a pleural collection on ultrasound is simply that: aspirate obtained by inserting a needle under image guidance into the abscess, which may reveal the pathogen [5].

Only 40% of countries in the sub-Saharan region have any CT scanners. This is in contrast to the situation in the Northern African region and in the Republic of South Africa, where academic radiology departments and other privately owned departments are better equipped and serviced. Currently, major South African cities have hospitals that provide such high-tech lung imaging to patients from the neighboring countries and even from as far as Central and Eastern Africa, where the few existing CT scanners cannot cope with the patient load.

Lung radiology in the wider context of health care

Thoracic imaging can be worthwhile only if it is cooordinated with the pulmonary medical and pathology services within the hospital or within the region. A chest radiograph is only as good as the report it generates, and the report has worth only when it helps the physician who manages the patient. In other words, a radiograph (or ultrasound scan) of the highest quality still needs intelligent and clinically relevant interpretation [2,5]. One must move away from the mindset that this interpretation must be provided at the site where the images have been acquired. Dedicated landlines can be linked to inexpensive modems to permit transmission of digital ultrasound data across vast distances. On a more global scale, the World Wide Web offers potential for image transfer and storage. Telemedicine is coming of age. The film or study can be moved from the "spoke" to a "hub." Once the film has been read by a trained radiologist at the hub, the

report can be sent back by a landline connection to the remote spoke. Such teleradiology is well established in parts of Scandinavia that are sparsely populated and isolated, especially in winter.

Disease profile of lung imaging in the tropics

The scarcity of manpower and resources and the logistical nightmares that ensue mean that lung

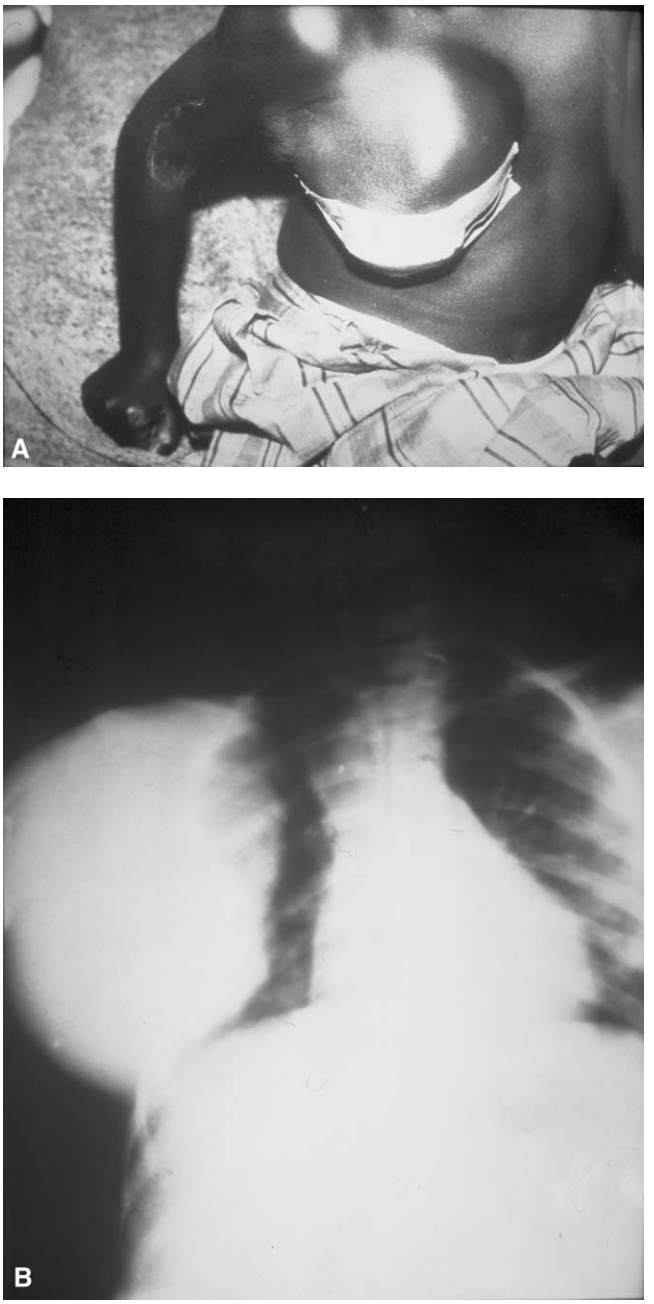

Fig. 2. Black and white photograph of a 41-year-old patient (A) with a biopsy proven right-sided huge non-Hodgkin's lymphoma chest wall of the lung. Chest radiograph (B) and ultrasound (C) demonstrate features of the well-circumscribed soft tissue mass. (Courtesy of Prof. M. Kawooya and Z. Muyinda, MD, Makerere University, Kampala, Uganda.)

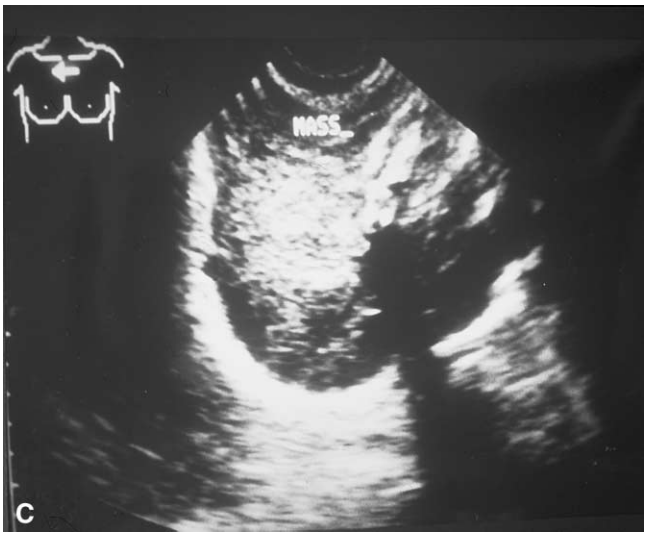

Fig. 2 (*continued*).

imaging in the tropics cannot be regarded as a variant of pulmonary radiology in the developed world. The other stark difference between tropical and temperate radiology is the disease profile of the patients.

