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REPORT OF THE WHO WORKING GROUP MEETING ON ANIMAL TUBERCULOSIS

Cairo, Egypt, 27 April 1992

CONTENTS

INTRODUCTION

Professors T. Adawy and Ali A. Moussa of the General Organization for Veterinary Services, Ministry of Agriculture of the Government of Egypt, and local organisers of the meeting, welcomed the participants (Annex I). Dr T. Fujikura, Veterinary Public Health, Division of Communicable Diseases, WHO, expressed his gratitude and appreciation for their excellent meeting arrangements and opened the meeting on behalf of the Director-General of WHO. He went on to explain the purpose and scope of the meeting, as follows:

- to review the world situation in animal tuberculosis (TB) and its public health implications;

- to discuss research activities and requirements of the institutions participating in the WHO working group activities dealing with various aspects of animal TB such as epidemiology, diagnosis, tuberculin production and control, TB in wildlife, vaccine developments, as well as prevention and control in animal TB with public health implications;

- to discuss international cooperation and related work plans for 1992-1993.

Professor C.O. Thoen was elected as Chairman, Professor Adawy as Vice-Chairman, and Dr Haagsma served as Rapporteur.

1. GENERAL OVERVIEW OF THE WORLD SITUATION IN ANIMAL TUBERCULOSIS AND ITS PUBLIC HEALTH IMPLICATIONS

1.1 WHO's activities against animal tuberculosis

The Veterinary Public Health unit (VPH) of WHO has been particularly interested in the public health significance of Mycobacterium bovis infection in man and animals as well as the safety of food of animal origin with regard to contamination by M. bovis. In this connection, WHO has been continuing its efforts (1) in the worldwide surveillance of animal TB, jointly with the FAO and OIE; and (2) research in epidemiology, standardization of diagnostic methods and reagents, measures for prevention/control, including food hygiene aspects, with special reference to intersectoral cooperation, as reflected in several publications[1 2 3 4 5] (references at end of document).

The Pan American Health Organization (PAHO/WHO), with the Pan American Zoonoses Center (CEPANZO) also elaborated, in 1989, "Guidelines for the Preparation of Plans for Programmes of Bovine Tuberculosis Eradication and Principles and Technical Criteria for the Conduct and Evaluation of Bovine Tuberculosis Eradication Programmes".[6] PAHO/WHO has recently organized in Washington D.C. the VIIth Inter-American Meeting, at Ministerial Level, on Animal Health, with priority discussions on a strategy and plan of action for the eradication of bovine TB in the Americas, including its public health aspects, as data indicate that approximately 7000 human cases annually are caused by M. bovis infection derived from infected animals in Latin America.[7]

In addition, since 1988, CEPANZO (which in November 1991 became the Pan American Institute for Food Protection and Zoonoses - INPPAZ), has also published a series on "The Status of Bovine Tuberculosis in Latin America and

the Caribbean", and the latest edition[8] includes precise epidemiological data on 33 countries in the Americas, together with information on new diagnostic methods and the Institute's research activities.

INPPAZ will continue to play an important role in research and services such as the provision of reference materials, information support and the training of technical personnel in respect to international cooperation. PAHO also convened a meeting recently in Mexico on eradication of bovine TB in the Americas based on the above developments.[9]

In the 1990 survey made by FAO, OIE and WHO,[5] 19 out of 175 countries (10.9%) reported enzootic TB or a high prevalence of the disease in cattle. In 58 countries (33.1%) its occurrence was characterized as "low sporadic". In the above countries, control measures have been taken by making bovine TB a notifiable disease, expanding control programmes to the whole country, test and slaughter, strict quarantine measures through prohibition of imported animals from infected countries, restriction of animal movement, precautions at frontiers, and other measures.

The VPH unit of WHO has organized and coordinates two working teams comprising 22 experts from 16 countries around the world. Their subjects are (1) epidemiology and public health aspects of animal TB, and (2) control and research in animal TB. Information exchange amongst team members was encouraged by a circular letter from VPH outlining possible further steps for international cooperation, and the present group meeting was convened in conjunction with the IUAT Conference on Animal Tuberculosis in Africa and the Middle East, Cairo, 28-30 April 1992. The WHO working group is also interested in collaborative studies on the modes of transmission of M. bovis:- human to human, human to cattle, and feral animals to humans and/or cattle, focusing on the public health significance of animal TB. The newly-developed gamma-interferon assay by a team in Australia for the diagnosis of M. bovis infection in cattle is also of direct interest for promotion of collaborative research by the working groups.

1.2 Report by the WHO Regional Office for the Eastern Mediterranean

In spite of the absence of reliable field surveys, slaughterhouse records show a comparatively high prevalence of bovine TB leading to the condemnation of notable quantities of cattle meat. The disease is thus not only of zoonotic importance but also causes considerable economic losses.

