TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE (2002) **96**, 236–241

Trends in the temporal and spatial distribution of visceral and cutaneous leishmaniasis in the state of Bahia, Brazil, from 1985 to 1999

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Abstract

Temporal and spatial trends in the geographical distribution of 12 413 cases of American visceral leishmaniasis (AVL) and of 48 138 cases of American cutaneous leishmaniasis (ACL) notified from 1985 to 1999 in the State of Bahia, Brazil, were analysed. The emergence of new endemic municipalities indicated an increasing trend for AVL and ACL. In the years 1985, 1990 and 1996, AVL was endemic in 7% ($n = 31$), 18% ($n = 73$) and 30% ($n = 123$), and ACL was endemic in 13% ($n = 54$), 27% ($n = 112$) and 34% ($n = 140$), of 415 municipalities. New trends were identified, and the relation with the ecoepidemiology of both diseases is discussed.

Keywords: leishmaniasis, *Leishmania braziliensis*, *Leishmania chagasi*, geographical distribution, epidemiology, Brazil

Introduction

The majority of leishmaniases are zoonoses, caused by a wide range of species of the genus *Leishmania* Ross, 1903 (Protozoa: Trypanosomatidae). A variety of phlebotomine sand fly species (Diptera: Psychodidae: Phlebotominae) are responsible for the transmission of the parasites among a wide range of reservoir hosts including humans and domestic and wild animals (LAINSON, 1988).

In the state of Bahia, in north-east Brazil, the causative parasite of American visceral leishmaniasis (AVL) is *Leishmania (Leishmania) chagasi* and the sand fly *Lutzomyia (Lutzomyia) longipalpis* is the main vector. American cutaneous leishmaniasis (ACL) is frequently associated with species of the *Leishmania (Viannia) braziliensis* complex, especially *L. braziliensis*, with the main vectors being *Lutzomyia (Nyssomyia) intermedia*, *Lutzomyia (Nyssomyia) whitmani* and *Lutzomyia migonei* (the migonei group) (DEANE & DEANE, 1962; GRIMALDI *et al.*, 1989; SHERLOCK, 1996; SHERLOCK *et al.*, 1996). According to the Brazilian National Health Foundation's data, Bahia is one of the states most affected by both forms of leishmaniasis.

In the last few decades, the ecoepidemiological pattern of AVL and ACL has been growing in complexity. A variety of synergistic interactions, spatial and temporal, between various risk factors is potentially responsible. These include human-made environmental changes, economic downturns, widespread waves of human migration, the increasing risk of co-infection with *Leishmania* and human immunodeficiency virus, and the recent trend to urbanization of the diseases, all of which may have contributed to transform leishmaniasis into a public health problem of considerable magnitude (SHERLOCK, 1964; CUNHA *et al.*, 1995; TESH, 1995; WHO, 2000). Because of these complex dynamics, continuous monitoring of geographical distribution trends in diseases is essential, enabling us to adjust control measures to local conditions (DESJEUX, 1996).

Based on case notifications to the Public Health Secretariat of the state of Bahia, this cross-sectional study describes the temporal and spatial distribution of AVL and ACL in the state of Bahia, over a period of 15 years. Epidemiological factors that might describe and explain the specific space–time pattern of leishmaniasis are discussed.

Methods

The state of Bahia is situated on the north-east Atlantic coast of Brazil, 8·5°–18·4°S and 37·3°–46·6°W. The surface area is 567 295 km², divided into 415 municipalities. The total population was estimated to be 13 093 243 in the year 2000 (Brazilian Institute of Geography and Statistics [IBGE], Demographic Census 2000). Bahia is divided into 5 climatic zones: (i) humid (yearly rainfall > 2600 mm), (ii) semi-humid (yearly rainfall 1200–2600 mm), (iii) dry (yearly rainfall 800–1200 mm), (iv) semi-arid (yearly rainfall 400–800 mm), and (v) arid (yearly rainfall <400 mm) (SEI, 1998a). The estimated annual population of each of the 415 municipalities from 1985 to 1999 was obtained from the Statistical Office of Bahia (SEI, 1998b) and from IBGE. The annual numbers of cases of both forms of leishmaniasis reported per municipality, based on passive case detection procedures, were obtained from the Public Health Secretariat of the state of Bahia. From 1985 to 1999, the state health authorities were notified of a total of 12 413 cases of AVL and 48 138 cases of ACL.