The ''tropics'' refers to that region of the earth between the Tropic of Cancer and the Tropic of Capricorn. Climatic conditions there are such that pathogenic organisms, their vectors, and intermediate hosts thrive [6]. Infectious diseases are a common cause of pulmonary disease in these areas. Some of the infections are seen in temperate radiology departments, others are peculiar to the tropics. The radiographic features of the tropical diseases are beyond the day-to-day experience of North American radiologists, and these are summarized later. More significantly, however, the radiographic features of the familiar conditions that affect the lungs are not necessarily synonymous in the tropics and the temperate regions, and these differences are emphasized in the following discussion.

Infectious diseases account for most of the lung pathology imaged. Sporadic infections in America are endemic in the tropics. Tuberculosis (TB) is rife in many of the poorer communities in the world, and the radiographic findings are so common as to be regarded as normal. The key is to be aware of the chest radiograph appearances that distinguish old disease from active or reactivated infection. The radiography of TB is all the more complex in the tropics because of the high coincidence of sarcoidosis in many regions. Sarcoid is a great mimicker, with myriad radiologic manifestations. To make matters still more difficult, the classic findings of TB on chest radiographs may not be seen in immunosuppressed patients. The specter of HIV and AIDS is ever present in the tropics.

It is a brutal and chilling fact that HIV will claim more lives than World War I and the Black Death combined. HIV is endemic in large swathes of Africa and in other regions of the tropics. There is correspondingly a high incidence of *Pneumocystis* pneumonia and thoracic Kaposi's sarcoma visible on tropical lung imaging. The coexistence of TB and HIV has been alluded to, and HIV has a strong association with lymphoproliferative disorders in the tropics.

Other infections that target the lungs (among other organs) are rare in the developed world yet are commonplace in the tropics. These infections include the parasitic infections of *Echinococcus* (hydatid), amebiasis, *Strongyloides,* paragonimiasis, and melioidosis. The radiology of these conditions as they affect the lungs is reviewed in the following discussion.

Lung tumors, although prevalent, do not have the same relative importance as in the developed world, both because of the differing economic factors and the high incidence of infectious lung disease. Their imaging features are comparable to the findings in temperate regions. No further reference is made to lung cancer in this article, except to note that the patients may present later so that the radiographic findings are at the same time more florid. Such an end-stage disease phenomenon is true for many lung conditions in the tropics:

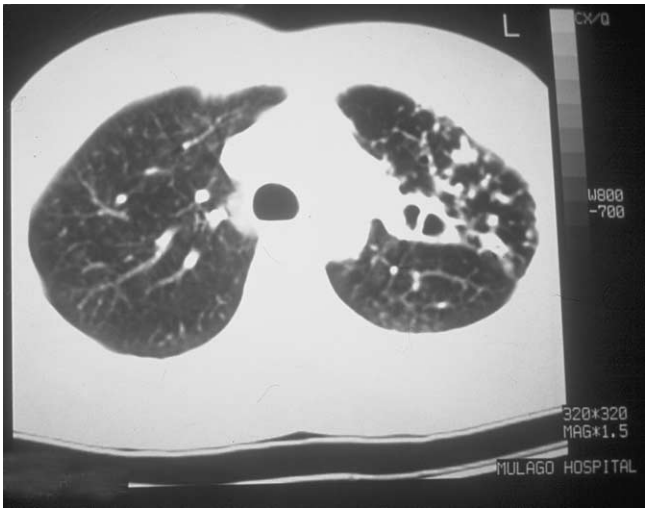

Fig. 3. Chronic Pseudomonas infection in a 31-year-old patient with AIDS. CT scan through the lungs demonstrates dilated bronchi with adjacent inflammation in the upper part of the lingula. Sputum smear and culture were positive for *Pseudomonas*; CD4 level was 30 cells/mm^3.

patients delay seeking medical advice because of poverty, traditional belief, and limited access to health care facilities or because they cannot afford to be sick.

Industrial lung disease, especially mining-related lung disease, kills many workers in parts of the tropics. There is less opportunity to safeguard personnel (and less legislation demanding the safeguards). The radiology of the pneumoconioses is not peculiar to the tropics (Figs. 1–5), and there are many worthy reviews of the radiologic evaluations of coal, tin, and gold miners. The discussion that follows is limited almost exclusively to the infectious diseases that ravage the lungs of many people in the tropics. By refining the content in this way, the essence of the differences between tropical and temperate lung radiology may be captured.

Pulmonary tuberculosis

Pulmonary TB is a global scourge, and it kills more people than any other single infectious disease. Currently, more than 90% of all cases of TB and 98%

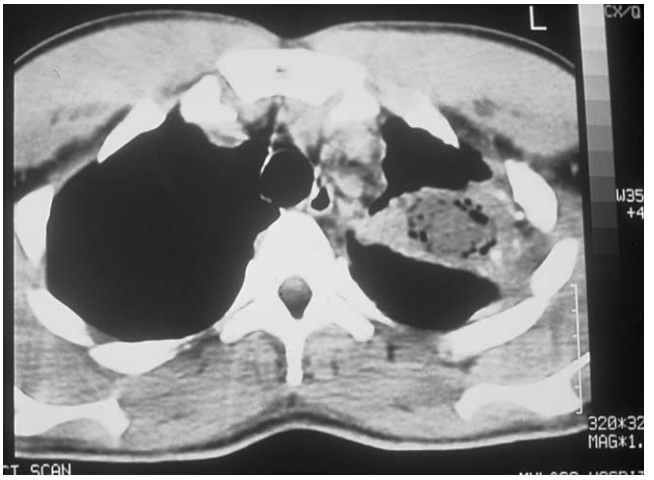

Fig. 4. Aspergilloma. CT scan through the lungs depicts a fungus ball in an old tuberculous cavity.

Fig. 5. Chest radiograph of "measles" pneumonia demonstrates respiratory complications made of pneumothorax and bullae attributed to *staphylococci* in a child with measles seen at the University Teaching Hospital, Lusaka, Zambia. Measles seems to be one of the most important causes of child mortality in the tropics.

of deaths caused by TB occur in developing countries. TB has adapted to the tropics admirably: unknown in sub-Saharan Africa before the nineteenth century, by the 1950s, infection caused by *Mycobacterium tuberculosis* could be found in up to 50% of the adult population. Subsequently, socioeconomic changes, rapid urbanization, and the HIV epidemic have resulted in a 300% to 400% increase in TB cases in sub-Saharan Africa [7].