Animal TB appears more frequently in older animals because it is chronic in character. Moreover, it is more prevalent among dairy than beef cattle. In developed countries bovine TB has been eradicated or is in an advanced stage of control, while in much of the eastern Mediterranean region the situation has not improved and in some cases prevalence of the disease is increasing. Some of the major constraints to development of effective bovine TB control programmes in the region can be identified: scarcity of veterinarians and related professional staff to plan and implement adequate surveillance and control programmes, legislation is not always adequately implemented, insufficient epidemiological information, absence of control measures on imported food, and shortcomings of laboratory facilities.

The history of human TB in the eastern Mediterranean region during this century shows a clear correlation between the decline of the problem and the rate of socioeconomic development as well as the standard of health services. The WHO Regional Office has expressed concern about the still relatively high

prevalence of TB and stressed the need for effective approaches to its control. Recent studies show that about 96% of the total regional population lives in countries with an intermediate to high prevalence, the annual risk of infection ranging from 0.5-3%. M. bovis infection in children is rather common, due to the habit of consuming unboiled milk which is invariably contaminated. The disease still continues to be an important public health problem in the region in spite of advances in reliable diagnostic tests and efficacious preventive and curative methods.

Although M. tuberculosis is the main cause of human TB, infection with M. bovis can cause clinical and pathological lesions similar to those caused by M. tuberculosis. The most prevalent forms caused by M. bovis are extra-pulmonary (e.g. TB of bones and joints, cervical adenitis, etc.) and young children represent the most affected age group especially in countries with a high prevalence of bovine TB and where raw milk or raw milk products are consumed. Special consideration should be given to particular features in this region with regard to the transmission of TB from animals to man. It is still a common social custom to keep cattle close to or even within the house where a family is living. This situation may create opportunities for transmission from animals to man, or the reverse, man to animals could also occur.

Pulmonary as well as extra-pulmonary human TB of animal origin in the region continue to be important problems of public as well as occupational health (with regard to farmers and slaughterhouse workers), especially in areas where prevalence of the infection in cattle is high. The inter-human transmission of M. bovis is still a matter of controversy, however, since only a few cases have been satisfactorily confirmed. Laboratory services for TB control are not widely available so that many patients are put on chemotherapy without bacteriological confirmation.

1.3 Report of the Subcommittee on Animal Tuberculosis of the International Union Against Tuberculosis and Lung Diseases (IUAT)

The operational purpose and scope of the Subcommittee is (1) to collect current epidemiological information on the occurrence of TB in livestock and wild animals, (2) to assess the public health consequences of animal TB and to recommend prevention and control of TB transmission from animal to man, and (3) to assess new diagnostic methods and vaccines against TB in conformity with recent advances of science and technology and to disseminate the information. Technology transfer of diagnostic methods, production technology of biological products and reagents are a vital part of the Subcommittee's activities. The Chairman of the Subcommittee reported the following points to the meeting:

In Morocco, slaughtered adult female cattle were found to be heavily infected in some districts with high isolation rates of M. bovis (30%) and M. tuberculosis (9.7%). In Spain, in goat flocks with an average mortality rate greater than 20%, there were very high tuberculin reactors ranging from 20-98% and TB lesions were frequently found in the mammary glands of the goats. In Germany, it is noteworthy that re-infection incidence has been increasing even in TB-free areas where the skin test has not been practised for more than two years. This is also causing increasing risks in shipment of animals from/to these areas. Meat inspection and tracing procedures have also been strengthened to prevent the spread of animal TB inside the country. In Ireland, an enzyme immunoassay (EIA) for identifying animal TB has been found useful when this technique is used in parallel with the skin test. In

Argentina, the rapid glutaraldehyde test has also been useful in detecting animals with TB lesions (85%). In Canada, emphasis has been placed on elaboration of improved safety protocols for workers engaged in the handling and disposal of wild animals infected with TB, or for those in contact with such animals, as there has been some accidental infection among workers who handled diseased elk and other animals.

1.4 Country report from Germany in controlling animal tuberculosis

An eradication campaign has been in action since the early 1950s. As a result, nationwide animal TB incidence has decreased from 40% (1952), 1.7% (1961), 0.32% (1971), 0.044% (1981), to 0.025% (1988). Despite this successful development, there has recently been an increase in the number of reactors in herds and in areas where the skin test has not been done for more than two years (Figure 1). Immediate consideration of the above facts is urged to effectively prevent a spread of infection through import/export of animals from/to the areas affected.

1.5 Mycobacterial infection in Chedolina Longicollis, Italy

The incidence of animal TB in this district was 3.9% in 1970, 1% in 1977, and has been 1.9-4.6% since 1984. Even in originally free areas, 79% of herds were infected. In this connection, the public health services in the district have been making efforts (1) to promote surveillance systems, (2) to improve slaughterhouse inspection, (3) to strengthen animal quarantine to control animal movements, and (4) to introduce a serological test such as EIA for prompt detection of infected animals. In other similar areas, despite animal TB campaigns, the incidence of TB in children has been increasing. In addition, positive rates of the skin test in veterinarians were recently as high as 31/70 (45%).

