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PULMONARY TUBERCULOSIS IN RECRUITS EXPERIENCES IN A SURVEY BY THE MICRORADIOGRAPHIC METHOD

BY

ERIC L. COOPER, M.D.

Lieut.-Colonel, Assistant Director-General of Medical Services, Australian Army Medical Corps

Radiological surveys as an indication of the incidence of pulmonary tuberculosis have in the past been limited by the expense of x-ray examinations. Fluoroscopy and paper films have been used in an attempt to reduce this cost. The value of fluoroscopy is limited in that the examination by a radiologist takes an appreciable time, exposure to x rays makes the method dangerous, there is no permanent record, and the results even with modern plants and screens leave much to be desired. However, at least one large insurance company in New York has found screening of such value that a fluoroscopic examination of the chest is a routine before acceptance of a proposal. While paper films are less costly than the usual x-ray film, they are still relatively expensive. Paper film must be recently prepared and kept in cold storage if good results are to be obtained (Douglas, 1939).

Photography of the fluorescent screen image was attempted in the early days of radiology, notably by Bleyer in 1896. Numerous experiments were carried out, especially in relation to cineradiography (de Abreu, 1939). With advances in output of the x-ray plants, and particularly with improvement in the quality of x-ray screens, fluorography has become a practical procedure (Dormer and Collender, 1939). Manuel de Abreu in Rio de Janeiro was responsible for many of the advances in technique (Lindberg, 1939), and in 1936 the first plant taking records on small photographic film was used in Brazil (de Abreu and Lindberg, 1939). By the beginning of 1939 twenty-five microradiographic plants were working in that country.

Since the discovery of cadets with active pulmonary tuberculosis at the Royal Military College in 1938 the medical directorate at Australian Army Headquarters has considered the possibilities of mass survey of recruits. On December 7, 1939, financial authority was received for the x-ray examination of the 6th Division, Second A.I.F. The first x-ray plant was delivered on December 23, 1939, and over 22,000 men were examined by March 1. Details of the equipment used, the procedure adopted for taking the radiographs, and an analysis of the results of this survey will be found in appendices to this paper.

The object of the survey was to detect those recruits who were suffering from active pulmonary tuberculosis. Transmission of infectious disease occurs readily in the Army because of the close contacts of men sleeping in hutments and tents (Radmilo, 1939). The removal of as many as possible of the sources of tuberculous infection would, it was hoped, reduce the incidence of pulmonary tuberculosis in the Australian Imperial Force. During 1939 pensions and medical treatment of tuberculous ex-soldiers of the First A.I.F. (1914-18) cost approximately half a million pounds. The exclusion of only some of

the infective tuberculous cases from the Second A.I.F. will almost certainly help to reduce the repatriation cost of the present war. Among the first 22,000 men of the A.I.F. 109 cases of active pulmonary tuberculosis were detected.

The normal procedure of enlistment includes a preliminary medical examination at the recruiting depot. This is followed by medical examination by a board of two medical officers at the recruit reception depot. Radiological examination takes place at this depot before the recruit is transferred to the training camp. Each recruit is informed that the first recruit medical examination is preliminary only, and that he is not to give up his usual employment until he has been examined by a medical board and his chest has been radiographed. Between 5% and 10% of men passed fit by the recruit medical examination are rejected by the medical board. Approximately 0.5% of the selected group of men passed as fit by the medical boards are found to have active tuberculosis after x-ray examination.

The Method

Every small film is examined by at least one physician and one radiologist. Usually more than two medical men are present during the viewing of films, and if anything suspicious is seen the opinion given is that of the whole group. Whenever anything abnormal is detected in the 35-mm. film a large radiograph is taken next day. No man is rejected on the small film alone. The 14 by 17 inch film is reported upon by a physician and a radiologist, and the large film, with the report, is made available to a medical board consisting of two physicians. No man is discharged from the Forces upon x-ray findings alone: in every instance in which radiological examination suggests tuberculosis a case history is recorded and the recruit's chest is re-examined by two physicians. If any sputum can be obtained it is examined for tubercle bacilli by staining and culture. In Victoria every man with a tuberculous lesion detected by x-ray examination is referred to Dr. R. Webster, who passes a small stomach tube and collects the fasting-stomach contents. These are cultured for tubercle bacilli. These bacteriological examinations have disclosed an extremely high proportion of positive results. The majority of cases of active tuberculosis detected by x-ray examination can be regarded as disseminating infection.

When the medical unfitness of the recruit is confirmed his discharge is effected and he is referred to the appropriate local State Health Authority for treatment and supervision. The x-ray report, the 35-mm. film, and the 14 by 17 inch film are filed with the recruit's medical papers in Base Records. A central referee medical board

consisting of specialists in diseases of the chest will decide whether there are grounds for compensation in any particular case.

The number of recruits examined from the Second A.I.F. (6th Division and reinforcements) up to March 1 was 22,000. Of this total 109 (0.5%) films were classified by radiologists and physicians as active pulmonary tuberculosis. In addition, 88 cases were classified as fibrosis, calcification, etc., in which the radiological appearances were not definitely those of a healed or quiescent lesion. The majority of these latter deferred cases were passed as medically fit by subsequent medical boards. Of the above 22,000 films about 9,000 were personally examined by me, and the remainder of this paper deals with the conclusions drawn from these 9,000 films.

It takes some time to become accustomed to reading the small films. Both the intensity of illumination and the character of the surface upon which the films are projected make an appreciable difference. Each radiologist has an optimal distance from the projection screen at which the image appears most like the large chest films to which he is accustomed. If one approaches too close to the screen the chest appears blurred. Some abnormalities are detected more easily at a distance of 8 to 12 feet from the projection screen, but for routine reporting a distance of 6 feet suits most of those who have seen a large number of these small films. The small films can be projected up to a size of approximately 12 by 14 inches without loss of detail. Enlargement to the usual 14 by 17 inch size to which we are accustomed in the examination of chests is not always possible.