In young children, the tuberculin skin reaction may be depressed, and the chest radiograph becomes critical in making the diagnosis [8,9]. Although no single pulmonary radiologic change is pathognomonic of TB, certain changes are associated with proven cases. Most children in the Nigerian and the South African studies had multiple pulmonary tuberculous lesions (compare with data from developed countries). This type of disease is probably caused by a combination of late presentation and the effect of malnutrition on their response [8,10].

Primary TB may manifest radiographically in five major ways: parenchymal consolidation, atelectasis, lymphadenopathy, pleural effusions, and miliary disease. The most frequent lesion seen in children in a Nigerian study of chest radiographs was mediastinal lymphadenopathy (79%), with right-sided involvement being more common [8]. In a South African study that looked at children with advanced TB when they had their first radiograph, the incidence of lymphadenopathy was lower (43%) [9].

Overall, the frequency of lymphadenopathy seems to be lower than that seen in the West and may be related to the fact that children from less affluent countries are malnourished and present at a later stage of disease [11]. Segmental lesions that consist of consolidation, collapse, and patchy inflammatory change are seen in more than two thirds of cases [8,9], with the right lung, particularly the right lower lobe, being most frequently involved. Leung and Muller [11] also found that right-sided changes were more common, although they did not observe a particular zonal predominance. The strong predilection of the right lobe (Fig. 6) as the site of parenchymal change would support the contention that the initial infection favors the right lung [9].

Pleural effusions, usually right sided, are seen in 12%, but hardly ever as the sole radiologic manifestation [8]. Miliary nodulation (10%) usually occurs in children younger than 5 years old [1,8]. In two thirds of the cases it is associated with bronchogenic disease, segmental consolidation, or effusion. Miliary disease on a chest radiograph (Fig. 7) must be considered TB and treated empirically, not least because other causes, including histoplasmosis, coccidioidomycosis, fibrocystic disease, and hemosiderosis, are rare in the tropics.

Cavitation, which is usually a feature of postprimary TB, is seen in 5% to 13% of cases [8,9]. These features are more common in the younger age group and often indicate extrapulmonary TB. Calcification is seen in older children and is related either to the primary focus or to mediastinal lymphadenopathy. Calcification is not an indication of inactive disease.

The chest radiograph of pulmonary TB in the immunocompetent adult (whether HIV infected or not) usually demonstrates the characteristic features of postprimary TB, namely, parenchymal infiltrates

Fig. 6. Chest radiograph in a 25-year-old HIV-negative patient with sputum that tested positive for acid fast bacilli (AFB) reveals tuberculous segmental consolidation in the right upper and left lower lobes and ipsilateral right hilar adenopathy. This pattern supports the contention that the initial tuberculosis infection favors the right lung.

and fibrosis that involves the apical regions with or without cavitation [7]. The details of the radiographic features of postprimary TB are beyond the scope of this article and have been reviewed extensively. The following section concentrates on the impact of HIV on TB.

Tuberculosis and HIV

The impact of the HIV epidemic on the incidence of TB is most evident in sub-Saharan Africa, where for the 10-year period from 1990 to 1999, 15 million incident cases of TB were expected. Of these cases, 3.9 million (25%) were attributable to HIV infection. The number of new cases of TB per year in this region is forecast to double by the end of the decade [1]. Estimates of persons dually infected with HIV and *M tuberculosis* in other developing countries in the world in 1994 include more than 1.15 million in Southeast Asia and 450,000 in the Caribbean and Latin America. These figures may be conservative.

Several studies have documented the modifying effect of HIV on TB and have compared the radiographic features of pulmonary TB in HIV-positive

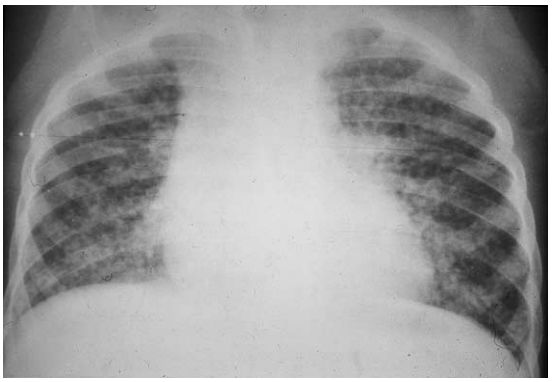

Fig. 7. Miliary tuberculosis. Diffuse miliary nodules with hilar and mediastinal adenopathy are seen bilaterally on the chest radiograph in this 3-year-old patient.

Table 1
Chest radiograph patterns in tuberculosis seen in the tropics in HIV-positive and HIV-negative patients

	Radiographic pattern	HIV positive (%)	HIV negative (%)
Batungwanayo et al [13]	Mediastinal and/or hilar adenopathy	30	0
	Pleural effusion	43	9
	Upper lobe infiltrate	16	55
	Cavitation	39	91
	Miliary disease	25	9
Pozniak et al [14]	Mediastinal and/or hilar adenopathy	31	16
	Pleural effusion	26	13
	Upper lobe infiltrate	43	67
	Cavitation	40	64
Awil et al [12]	Mediastinal and/or hilar adenopathy	26	6
	Pleural effusion	23	11
	Pneumonic infiltrate	46	26
	Cavitation	18	57
	Miliary disease	7	0
Saks and Posner [15]	Mediastinal and/or hilar adenopathy	50	8
	Pleural effusion	38	20
	Miliary disease	8	0
	Cavitation	38	82
	Atelectasis	31	82
Tshibwabwa et al [37]	Mediastinal and/or hilar adenopathy	26	13
	Pleural effusion	16	6.8
	Miliary disease	9.8	5
	Cavitation	33	78
	Atelectasis	12	24

and HIV-negative patients [12–16]. The general consensus is that patients with HIV are more likely to exhibit the radiographic features of primary TB. These manifestations (Table 1) include mediastinal and hilar lymphadenopathy, pleural effusions, middle and lower lung infiltrates, and miliary dissemination, with less cavitation being described. The typical radiographic appearances in HIV-negative individuals are usually that of postprimary TB, namely, cavitation, calcification, and upper lobe fibrotic changes. Although the features of dual HIV and TB infection are characteristic of primary TB, in most of these patients the disease is believed to be caused by reactivation as a result of cellular immunodeficiency. These patients behave as immunonaive individuals and develop a "childhood" pattern of TB [13].