1.6 Report from New Zealand

This report centred on TB in farmed/wild deer. Research programmes aimed at investigating epidemiological factors of the TB in deer: (1) effects of nutrition, climate, age, breeds, management of farming, disease susceptibility, and immune competence; (2) altered states of resistance; (3) model system of vaccine efficacy testing; (4) mode of transmission of M. bovis as horizontal/vertical, natural exposure to environmental mycobacterium; and (5) responsiveness of newborn and juvenile animals to M bovis infection. To date, a BTB (blood test for TB, EIA) is suitable for to detect infected animals among farmed deer (sensitivity is greater than 95%, specificity is 98.6% in conformity with detailed histopathological /bacteriological tests). A lymphocyte transformation test (LT) can also identify infected animals when tested 10 days after the skin test due to a significant increase in inflammatory proteins in infected animals exposed to bovine PPD. BCG is safe for deer but may not be adequate to provide effective immunity; however, it provides measurable levels of immunity in juvenile and adult deer. This is a logical starting point for improving vaccine efficacy. Figure 2 illustrates a radial plot showing the levels of inflammation in diseased, immune, and non-infected deer.

1.7 Handling and processing of milk and milk products in controlling M. bovis transmission to human populations

It should be remembered that not only the bovine type of mycobacterium, but also avian and human types of tubercle bacilli may be excreted even from clinically normal udders and such potential and acute excreters often exist in uncontrolled conditions. One cow can excrete a sufficient number of tubercle bacilli to contaminate the milk from 100 healthy cows. Through respiratory contact, pathogenic mycobacteria can be transmitted from cattle to humans and vice versa. However, effective measures to break down the transmission cycle should be (1) adequate heating of milk, namely pasteurization, and (2) eradication of TB in animals.

The term "pasteurization" should be reserved for heat treatment at a prescribed temperature for a prescribed time in properly designed and operated equipment. In some countries the time and the temperature of exposure to heat are legally prescribed; in others, a heat-treatment procedure that consistently yields milk giving a negative phosphate reaction is regarded as satisfactory from the public health standpoint. In the former countries, two types of pasteurization have been in general use for many years: (1) the holding method, in which milk is held at a temperature of 63-66°C for at least 30 minutes, and (2) the high temperature short time (HTST) method, in which the milk is held at a temperature of not less than 72°C for at least 15 seconds. In the latter countries pasteurization procedures have been used in which milk is heated for 1-40 seconds at a temperature of 70-80°C.

Special problems of hygienic milk production in warm countries are: (1) proper disposal of animal and human waste to eliminate contamination of zoonotic pathogens including mycobacteria, (2) adequate supply of clean water to avoid cross-contamination in processing the milk through milkers and other equipment, (3) cooling the milk until delivery. Overall milk hygiene control programmes should further be improved to become an integral part of public health activities for prevention and control of TB in animals.

1.8 Mycobacteria isolated from exotic animals

Mycobacteria have been isolated from many of the species of captive, non-domesticated animals, non-human primate colonies, or wildlife animals in national parks. The M. tuberculosis complex (M. bovis, M. africanum, and M. tuberculosis) are the organisms most commonly isolated from animals with pulmonary diseases. The most common cause of disease in exotic birds is M. avium.

The above situation indicates that it is of vital importance to elucidate further the existence of potential reservoirs of TB to man, farm animals and household pets. The current list of pathogenic mycobacteria in animals is given in ANNEX II of this report.

2. RESEARCH ACTIVITIES AND REQUIREMENTS OF INSTITUTIONS PARTICIPATING IN WHO WORKING GROUPS

2.1 Research activities

The following is a summary of activities within the institutions participating in the WHO working group. The number given in brackets at the

end of each sub-item corresponds to the number quoted before each institution listed below.

(1) Department of Microbiology and Preventive Medicine, Iowa State University, Ames, Iowa, USA.
(2) Institute of Animal Hygiene and Infectious Diseases, Justus-Liebig-University, Giessen, Germany.
(3) Department of Bacteriology, Central Veterinary Institute, Lelystad, Netherlands.
(4) Laboratoire central de Recherches vétérinaires, Centre national d'Etudes vétérinaires et alimentaires (CNEVA), Maisons-Alfort, France.
(5) Veterinary Research Institute, Onderstepoort, South Africa.
(6) Deer Research Laboratory, University of Otago, Dunedin, New Zealand.

2.1.1 Epidemiology

- collection of epidemiological data of the incidence of M. bovis in man and of M. tuberculosis in animals (3);

- supervision for the control of M. bovis infection in cattle and other animals in the Netherlands and maintenance of the TB-free status (3);

- participation in the African buffalo and other wild animal TB research programmes in the Kruger National Park (5).

2.1.2 Diagnosis in bacteriology and pathology

- diagnostic examination of suspected TB cases in the Netherlands (isolation, identification of cultures, histopathology) (3);

- microscopic examination of faecal smears stained with the Ziel-Neelsen method (5);

- identification of mycobacterial isolates from buffalo and other wild animals (5);

- DNA typing of M. bovis from buffalo and other wild animals (5);

- application of PCR for diagnosis of animal TB (2);

- diagnosis of TB in non-human primates (1).