Based on digital polygon data for the political and administrative boundaries of Bahia (Digital Municipal Mesh of Brasilia; reference map scale 1:1 000 000; IBGE, 1997), the incidence per 10 000 inhabitants of AVL and ACL was plotted on a series of maps. To test whether the maps displayed a spatially autocorrelated pattern, Oden's I_{pop} statistic was used (ODEN, 1995). Oden's I_{pop} is an autocorrelation index to study clustering of disease cases in areas with different known population densities. The test statistic considers both the spatial pattern and the differences in population size across areas. If ignored, large differences in population size decrease the ability to detect departures from spatial randomness. The statistical significance is estimated as a value of P by Monte Carlo simulation (number of runs = 1000). A significant P value ($P < 0{\cdot}05$) corresponds to a non-random geographical pattern on the observed disease map.

To study the emergence of new endemic areas over time, the municipalities were classified into 3 categories — (i) endemic: municipalities with cases in the current year and in the following 3 years (i.e., 4 consecutive years) and those which satisfied this definition in previous years were classified as endemic (i.e., endemic municipalities were always endemic in our analysis); (ii) sporadic: all municipalities with notifications of cases which were not defined as endemic until 1996; (iii) uninfected: municipalities free of leishmaniasis in all years. The endemic municipalities in 1985, 1990 and 1996 were included in the analysis, together with all the sporadic and uninfected municipalities. Based on data from the Superintendency for the Development of North-east Brazil (SUDENE) concerning recent periods of drought in Bahia (1979–1984, 1987–1988, 1991–1993, 1998–2000), the relative contributions of

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municipalities with sporadic infection to the annual incidence rates of AVL and ACL in years with drought and those with no drought were compared using the Mann–Whitney *U* test. In addition, medians and quartiles of the corresponding rate ratios were calculated.

Spatial data were analysed using ArcView, version 3.2a (ESRI, Redlands, California, USA). Data handling and statistical analyses were performed with the aid of S-Plus 2000 (Mathsoft Inc., Seattle, Washington, USA).

Results

In the state of Bahia, 12 413 cases of AVL and 48 138 cases of ACL were reported between 1985 and 1999, with annual averages of approximately 800 and 3200 cases and incidence rates of about 7·1 and 28·5 per 100 000 inhabitants, respectively. The geographical distribution of the annual incidence per 10 000 inhabitants over these 15 years was analysed and the years 1985, 1990 and 1999 (Fig. 1) were selected to illustrate the spatial spread of both forms of leishmaniasis in the observed period. Statistically significant evidence (Oden's I_{pop} $P < 0{\cdot}001$) of spatially autocorrelated patterns was obtained in each year analysed for both AVL and ACL (Table 1). The annual incidences of both AVL and ACL from 1985 to 1999 (Fig. 2) show a clear oscillatory pattern which, for AVL, suggested a recurring 4–5 year cycle. An apparent spatial spread of both diseases was observed. This corresponds to an increasing number of municipalities with reported cases of AVL and ACL (Fig. 3).

Based on our classification into endemic, sporadic and free municipalities, the emergence of new endemic municipalities for both forms of leishmaniasis occurred with a rapidly increasing trend over the later years. In 1985, 1990 and 1996, of 415 municipalities (Figs 4 a, b), AVL was endemic in 7% ($n = 31$), 18% ($n = 73$) and 30% ($n = 123$) of the municipalities, and ACL was endemic in 13% ($n = 54$), 27% ($n = 112$) and 34% ($n = 140$) of the municipalities, respectively. Approximately 74% of the endemic municipalities with AVL and 79% with ACL, which were identified in both 1985 and 1990, showed at most one year without reported cases up to 1999. In 1999, the municipalities that had been endemic for AVL since 1985, 1990, and 1996, and those with sporadic infection, were, respectively, responsible for 27%, 25%, 23% and 25% of the annual incidence. In the same year, the ACL endemic municipalities of 1985, 1990, and 1996, and the 'sporadic' municipalities were responsible, respectively, for 37%, 44%, 14% and 5% of the annual incidence. Almost all new endemic municipalities were derived from those previously considered to be sporadically infected. In Bahia, the relative contribution to the annual incidence of AVL by 'sporadic' municipalities was significantly higher during drought periods than in years of no drought ($P = 0{\cdot}02$) (Table 2). Medians and (in parentheses) quartiles of the rate ratios were 8·12% (7·55%, 11·61%) in years of no drought and 12·79% (11·90%, 18·77%) in drought years. The corresponding comparison of ACL incidences was not significant ($P = 0{\cdot}54$) (data not shown).