Atypical mycobacterial infection is rare in Africa despite its presence in the environment [7]. Even in patients with AIDS, *Mycobacterium avium-intracellulare* has been isolated infrequently, which is in contrast to the North American experience [17]. It has been postulated that the reason for the low prevalence is that disease caused by *M avium-intracellulare* occurs late in the course of HIV-related immunosuppression after the occurrence of more virulent species.

Pulmonary complications in HIV infection

Several studies from different countries in Africa have investigated HIV-positive patients who present with symptoms of bronchopulmonary disease [16,18–20]. The findings have highlighted several points regarding the pulmonary manifestations of HIV-positive patients in this region.

1. TB is the most frequently encountered pulmonary complication that occurs in 23% to 49% of cases. Pulmonary infection by atypical Mycobacteria, *M avium-intracellulare,* is rare. Mahomed et al [19] suggest, however, that with increasing length of survival of HIV-infected patients in Africa, this infection will be found to be part of the spectrum as in the rest of the world.
2. Infection with *P carinii* is less common in African patients in contrast to patients with AIDS in North America and Europe. Some researchers have attributed the lower prevalence rate to the fact that African patients with HIV infection die of diseases caused by more virulent organisms than *P carinii*, (eg, *M tuberculosis*) before *P carinii* pneumonia can develop. There is, however, regional

variation in the incidence of *P carinii* pneumonia infection within the tropics (up to 40% in a cohort from Zimbabwe [19]), and *P carinii* pneumonia is ignored when reading a chest radiograph with jeopardy. The problem is that several radiographic patterns have been documented, and they are usually nonspecific. Fine reticulonodular shadowing has been identified as being a strong independent predictor of *P carinii* pneumonia [7,20]. Other radiographic findings include alveolar or air space consolidation, lobar disease, and cystic lesions that result in pneumothorax. Some patients with *P carinii* pneumonia may have a normal chest radiograph. The impression of other groups is that although *P carinii* pneumonia occurs in Africa (Fig. 8), in a continent where diagnostic facilities are generally unavailable, Pneumocystis is unlikely to be a relevant diagnosis [18].

3. Bacterial infection is common and is often found in association with other diseases.

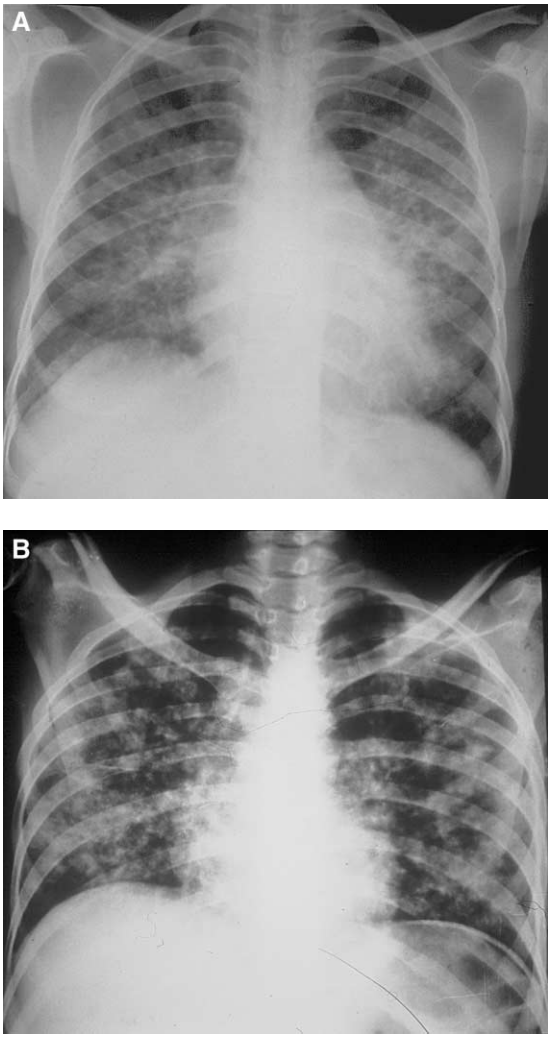

Fig. 8. *Pneumocystis carinii pneumonia*. (A) Chest radiograph in a 27-year-old patient with AIDS depicts bilateral, coarse reticulonodular infiltrates predominantly in the parahilar middle zone of both lungs. On both sides, the pulmonary lesions radiate out from the hilar regions. Bronchoalveolar lavage (BAL) was positive for *P carinii pneumonia*. (B) Chest radiograph in a 39-year-old patient with AIDS demonstrates extensive and fairly symmetrical alveolar nodules throughout the lungs. The apices are relatively spared. The pulmonary lesions resolved after 30 days of treatment with trimethoprim and sulfamethoxazole (TMP/SMX) for *P carinii pneumonia*.

Fig. 9. Chest radiograph in a 30-year-old HIV-positive patient demonstrates an abscess cavity that contains fluid level in the mid lobe of the right lung. Note smooth wall and absence of adjacent air space consolidation. No ipsilateral adenopathy is evident. Sputum smear and culture were positive for Klebsiella pneumonia.

Streptococcus pneumonia, Staphylococcus aureus, Nocardia, Klebsiella, and *Haemophilus influenza* are among the most common pathogens isolated (Fig. 9, see Fig. 3).

4. Fungal infections are rare, in most studies they appear infrequently. A study conducted by Batungwanayo et al [13] reported pulmonary *Cryptococcus* in 13% of patients. The chest radiographic patterns associated with cryptococcal pneumonitis include alveolar shadowing, interstitial infiltrates, miliary pattern, hilar adenopathy (Fig. 10), and even a normal chest radiograph [21]. Aspergillosis also seems to be the most common pulmonary fungal infection in the authors' experience of the East and Central African setting (Fig. 11).
5. Inevitably, where laboratory and diagnostic services are limited, nonspecific pneumonitis is a common diagnosis (range:19.4–38%).