2.1.3 Serological diagnosis

- preparation of an European Community project on the development of blood based tests for the diagnosis of bovine TB (4);

- standardization of assays for cellular immune response, intradermal tuberculin test, and gamma interferon (5);

- comparison of enzyme immunoassay and other tests for humoral response (5);

- agar gel immunodiffusion test and complement fixation test (5);

- evaluation of M. bovis EIA with cell-wall antigen (KCL-extracted) in cattle and other animals (3);

- application of gamma-interferon assay for TB diagnosis in cattle and other animals (3).

2.1.4 Biological standardization

- establishment of standard procedures of PPD in guinea-pigs and cattle (3);

- production of tuberculin (bovine PPD, avian PPD, and Johnin) (3).

2.1.5 Research on TB in deer

- pathological and immunological research in deer as a TB animal model (6);

- research in naturally-infected deer herds to identify factors/parameters involved in the infected herds (6);

- research in experimentally-infected deer herds to assess vaccine trials and identify major factors involved in the transmission and spread of the disease (6);

- vaccine developments with special reference to BCG (M. bovis) and to compare immunity of vaccinated and naturally-infected animals (immunity/ hypersensitivity) (6).

2.1.6 Research on virulence, immunology, and treatment

- study of M. bovis-infected buffalo under different environments (5);

- pathogenesis of M. bovis in captive wild animals (5);

- study of virulence of the isolates from cattle and buffalo (5);

- experimental treatment of TB in exotic animals (3);

- research on adhesion molecules on T-lymphocytes isolated from tuberculous granulomas (1).

2.2 Research requirements

The group proposed the following subjects for research:

- collection of epidemiological data on animal TB in Africa;

- epidemiological studies of M. bovis infection in human populations in Africa and other regions through intersectoral collaboration of veterinary and public health institutions;

- improvement of diagnostic methods for animal TB;

- studies on control measures in badgers and possums as reservoirs for wildlife TB;

- research on application of gamma-interferon assay to animal TB control programmes and development of TB vaccines for cattle and wildlife animals;

- study on the public health significance of M. bovis infection in human populations and related food hygiene aspects;

- epidemiological, diagnostic and control studies on TB in big game animals (buffalo, elephants, and others);

- study on M. tuberculosis infection in pigs in Africa.

3. INTERNATIONAL COOPERATION

The following participating institutions are continuing international cooperation on specific topics of animal TB:

(1) School of Veterinary Medicine, Iowa State University, Ames, Iowa, USA.

- M. bovis infection in cattle, epidemiology and public health significance in Morocco;

- M. bovis infection in Camilidae (such as llamas, alpacas) in Mexico;
- diagnosis of TB in llamas in Canada;

- M. bovis infection in buffalo and application of EIA for diagnosis in South Africa;

- diagnostic research on TB in orang-utans in Taiwan;

- public health significance of animal TB in Turkey;

- development of rapid diagnostic methods for bovine and other animal TB in Egypt.

(2) Institute for Veterinary Microbiology, Justus-Liebig-University, Giessen, Germany:

- surveillance of bovine TB and its public health consequences; related laboratory research with scientists from Egypt and Ethiopia.

The following subjects were proposed for international collaborative studies and activities:

(3) Veterinary Research Institute, Onderstepoort, South Africa.

- training in processing specimens, typing isolates and bacteriology of Mycobacterium, biosafety aspects, research and field operations for surveillance in animal TB;

- production and control of PPD (bovine and avian tuberculin);

- cooperation in TB eradication programmes including infrastructure, diagnostic schemes, tuberculin testing, identification of TB-free herds, and evaluation of the programme.

The following goals for international cooperation were set by the Subcommittee on Animal Tuberculosis of the IUAT:

- development of improved safety procedures to reduce the risk for workers handling tuberculous animals:

- collection of reliable information on animal TB in developing countries;

- transfer of scientific knowledge and provision of assistance to developing countries;

- application of new procedures (i.e. restriction endonuclease analysis) for characterizing pathogenic mycobacteria. This information would be useful in conducting epidemiological investigations and in tracing zoonotic sources and reservoirs of infection;

- determination of the public health risk of M. bovis infection in dairy goats, particularly in Mediterranean countries;

- development of improved diagnostic procedures for detecting TB in captive wild animals;

- collection of additional information on potential sources of M. avium complex infections in animals and man. Investigations are in progress to determine the similarity of isolates using improved DNA technologies and to collect information on the pathogenesis of M. avium complex infections in animals and man.

4. WORK PLANS FOR 1992-1993

Professor Thoen, Chairman of the working group, will contact group members to elaborate work plans for which the participating institutions and scientists will embark on collaborative studies based on the meeting discussions and their common scientific interest in animal TB.

The following opportunities for future meetings of the working group were suggested, in conjunction with IUAT meetings or in discussion with Professor Schliesser, Germany:

- IUAT Workshop on M. bovis, Paris, France, 6 October 1993;

- IUAT Meeting on the Zoonotic Importance of M. bovis, Mainz, Germany, 13 June 1993;

- proposed WHO Committee on Animal Tuberculosis, Giessen, Germany, 17 April 1994;

- II International Conference on TB in Animals in Africa and the Middle East, Morocco, March 1995.