Discussion

Our study was designed to contribute to a better understanding of some general trends of both forms of leishmaniasis in Bahia, analysing the temporal and spatial distribution of 12 413 cases of AVL and 48 138 cases of ACL in the period 1985–99. The official data sets utilized in our study were based on passive case detection. Therefore an underestimation of the true incidence in the state of Bahia has to be expected, as with official data sets from other endemic countries (DESJEUX, 1996). A prospective study of AVL in Jacobina, Bahia (BADARÓ *et al.*, 1986) demonstrated that the ratio of infected but asymptomatic children to children with clinical illness was 18·5:1 for the entire study area and 6·5:1 for the section with the greatest number of cases. However, passive case data sets can be useful in giving a rough indication of infection trends and an estimate of the effort required to control the disease (WHO, 1990). Moreover, they are indispensable for identifying changing geographical distribution patterns of both diseases.

The annual number of AVL cases in Bahia varied throughout these 15 years, with peaks in 1985–86, 1989–90, 1995–96 and an apparently new increase in 1999. All these epidemic waves were followed by periods with relatively lower numbers of cases. In addition, there seemed to be a relationship between long-lasting drought periods (1979–84, 1987–88, 1991–93, 1998–2000) and a subsequent increase in the annual incidence of AVL in the following years that warrants further investigation. The annual numbers of ACL cases increased during the period 1987–91 and a strong peak in the year 1994, with almost 5000 cases (the total population was estimated to be 12 653 332 in 1994), followed, until 1999, by a relatively lower, but still persistent, annual incidence of about 3500 cases (the average population was estimated to be 12 748 350 in 1995–99).

In each year analysed, the distribution of both diseases showed clear spatially autocorrelated patterns indicating similarity between neighbouring municipalities, even after adjusting for local population density. Most of the AVL cases occurred in the semi-arid zone in the central area of Bahia, and the ACL cases occurred predominantly in the humid and semi-humid zones along the south-east Atlantic coast and in some dry to semi-humid zones of the inland mountainous regions. These results are consistent with previous studies in Brazil (DEANE & DEANE, 1962; LAINSON, 1989; GRIMALDI *et al.*, 1989).

In an earlier study, SHERLOCK (1996) described the spread of AVL in the state of Bahia in 1964–93. Our results confirmed this trend and revealed an increasing number of municipalities with reported cases of AVL in the following years. We also observed a rapid spread of ACL in the last 15 years in the state. The oscillation of annual incidence observed for both AVL and ACL (Figs 1 and 2) is a well-known pattern exhibited by microparasitic infections in which epidemic years are followed by endemic periods with a very low incidence level. During epidemic phases the pool of susceptible individuals in the host population is reduced and the epidemic declines until the number or density of susceptible hosts is increased by birth and immigration and the process repeats itself (ANDERSON & MAY, 1991). This topic has already been addressed by other authors: COSTA *et al.* (1990) proposed that the progressive reduction in the number of susceptible people contributed to the extinction of the AVL epidemic that occurred in 1984 in Teresina, Piauí, and SHERLOCK *et al.* (1996b) observed, in some ACL endemic regions in Bahia, that new human cases tended to become very rare after an epidemic period. The implications of this epidemiological behaviour of *Leishmania* species on national and local control strategies, world-wide, has been discussed by DESJEUX (1992, 1996) and the World Health Organization (WHO, 2000).

According to our classification, the number of both AVL and ACL endemic municipalities in Bahia showed a rapid increase. In 1985, AVL and ACL were endemic in 7% ($n = 31/415$) and 13% ($n = 54/415$) of the municipalities of Bahia, respectively. Fourteen years later, these percentages had reached 30% ($n = 123/415$) and 34% ($n = 140/415$), respectively. In more than 70% of these new endemic municipalities, AVL or ACL cases were registered each year until 1999. Furthermore, almost all of these new endemic municipalities were derived from those previously considered to have sporadic infections, where cases of leishmania-

Fig. 1. Maps of the State of Bahia in Brazil showing the incidence rates of (a) visceral and (b) cutaneous leishmaniasis per municipality in the years 1985, 1990 and 1999 (light grey indicates an incidence rate per year of 1–10 cases/10 000 inhabitants, dark grey indicates 11–20, and black indicates >20).