Kaposi's sarcoma

Kaposi's sarcoma has been reported to occur fairly commonly in older patients in Central Africa, and the endemic variety, which is not HIV related,

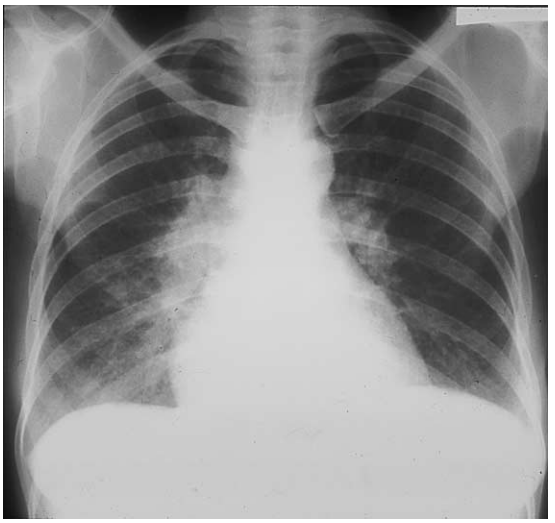

Fig. 10. Chest radiograph of a 26-year-old patient with AIDS with proven Cryptococcal infection depicts extensive right hilar and mediastinal adenopathy and presence of parahilar airspace consolidation. The CD_4 level was 41 cells/mm^3.

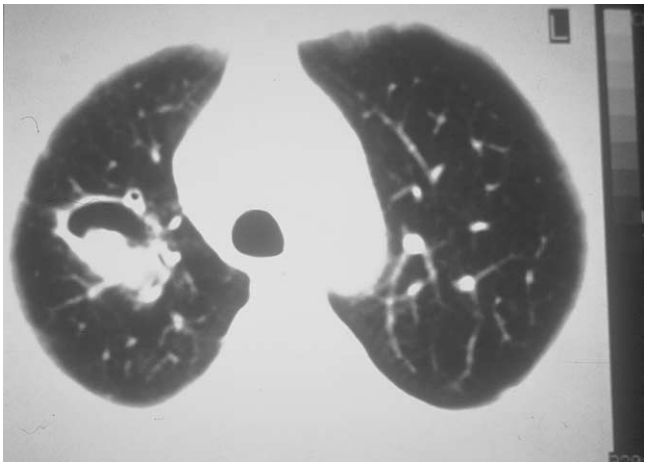

Fig. 11. Aspergillosis infection in a 22-year-old patient with AIDS. CT scan through the lungs reveals a right upper lobe irregular thick-walled cavity with a crescent of air and internal soft tissue mass. The CD_4 level was 31 cells/mm^3.

is a slowly progressing tumor that presents with chronic lymphedema of the limbs in association with cutaneous and subcutaneous plaques and nodules [14]. In patients with AIDS, the tumor is more aggressive, often multicentric, and progresses more rapidly than the endemic variety; bronchopulmonary lesions are common. The incidence of Kaposi's sarcoma in HIV-positive individuals who present with pulmonary disease is in the range of 6% to 16% [16]. The radiographic features of Kaposi's sarcoma are essentially indistinguishable from opportunistic infections and include alveolar, interstitial,

Fig. 12. Endemic variety of Kaposi's sarcoma. Chest radiographs in a 25-year-old patient with grade IV-B Kaposi's sarcoma depict progression of shadows from (A) increased bronchovascular shadows to (B) reticulolinear , and finally (C) a faint nodular pattern predominantly in both lung bases. (Courtesy of Prof. M. Kawooya, Makerere University, Kampala, Uganda, and E. Katongole Mbidde, MD, Uganda Cancer Institute, Kampala, Uganda).

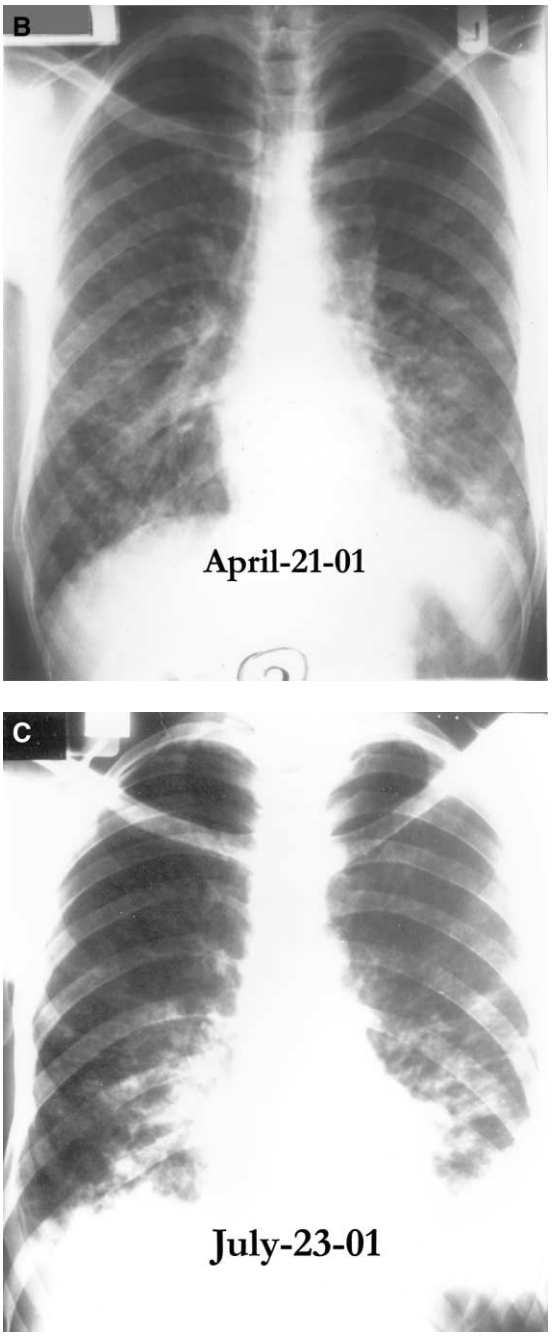

Fig. 12 (*continued*).

mixed alveolar-interstitial, and nodular patterns, with the nodular pattern being the most common. Clinical and bronchoscopic findings are central to the diagnosis (Figs. 12,13).