5. RECOMMENDATIONS

1. Improved surveillance and reporting systems on animal TB should be established in interested countries using modern technologies for both diagnosis and surveillance. In particular, TB in livestock should

become a notifiable disease. In this connection, epidemiology and public health implications, including TB in wild animals, should be further investigated.

2. Diagnostic methods such as the tuberculin test, M. bovis and Mycobacterium spp. isolation/identification, serological tests such as EIA, gamma-interferon assay, as well as related diagnostic reagents, should be standardized with regard to sensitivity, specificity, stability and applicability to different settings in developing countries.

3. The group agreed that animal TB is still posing serious public health problems in many developing countries and its control should be further strengthened. To this effect, planning and management of control programmes at national and regional levels, education, technical personnel training, food safety measures (including meat inspection and milk processing and hygiene) should be particularly strengthened. Intersectoral cooperation between public health and clinical medical sectors is necessary to protect the population at risk, as well as good continuous health education and health care systems for particular occupational groups at risk, including milk handlers.

4. Research such as development of Mycobacteria species-specific antigens against animal TB should be given priority by the group. The group agreed to participate in these specific activities and to play a leading role, in close collaboration with WHO, IUAT and other international organizations such as the FAO, OIE, European Community, and interested WHO Member States.

5. The WHO-coordinated working group should provide information support with respect to all aspects of animal TB as well as reference, research and training services. In this connection, WHO is requested to develop an institutional network at regional/global levels, including WHO Collaborating Centres as appropriate.

ACKNOWLEDGEMENTS

The group wishes to acknowledge the valuable contributions (working papers, provision of recent reprints and other forms of assistance) made by the following scientists who were unable to participate in the meeting: Dr Isabel Kanytor, PAHO/WHO International Institute for Food Protection and Zoonoses (INPPAZ), Buenos Aires, Argentina; Dr P.R. Wood, Animal Health Laboratory, CSIRO, Parkville, Victoria, Australia; and Dr L.M. O'Reilly, Veterinary Research Laboratory, Department of Agriculture and Food, Dublin, Ireland.

The group also wishes to express its gratitude to all the staff of the General Organization of Veterinary Services of the Ministry of Agriculture, Cairo, for their valuable assistance as well as for their kind hospitality to all the participants.

Fig. 1. EFFECT OF INTERVALS OF REPEATED TUBERCULIN TESTING IN CATTLE HERDS TO INCREASED NUMBER OF REACTORS
(Germany, 1982-1988)