Table 1. Values of Oden's I_{pop} statistic for visceral and cutaneous leishmaniasis in Bahia, Brazil, 1985–1999[a]

Year	Visceral leishmaniasis I_{pop}	Cutaneous leishmaniasis I_{pop}
1985	0·00101	0·00185
1986	0·00090	0·00169
1987	0·00058	0·00111
1988	0·00018	0·00219
1989	0·00043	0·00240
1990	0·00040	0·00257
1991	0·00044	0·00200
1992	0·00022	0·00106
1993	0·00024	0·00106
1994	0·00042	0·00256
1995	0·00055	0·00174
1996	0·00052	0·00225
1997	0·00064	0·00198
1998	0·00019	0·00203
1999	0·00022	0·00304

[a]See text for explanation; $P < 0·001$ for all values of I_{pop}.

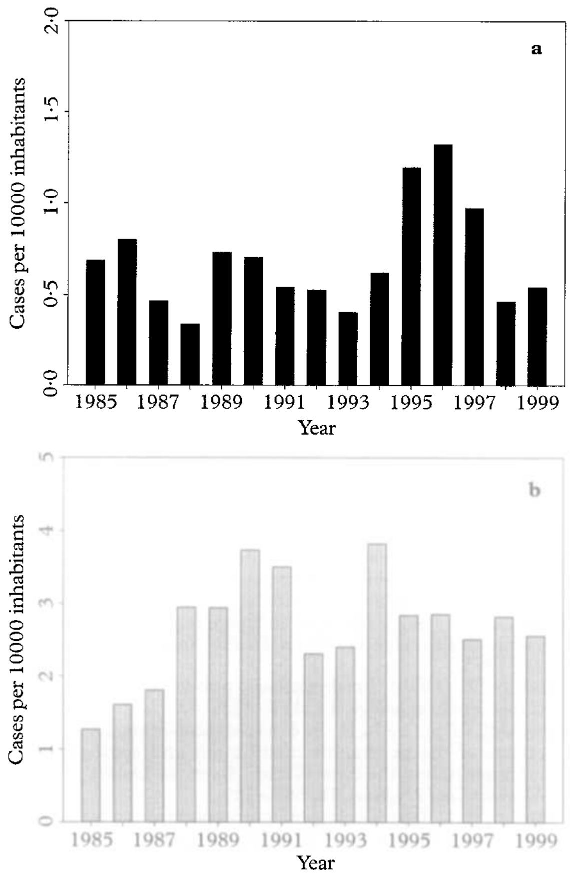

Fig. 2. Annual incidence rates of (a) visceral and (b) cutaneous leishmaniasis in the State of Bahia, Brazil, 1985–1999.

sis had been only infrequently reported. We conjecture, in relation to AVL especially, that the recurrent migration of infected people and animals from endemic to sporadic municipalities during drought periods contributed to the gradual establishment of the disease in the new endemic areas. This assumption is supported by the significant increase in the relative contribution of

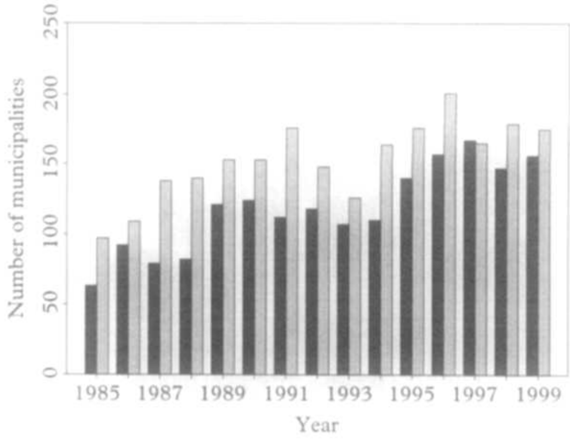

Fig. 3. Number of municipalities with any reported cases of visceral (black bars) and cutaneous leishmaniasis (grey bars) per year in the State of Bahia, Brazil, 1985–1999.