Amebiasis

Amebiasis is the third leading parasitic cause of death in the world. The disease is endemic in Mex-

Fig. 13. Kaposi's sarcoma pulmonary involvement. Chest radiograph depicts interstitial infiltrates consistent with interlobular septal thickening in a 28-year-old patient with AIDS with mucocutaneous Kaposi's sarcoma. This nodular thickening radiates from both hila toward the lower lobes. Airspace consolidation and segmental atelectasis in the left lower lobe are evident.

ico, the western part of South America, South Africa, Egypt, India, and Southeast Asia. Approximately 500 million people are infected with *Entamoeba histolytica*.

Amebic colitis and liver abscess are the most common intestinal and extraintestinal manifestations of *E histolytica* infection. Pleuropulmonary complications occur almost exclusively in individuals with a liver abscess, with a reported incidence between 4% and 14%. Thoracic disease may involve the pleura, lung parenchyma, or pericardium [22]. Rupture of an amebic liver abscess into the pleural cavity leads to an amebic empyema, and subsequent rupture into the lung may produce an abscess or an area of consolidation. Other pleuropulmonary complications include right-sided sympathetic effusions and basilar atelectasis. Bronchohepatic fistula is an unusual and distinctive problem characterized by expectoration of sputum that may resemble anchovy paste. Left hepatic abscesses occasionally produce left-sided pleuropulmonary complications and may result in lethal rupture into the pericardium.

Amebic invasion of the thorax also has been reported to occur by way of the lymphatics from beneath the diaphragm. The occasional lung abscesses that occur with or without associated demonstrable amebic liver abscess have been attributed to embolization from a diseased liver or colon via the portal system or hepatic veins, the valveless paravertebral veins, the inferior vena cava, and through the thoracic duct and subclavian vein.

The radiographic features of pleuropulmonary amebiasis are not specific for the disease, but in conjunction with the history, a physical examination may suggest the diagnosis (Fig. 14). Elevation of the right hemidiaphragm is a frequent finding and occurs in approximately 50% of patients with amebic liver abscess. Other features include areas of consolidation adjacent to the diaphragm, which may contain a cavity; occasionally a pulmonary abscess may be seen distant from the liver and indicates hematogenous dissemination [22,23]. Pleural effusions seen on chest radiograph may be massive (29%) or small and produce only blunting of the right costophrenic angle (20%). Ultrasound of the pleural space (and image-guided aspiration) provides a cheap and reliable means of making the diagnosis (Fig. 15).

Hydatid disease

Hydatid disease is a worldwide zoonosis produced by the larval stage of the *Echinococcus* tapeworm. Humans may become intermediate hosts through contact with a definitive host (usually a domesticated dog) or ingestion of contaminated water or vegetables.

Hydatid disease primarily affects the liver; however, there are many potential local complications,

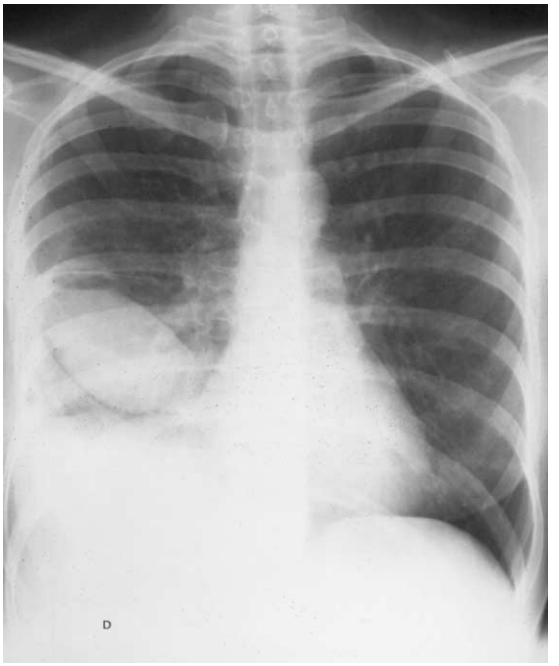

Fig. 14. Chest radiograph of a 35-year-old patient demonstrates an amebic empyema tracking in the right oblique fissure. There is elevation of the right dome diaphragm. This particular patient had an amebic abscess of the liver that ruptured through into the pleural cavity.

including transdiaphragmatic thoracic involvement. The lung also may be involved via hematogenous dissemination. In humans the liver is involved in approximately 75% of cases, the lung in 15%, and other anatomic locations in 10% [23].

Most cysts in the lung are acquired in childhood, remain asymptomatic for many years, and are discovered incidentally on "routine" chest radiographs.

The typical hydatid cyst on chest radiograph is a well-defined homogenous nodule more than 3 cm in

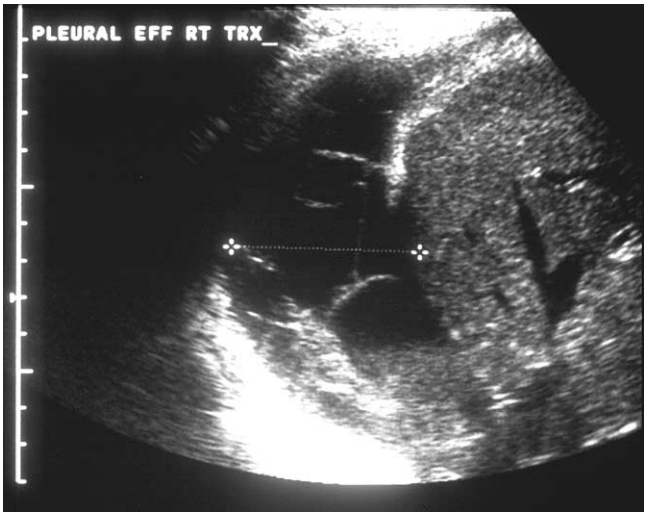

Fig. 15. Pleuropulmonary amebiasis in a 27-year-old patient with *Entamoeba histolytica* intestinal manifestation. Subcostal abdominal ultrasound demonstrates a large loculated pleural effusion with internal echoic debris. No associated demonstrable amebic liver abscess was evident. Ultrasound-guided aspiration reveals characteristic chocolate-brown pus.