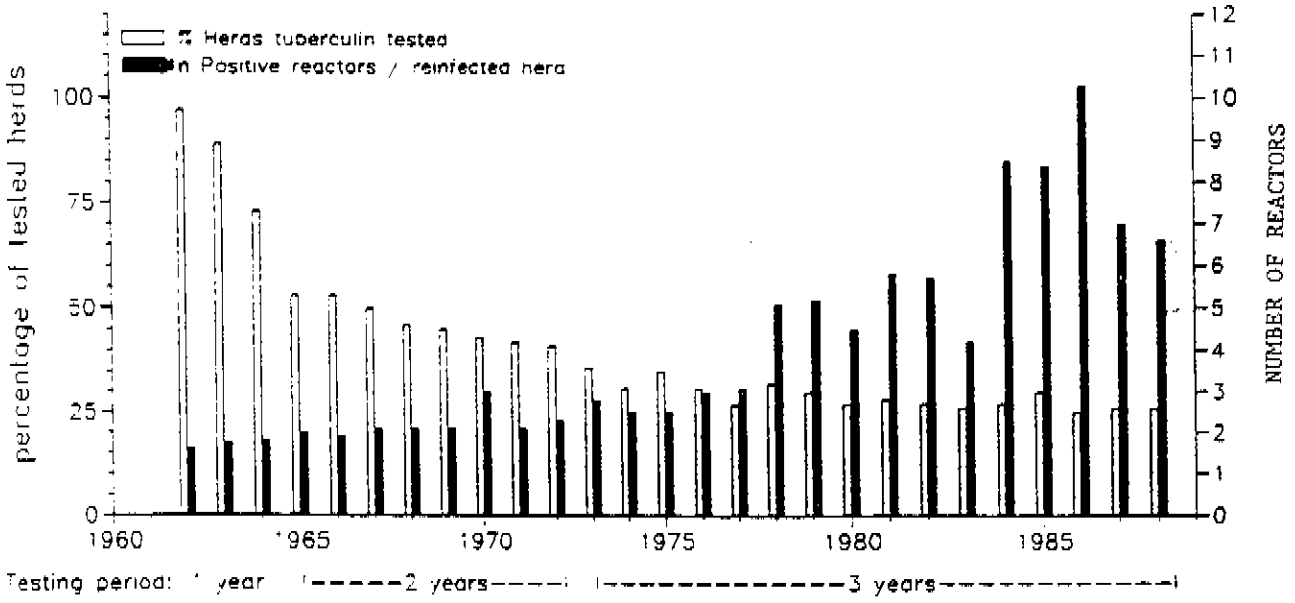
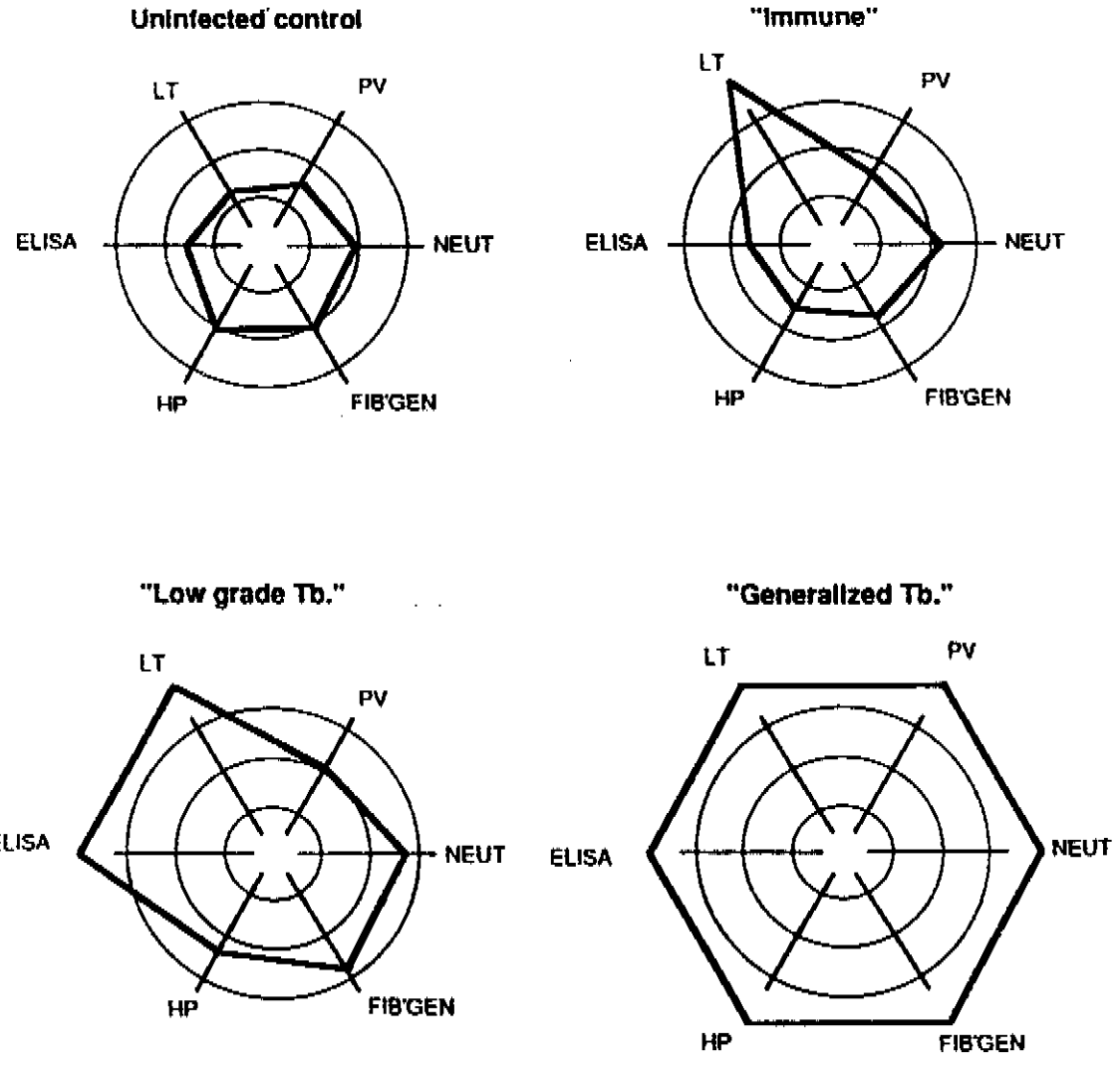


Fig. 2. RADIAL PLOT SHOWING LEVELS OF INFLAMMATION IN DISEASED, IMMUNE AND NON-INFECTED DEER



The outer and inner circles represent two standard deviation values (above and below) for the species. The mean value is represented by the circle that lies between these two circles.

For abbreviations; NEUT for neutrophils, FIB'GEN for fibrinogen, PV for plasma viscosity, ELISA for antibody, and LT for lymphocyte

ANNEX I

LIST OF PARTICIPANTS

Professor A.T. Adawy, c/o General Organization for Veterinary Services, Nadi El-Seid Street, Dokki, Giza, Cairo, Egypt (Vice-Chairman)

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Secretariat

Dr A.E. Abdou, Division of Prevention and Control, WHO Regional Office for the Eastern Mediterranean, Alexandria, Egypt

Dr T. Fujikura, Veterinary Public Health, Division of Communicable Diseases, WHO, Geneva (Secretary)