'sporadic' municipalities to the annual incidence rate of AVL during drought periods in Bahia. A similar process is apparently involved in the emergence of endemic AVL municipalities on the north coast and in the extreme west of Bahia, where humid and semi-humid conditions predominate. CUNHA *et al.* (1995) described an epidemic in one such municipality in the north coastal region and suggested that intense migration to this region in the wake of droughts in the semi-arid areas, or driven by local industrial development, may have created a new, artificial environment. Fast-growing urbanization creates a high population density of humans and domestic animals, which appear to be able to maintain a sustainable secondary transmission cycle of *Leishmania chagasi*. Indeed, the emergence of endemic municipalities of both diseases in the extreme west of Bahia is most probably a consequence of environmental change and population growth following the intensive agro-industrial development of soya bean and rice production since the early 1990s.

Although sporadic occurrences of ACL are reported in almost the whole of Bahia, ACL showed an increasing concentration in the south-east of the state, especially in the traditional cocoa-growing region along the south Atlantic coast. This region contributes approximately 90% of the total cocoa production of Brazil. Cocoa plants need the shade of primary or secondary forests for growth, thus large areas of these remnant forests have been preserved (SEI, 1997). The collapse of the cocoa industry in Bahia began in 1987, caused by the fall in the international price of cocoa and the rapid spread of *Crinipellis perniciosa*, the causative agent of witches' broom disease of cocoa. This led to a reduction in cocoa yields of 60% between 1990 and 1994 (PEREIRA *et al.*, 1996; SEI, 1997). From 1987 to 1988, the annual incidence of ACL in Bahia increased from 1985 to 3358 cases (the total population was estimated to be 9 454 346 in 1987 and 1988), and in 1994 it had reached 4834 cases (the estimated population was 12 653 332 in 1994). In the following years up to 1999, the average annual incidence of ACL has remained at about 3500 cases (the average population was estimated to be 12 748 350 in 1995–99). These data suggest a possible relationship between the regional economic downturn in the cocoa industry and the increase in the annual incidence of ACL, as well as its spread throughout the whole south-eastern region. The most likely factor behind the emergence or re-emergence of epidemic foci of ACL is increased human contact with infected sand fly vectors due to the extraction of wood or the expansion of pasture and other

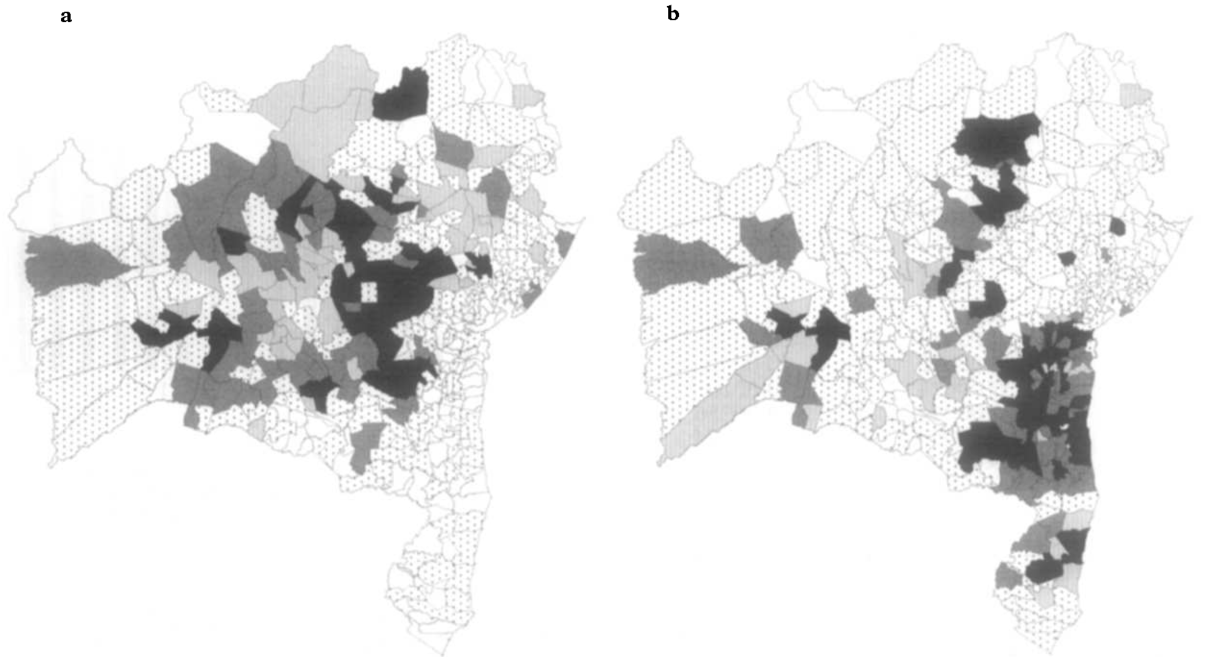

Fig. 4. Maps of the State of Bahia in Brazil illustrating the emergence of new endemic municipalities of (a) visceral and (b) cutaneous leishmaniasis in 1985 (black), 1990 (dark grey) and 1996 (light grey). Municipalities with sporadic infection are stippled and those free of infection in all years are white.