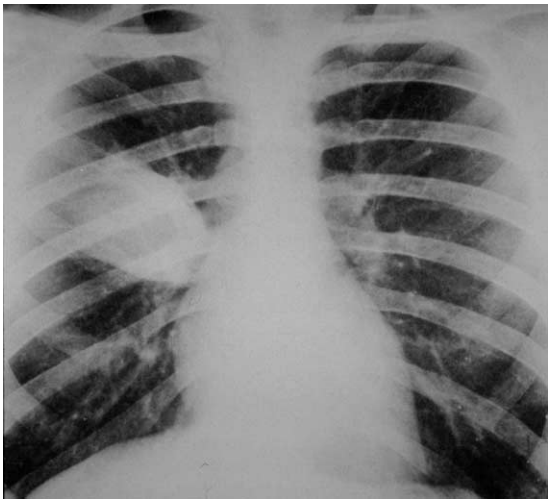

Fig. 16. Pulmonary hydatid disease. Chest radiograph in a 40-year-old patient demonstrates a well-demarcated homogeneous mass consistent with an unruptured hydatid cyst in the right upper lobe. (Courtesy of the Department of Radiology, McMaster University, Hamilton, ON, Canada).

diameter, although they may vary from 1 to 20 cm (Fig. 16). Centrally located cysts are usually round, although more peripheral cysts may be oval or polycyclic [21]. Cysts are multiple in 30% of cases, bilateral in 20%, and located in the lower lobes in 60%. Calcification in pulmonary cysts is extremely rare (0.7% of cases) [24], although it may be a feature of pericardial, pleural, and mediastinal cysts [25,26].

A closed cyst is indistinguishable from other large nodular lesions within the lung on chest radiograph [27]. When cyst growth produces erosions in the bronchioles, air may be introduced between the pericyst and the ectocyst (laminated membrane). This air manifests as a thin radiolucency in the upper part of the cyst and is known as the crescent sign or meniscus sign [21,23,24]. This sign, however, is not specific for hydatid disease and is seen in cavities that contain a fungus ball or tumor. If more air enters this space, the parasitic membranes (endocyst) collapse further, and an air-fluid level is seen. When it has collapsed completely, the crumpled endocyst floats freely in the cyst fluid, which is the water lily sign [21,24]. von Sinner et al [25] have outlined several newer radiologic signs of hydatid disease on ultrasound, CT, and MRI, which are summarized in Table 2. In some cases, in which signs such as the ''serpent'' and ''spin'' signs, are characteristic, a confirmed diagnosis of *Echinococcus* may be possible.

Table 2
Summary of the radiologic signs of hydatid disease seen on ultrasound, CT or MRI

Radiologic sign	Diagnostic characteristics
Rim sign	The presence of a low-signal intensity rim separating the parasitic cyst from the patient's tissue assumed to represent the pericyst. More conspicuous if it is contiguous to the thoracic wall and less so if it is bordering lung parenchyma.
Serpent sign	The ''snake'' appearance on ultrasound, CT, and MRI that results from collapse of parasitic membranes.
Spin or whirl sign	Collapsed parasitic membranes on MRI may have a twirled and twisted appearance.
Cyst wall sign	Cyst wall can be visualized on ultrasound, CT and MRI.
Ring enhancement sign	Ring enhancement of the pericyst following contrast, which occurs mainly in infected cysts due to hypervascularization of the pericyst. On CT and MRI, the ring enhancement is similar to that of an abscess.
Halo sign	A dense halo sign may be seen surrounding pulmonary hydatid cysts in CT and MRI. It is caused by allergic or inflammatory infiltrates or atelectatic lung.

From von Sinner WN, Rifai A, Te Strake L, Siek J. Magnetic resonance imaging of thoracic hydatid disease. Acta Radiol 1990; 31:59–62; with permission.

Pulmonary strongyloidiasis

Strongyloides stercoralis is a small nematode endemic in tropical and subtropical regions. The ova of the female nematode hatch into rhabditiform (nonmigratory) larvae that are capable of maturing into noninfectious adults or moulting into filariform (infective) larvae. Initial invasion occurs when the patient's skin is exposed to contaminated soil or feces. The filariform larvae penetrate the dermis and migrate through the venous system to the lungs, ascend the trachea, are swallowed into the digestive tract, and infect the small intestine mucosa. Most larvae penetrate the glandular epithelium into the intestinal lumen and are excreted as feces. Some larvae, however, reenter the blood stream and migrate through the lungs without a soil cycle. This ability for autoinfection means that infestation can be lifelong and extremely heavy; massive autoinfection leads to disseminated strongyloidiasis, the hyperinfection syndrome, which results in severe pulmonary disease [28,29].

The primary migratory phase of the parasite through the lung results in the larvae piercing the pulmonary capillaries and entering the alveolar ducts. During this transit from the vascular bed to the respiratory tree, variable degrees of hemorrhage and edema result along with desquamation of epithelial cells and the migration of macrophages and inflammatory cells toward the parasites, which produces ill-defined, patchy homogenous consolidation or, less frequently, fine miliary nodulation on chest radiographs. In patients with preexisting chronic lung disease, the progress of the filariform larvae's primary migration through the lungs is retarded by excessive bronchial secretions or inflammation, which causes a moderate to severe pulmonary strongyloidiasis. This infection may produce segmental or even lobar opacities. Pulmonary opacities can be chronic, and serial radiographs may show migration of the opacities through the lungs.

The pulmonary manifestations of the hyperinfection syndrome include severe bronchospasm, extensive pneumonia, pulmonary hemorrhage, and the development of the adult respiratory distress syndrome.

Pleural effusions are seen (40%) [28] more frequently in patients with heavy *Strongyloides* infection. Secondary infections from bacteria or fungi are common and are significantly associated with the development of shock lung. Pulmonary cavitation and abscess formation may occur, which suggests superimposed bacterial infection.