Birds

Mycobacteria	Species	Lesions	References
M. avium 1, 2, 3	parrots & parakeets psittaciformes	liver, spleen	Forster *etal* 1988 Dtsch. Tieraerztl Wochensch *95*, 338-342
	whooping crane *Grus americana*	liver, intestine kidney, spleen	Stroud *etal* 1985 J wildl Dis, *22*, 106-110
	goshawks *Accipiter gentilis*	generalized arthritis meningitis encephalitis	Nie *etal* 1982 Tijd. Diergeneeskd, *107*, 563-572
	lanner falcon *Falco biarmicus sp*		
	kestrel *Falco tinnunculus*		
	buzzards *Buteo buteo*	spleen, liver wounds	Smit *etal* 1987 J wildl dis *23*, 485-487
M. tuberculosis *M. bovis*	parrots	variable, weight loss	Fowler 1986 Zoo & wild anim. med., 230
M. scrofulaceum	parrots		CNEVA-LCRV
M. silvaticum	crane *Balearica*	liver	CNEVA-LCRV

[a] Prepared by Professeur M.F. Thorel, Maisons-Alfort, France, 1992.

Cold Blooded Animals

Mycobacteria	Species	Lesions	References
M. thamnopheos	greater snakes *Thamnophis sirtalis*		
M. xenopi	toad *Xenopus laevis*		Schwabacher 1959 J Hyg, *57*, 57-67
M. marinum	toads *Bufo cognatus* *Bufo wood housei*	lung, liver, kidney, intestine and skin	Shiveley *etal* 1981 J wildl Dis, *17*, 3-7
M. chelonae	boa constrictor *Constrictor constrictor*	ulcerative stomatitis	Quesenberry *etal* 1986 JAVMA, *189*, 1131-1132
M. simiae	python *Python regius*	stomatitis	CNEVA-LCRV
M. terrae	Tortoises *Testudo hermanni* *Testudo greca*	enteritis	Thorel 1980 Ann Microbiol I. P., *131A*, 61-69

Non Human Primates

Mycobacteria	Species	Lesions	References
M. africanum	chimpanzee *Pan troglodytes*	lungs, kidneys, spleen, nodes	Thorel 1980 Tubercle, *61*, 101-104
	african green monkey *Cercopthecus aethiops*	nodes	Thorel 1980 Tubercle, *61*, 101-104
M. leprae	chimpanzee *Pan troglodytes*	nodules in the skin of the supra orbital area, lips, chin, ears and scrotum	Hubbard *etal* 1991 Vet. Pathol., *28*, 546-548
M. tuberculosis	orang utan *Pongo pygmaeus*	lung	Kehoe *etal* 1984 Aust. Vet. J, *61*, 128
M. bovis	rhesus monkey *Macaca mulatta*	lung	Sue West *etal* 1981 JAVMA, *179*, 1240-1244
	spider monkey *Ateles geoffroyi*	lung	Sue West *etal* 1981 JAVMA, *179*, 1240-1244
	olive baboons *Papio cynacephalus anubis*	generalized pulmonary	Tarara *etal 1985* J. Wildl Dis, *21*, 137-140 Sapolsky & Else 1987 J Med. Primat., *16*, 229-235
	dusky langur *Presbytis obscurus*	lungs, spleen, intestines	Himes *etal* 1982 JAVMA, *181*, 1355-1257
	Rhesus monkeys *Macaca mulatta*		Zumpe *etal* 1980 Lab. Anim. Sci., *30*, 237-240

Non Human Primates

Mycobacteria	Species	Lesions	References
M.avium	cynomolgus monkey *Macaca fascicularis*	ulcerated cutaneous	Bellinger& Bullocks 1988 Lab. anim. Sci., *38*, 85-86
	rhesus monkey *Macaca mulatta*	lung, mesenteric lymph nodes	Goodwin *etal* 1988 Lab. anim. Sci., *38*, 20-24
M. intracellulare serotype 10	rhesus monkey *Macaca mulatta*	lungs, spleen, liver and kidney, diarrhea	Fleischman *etal* 1982 JAVMA, *181*, 1358-1362
M. scrofulaceum	patas monkey *Erythrocebus patas*	lung and liver	Renquist & Potkay 1979 Lab. Anim. Sci., *29*, 97-101
M. paratuberculosis	stumptail macaque *Macaca arctoides*	chronic diarrhea, progressive weight loss to death	Mc Clure *etal* 1987 J. Inf. Dis, *155*, 1011-1019
M. kansasii	rhesus monkey *Macaca mulatta*	pulmonary	Jackson *etal* 1989 Labo Anim. Sci., *39*, 425-428