Table 2. Relative contribution to the annual incidence of visceral leishmaniasis in Bahia, Brazil by municipalities with sporadic infection in years with and without drought

Drought-free		Drought	
Year	Incidence rate ratio	Year	Incidence rate ratio
1985	3·230	1987	8·354
1986	7·617	1988	11·953
1989	14·223	1991	11·835
1990	7·440	1992	16·102
1994	7·591	1993	12·796
1995	8·618	1998	21·432
1996	11·499	1999	24·773
1997	11·943		

agricultural production as an economic alternative to the cocoa industry (SEI, 1997).

The spatial and temporal trends revealed by this study suggest that both diseases will have an increasingly important impact on public health in Bahia. This could be exacerbated by already known trends such as global climate change, desertification, increasing migration, and concentration of wealth. It is expected that in the future specific control measures will have to be linked with movements towards social, economic and environmental improvement.

Acknowledgements

We are grateful to the Alexander von Humboldt Foundation for supporting this study by a grant (III-ERSX-BRA/1067633). We thank the Statistical Office of Bahia (SEI), the Superintendency for the Development of North-east Brazil (SUDENE), and the Public Health Secretary of the State of Bahia for making available data used in this study. We also thank R. Schröder and D. Klöß for their help with data management and computing.

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Received 30 April 2001; revised 27 September 2001; accepted for publication 1 October 2001

TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE (2002) **96**, 241

Book Review

The Imaging of Tropical Diseases with Epidemiological, Pathological and Clinical Correlation. Volumes 1 and 2. (2nd edition of Radiology of Tropical Diseases). P. E. S. Palmer & M. M. Reeder (editors). Berlin, Heidelberg, New York: Springer Verlag, 2001. xxvi + 1684 pp. Price £350.00 (US$589.00). ISBN 3-540-66219-7.

When I commenced training in radiology at the Hospital for Tropical Diseases, London, 30 years ago, a copy of *Tropical Radiology* by Professor Howard Middlemiss was of necessity always by my side. This small volume was all I needed by way of an introduction to this specialist field. Great was my joy when a new book *Clinical Radiology in the Tropics*, edited by Peter Cockshott and Professor Middlemiss, appeared—larger, but not too large—with a pleasing layout and well-reproduced images. If greater detail on any subject were required, one could always refer to original articles by those in the field (I never travelled beyond central London), such as by Professors Palmer and Bohrer. However, a glimpse at the denizens of all major large cities will show that there is perhaps no such entity as 'tropical radiology' but rather 'radiology of people from the tropics', including holidaymakers.

Because of the broad distribution of the different diseases of the tropics, no single author today is capable of writing an encyclopaedic text. It is to the great credit of the distinguished editors of this 2-volume text that they have assembled a scholarly panel of authors from around the world to contribute to this comprehensive textbook.

The wide range of tropical diseases is well covered in this very-well-produced and -referenced textbook. The editing is good and, as is necessary, each disease is introduced with a list of synonyms, a definition, its geographical distribution, epidemiology and pathology, as well as the the laboratory and clinical findings, before a description of the radiological appearances. The pathological changes in particular are generally very well described.

In my own field of interest — musculoskeletal disease — much had been written about in specialized journals in the days when the plain film, intravenous urogram, and barium ruled. Since then, modern imaging techniques have become used routinely and, even if magnetic resonance imaging (MRI) is not ubiquitously available, ultrasound and computed tomography (CT) scanning are. However, conventional radiography still seems the backbone of the imaging process, but many of the illustrations in this book are of ultrasound and, to a lesser extent, CT and MRI. The chest X-ray examination findings may not be accompanied by as many CT scans as I would like, or orthopaedic plain films by MRI, but this may reflect the local unavailability of these latter imaging techniques.

This very readable book should find a well-deserved place in our departmental libraries. When a perhaps-jaded radiologist is tired of looking at degenerative disease of the spine or knee, s/he could then open up a chapter on filariasis or hydatid disease and see what radiology is really about!

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