Paragonimiasis

Paragonimiasis is an infestation caused by the trematode parasite *Paragonimus.* The lungs are primarily affected, although central nervous system involvement does occur [30]. The radiographic features are not specific and are easily confused with

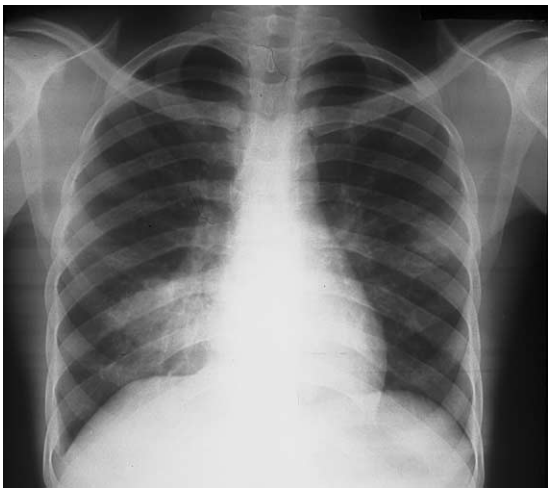

Fig. 17. Paragonimiasis. Chest radiograph in this 35-year-old patient from Congo who presented with cough and brown sputum demonstrates bilateral infiltrates with subtle foci of lucency, which suggest cavitation. Sputum was negative for acid fast bacilli (AFB) but positive for paragonimiasis. Complete regression of both lesions was evident on follow-up after therapy with praziquantel.

those of pulmonary TB. There is a high rate of a normal chest radiograph in confirmed cases of paragonimiasis: 12.8% from a study in India [31] and 20% from a Nigerian study [30]. The most common radiographic feature is multiple areas of patchy shadowing of low density with indistinct margins. There is no lobar or segmental preponderance, but the midzones are commonly affected with shadowing that extends from the perihilar regions to the periphery. Occasionally, cystic areas develop eccentrically within the areas of opacity; these have smooth outlines and have been likened to ''bubbles'' that develop within the shadow [30]. Linear streaky shadows are seen less often (2.6%) [31]. Other features include pleural reaction or thickening (28%), with pleural effusion seen in 10%. Although none of the radiographic features is pathognomonic, a combination of these appearances should alert the radiologist to the diagnosis in a patient from an endemic area who presents with typical blood-stained, rusty, or chocolate-colored sputum (Fig. 17).

Melioidosis

Melioidosis is endemic in Southeast Asia. The organism is a gram-negative bacillus, *Pseudomonas pseudomallei,* that infects humans via contaminated

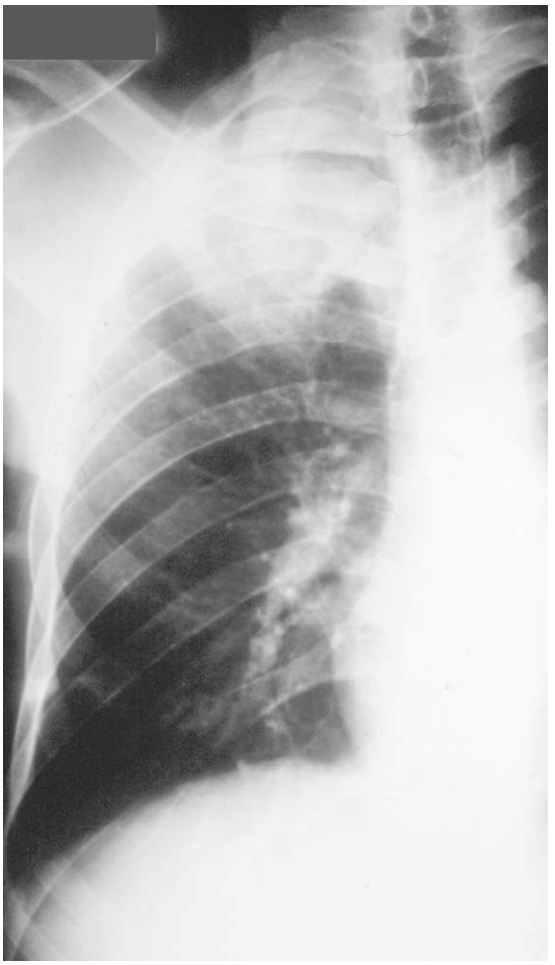

Fig. 18. Pulmonary melioidosis. Chest radiograph in a 36-year-old non-autochthonous patient with chronic cough demonstrates a right upper lobe air space consolidation. The pulmonary lesions resemble those of tuberculosis (TB) reactivation. Sputum for acid fast bacilli (AFB) and TB cultures tested negative. This particular patient from Southeast Asia was seen with the disease during his visit in Congo on business. *Pseudomonas pseudomallei* were obtained from culture and sputum. (Courtesy of Pierre-Anatole Matusila, MD, Kinshasa, Congo.)

soil or dust that enters the respiratory or alimentary tract or enters through a skin wound [32]. The bacteria may remain quiescent in an infected person for long periods and then become reactivated and cause clinical symptoms [33,34]. Clinically, melioidosis may manifest in four different ways [32].

- Patients with the acute form present with fever and chills, and without antibiotics there is usually rapid progression to overwhelming septicemia. A diffuse pneumonitis develops accompanied by multiple liver, spleen, and subcutaneous abscesses. Acute respiratory distress syndrome is a common sequela. The most common radiographic appearance in the acute form is the presence of multiple, small, irregular densities that range in size from 4 mm to 10 mm, which can simulate disseminated TB. These nodules may coalesce, which results in segmental or lobar consolidation. Pleural effusion or empyema is seen, but hilar adenopathy is rare.
- The subacute form begins with a prodromal period that eventually presents with chest pain, low-grade fever, and weight loss. Chest radiograph (Fig. 18) normally reveals a lobar infiltrate, usually within the upper lobe, and often shows cavitation.
- In subclinical melioidosis, the patient is asymptomatic, although serologic test results are positive. Most infected persons fall into this category [35]. The radiographic appearances mimic those of TB with an upper lobe infiltrate and cavity formation. These patients are at risk of developing an acute exacerbation.
- Chronic melioidosis is usually extrapulmonary, in which skin lesions or osteomyelitis represents the primary site of infection.

The most important factor involved in establishing the diagnosis of melioidosis is a high index of suspicion, and the diagnosis should be entertained in patients with a febrile illness and a localized suppurative process in an endemic area [36].

Summary

A high-quality chest radiograph and a timely, accurate report are often impossible in the tropics. Rationale matching of service to need, enthusiasm, commitment, and exploitation of information technology all go some way toward enabling patients with pulmonary disease to be imaged. The radiologic findings reflect the high preponderance of infectious disease. TB, HIV, and TB modified by HIV may be "routine" features in some parts of the tropics. Elsewhere, infestation with ameba, hydatid, and strongyloidosis, paragonimiasis, and melioidosis accounts for radiographic signs. The key is to have these conditions firmly in mind when reading tropical radiographs and be aware that the pattern of disease may be different between the patient from the tropics and the more familiar patient from downtown New York.

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