Hoofed Animals

Mycobacteria	Species	Lesions	References
M. tuberculosis	alpacas *lama pacos*	generalized	Tijds Diergeneeskd 1989 *114*, 227
	asian tapir *Tapirus indicus*	lungs mediastinal and bronchial lymph nodes	Diavakaran Nair etal 1985 Indian vet J, *62*, 1086-1087
	rhinoceros	lung and enlarged lymph nodes	Powers and Price 1967 JAVMA, *151*, 890-892
	spotted deer *Axis axis*	multiple subcutaneous abscesses	Arora 1987 Vet. Rec., *120*, 17
M. bovis	african buffaloes *Syncerus caffer*	generalized	Woodford 1982 Trop. anim. Heatlh Prod., *14*, 81-88
	american bison *Bison bison*	lung, liver and lymph nodes	Tessaro *etal* 1990 Can. Vet. J., *31*, 174-180 Thoen 1986 Bull. UICT, *61*, 66-67
	greater kudu *Tragelaphus strepsiceros*	lungs, thoracic lymph nodes, spleen	Himes *etal* 1976 JAVMA, *169*, 930-931
	black rhinoceros *Diceros bicornis*	lungs	Mann *etal* 1981 JAVMA, *179*, 1123-1129
	bactrian camels *Camelus bactrianus*	progressive disease	Bush *etal* 1986 Proceedings Am. Ass. Zoo Vet., 22-23
	warthog	generalized	Woodford 1982 Trop. Anim. Health Prod., *14*, 155-160
	Fallow deer *Dama dama*	liver, nodes	Thorel 1980 Ann. Microbiol. I P., *131A*, 61-69

Hoofed Animals

Mycobacteria	Species	Lesions	References
M. microti	Vicuña *Lama vicugna*	lungs, liver, kidneys, trachea aorta and lymph node	Pattyn *etal* 1970 Acta Zoo Path., *51*, 17-24
M. avium	pudu *Pudu pudu*	generalized	Meurichy *etal* 1985 Verhandlungsbericht... 27, 469-480
M. paratuberculosis	pudu *Pudu pudu*	mesenteric lymph nodes	Meurichy *etal* 1985
	camels	diarrhea	Ovdienko *etal* 1985 Vet Moscow, *4*, 65-68
	Tule elk *Cervus elaphus nannodes*	diarrhea, walls of jejunum and ileum thickened	Jessup *etal* 1981 JAVMA, *179*, 1252-1254
	bighorn sheep *Ovis canadiensis*	intestine	Williams *etal* 1979 J Wildl Dis, *15*, 221-227
	rocky mountain goat *Oreamnos americanus*	intestine	Williams *etal* 1979
M. fortuitum	indian buffalo *Bubalus babalis*	bronchial lymph node	Hardjoutomo *etal* 1990 Penyakit Hewan, 22, 86-89
M. kansasii	fallow deer *Dama dama*	nodes	CNEVA-LCRV

Other Wild Animals

Mycobacteria	Species	Lesions	References
M. bovis	brush - tailed possums *Tichosurus vulpecula*	generalized	Collins *etal* 1986 J Hyg, *96*, 431-438 Brockie *etal* 1987 New Zealand Vet J *35*, 201-203
M. intracellulare	brush taled bettong *Bettongia penicillata*	osteomyelitis	Richardson & Read 1986 J. Wildl Dis., *22*, 425-429
M. intracellulare serotype 42	wallaby *Macropus eugenii*	liver, mediastinal lymph node	Peet *etal* 1982 Aust. Vet. J., *58*, 215
M. intracellulare serotype 20	*Macropus irma*	tail abscess	Peet *etal* 1982
M. ulcerans	koalas *Phascolarctos cinereus*	ulcers on the face, forearm, rump, groin, footpads...	Mitchell *etal* 1987 J. Wildl Dis., *23*, 386-390
		cutaneous and respiratory tract	Mc Orist *etal* 1985 J Wildl Dis, *21*, 171-173
M. avium 15	wallaby *Macropus parma*	osteomyelitis, lymph nodes, liver, kidney	Mann *etal* 1979 JAVMA, *181*, 1351-1333
	rat kangaroo *Paorous tridactylus*	osteolytic changes, liver and lungs	
	tree kangaroo *Dandrolagus ursinus*	osteomyelitis	
M. avium 2	kangaroo	liver and spleen	Thorel 1980 Ann. Microbiol. IP, *131A*, 61-69

Other Wild Animals

Mycobacteria	Species	Lesions	References
M. tuberculosis complex	seals	lung, lymph nodes	Cousins *etal* 1990 Res. Vet. Sci., *48*, 196-200
M. chelonae	amazonian manatee *Trichechus inungius*	pyoderma	Boever *etal* 1976 JAVMA, *169*, 927-929
M. marinum	manatee *Trichechus inungius*	lung	Morales *etal* 1985 JAVMA, *187*, 1230-1231
M. fortuitum	southern sealion *Otaria flavescens*	nodules on the head back, flanks and flippers	Lewis 1987 Aquatic mammals, *13*, 105-108
M. smegmatis	california sealion *Zalophus californicus*	generalized	Gutter *etal* 1987 J. Zoo An. Med., *18*, 118-120
M. fortuitum	harbor seal *Phoca vitulina conealor*	pyogranulanatous dermatitis lymphadenitis and interstitial pneumonia	Wells etal 1990 J. Zoo Wild. Med., *21*, 73-78

Other Wild animals

Mycobacteria	Species	Lesions	References
M. tuberculosis	elephant	lung, chronic weight loss	Greenberg *etal* 1981 Amer Rev. resp Dis, *124*, 341
M. bovis	tiger	lungs, liver, bone	Lumeij *etal* 1987 Vet. rec., *120*, 302-304
	lion	lungs	Thorel 1980 Ann. Microbiol. IP, *131A*, 61-69

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