The maximum number of 35-mm. films reported upon by a group was about 1,000 in an evening of three hours. As fatigue occurs rapidly the practice was adopted of one radiologist reporting upon not more than 70 to 100 successive chests without relief by one of the others present.

A comparison between the 35-mm. pictures and the 14 by 17 inch film demonstrates that there are factors operating in the microradiographic technique which result in variations from what is generally regarded as a normal chest radiograph. Owing to the reduced tube-screen distance and longer exposure the heart outline is blurred and relatively large. More lung tissue is seen above the clavicles, and pleural scars and apical calcifications show up more readily, in the small film than in the 14 by 17 inch film of the same individual. Vascular markings in the infraclavicular areas of the chest appear more obvious in the small films. During the examination of the first thousand 35-mm. films a large number of 14 by 17 inch films were ordered under the impression that these shadows represented fibrosis or infiltration. After subsequent comparisons with the large films it was clear that the shadows in the 35-mm. films were of vascular markings within the limits of normality. Fewer 14 by 17 inch films were needed in the later stages of the survey. Basal thickenings seemed more common than was expected, but as attention was centred on a search for pulmonary tuberculosis the presence of heavy vascular markings at the bases of the lungs was not always confirmed by large films. The outline of a lung cavity was often more clearly seen and areas of consolidation sometimes appeared larger in the 35-mm. picture than in the 14 by 17 inch film.

Difficulty was encountered in deciding whether nodules were calcified, fibrotic, or soft in outline. It might well be said that the decision should be left to the medical boards examining the recruit in addition to seeing his films. However, as the large majority of recruits in whom pulmonary tuberculosis was detected had few, if any, clinical signs of disease, a radiological opinion as to the

quiescence or activity of a lesion must influence a subsequent medical board. The function of microradiography is merely to reduce the number of large x-ray films to be taken, and therefore the decision as to activity rests upon the interpretation of the 14 by 17 inch film rather than that of the 35-mm. film. The activity of a tuberculous lesion can rarely be determined upon a small film alone.

Shadows thrown by ribs and transverse processes of the vertebrae gave rise to more difficulties than are usual with large films. In the small films the outline of the descending aorta is seen more clearly behind the heart, and the vertebral bodies can often be observed through the heart shadow. Soft-tissue shadows, particularly those thrown by the pectoral and the sternocleidomastoid muscles, caused arguments.

Survey of Results

In addition to the discovery of 49 cases of pulmonary tuberculosis many other lesions were detected in the men examined. In 9,000 chests there was one large cyst at the right base, two mediastinal neoplasms, and several aneurysms of the aorta. Two recruits with congenital polycystic disease of the lung were discovered, as well as one large solitary air-containing cyst occupying a third of the right chest. The diagnosis of non-tuberculous pneumonitis was made in several recruits. In one man an area in both the large and small films was reported by the group of radiologists as tuberculous, and the recruit was found medically unfit by a subsequent board. Two weeks later an x-ray examination showed the chest was clear. In all there were eight films in which consolidation at the base or middle zone of the lungs suggested bronchopneumonia or were labelled "pneumonitis."

The cardiac outline was regarded as abnormal in many films; several reports that the heart shadow suggested mitral or aortic valvulitis were confirmed by subsequent clinical examination. One heart was reported upon as the type found in congenital pulmonary stenosis, and examination agreed with this diagnosis. Dextrocardia was recorded twice only in 9,000 chests. Gross cardiac enlargement with pulmonary congestion was recorded in two cases. The aortic shadow was reported as abnormal in shape and density in many films, and these men were re-examined. The age recorded at the time of enlistment was often found to be false, and in a few instances abnormal blood pressures were discovered.

Pulmonary Tuberculosis

Examination of the x-ray films and medical records of the 49 cases of pulmonary tuberculosis demonstrates the limitations inherent in the usual methods of clinical examination of the chest. While admitting all the difficulties of hurried examination in a noisy drill hall at the time of the recruit medical examination, and taking full account of the disabilities under which the medical boards worked in the camps, it is still rather disconcerting when x-ray examination discovers large areas of consolidation and extensive cavitation. Still more disturbing is the fact that even when the medical boards were aware of the area of lung involved no physical signs could be detected in many of the men examined. It is customary to teach students that they are not to rely on the x-ray film for diagnosis, yet here we have discovered over 30 cases of tuberculosis, many with sputum or stomach contents containing tubercle bacilli, in which there are neither clinical symptoms nor physical signs of disease.

The medical records of the cases examined after a diagnosis of tuberculosis had been made by the radiologist reveal a few interesting facts. Many of the men found to have pulmonary tuberculosis were under weight

at the time of enlistment, and practically every one of the men lost weight during his period of training under camp conditions. It is usual for healthy recruits to lose weight during the first week or so in camp, but the weight rapidly returns and almost invariably exceeds the pre-enlistment level within six weeks of entering camp. If a man continues to lose weight after the first two or three weeks he probably has some physical or psychological abnormality.

The following cases are quoted as illustrating the value of routine radiography.

One man serving in a medical unit was passed as "Fit, Class I," at two medical examinations. X-ray examination showed extensive chronic tuberculosis with large cavities in both lungs. The sputum contained tubercle bacilli. On being challenged he admitted that he had been under treatment for tuberculosis for the past three years.

Examination of the medical records of another recruit showed he had signed a form stating that he had never had "pleurisy" or "spitting of blood." At two medical examinations he was passed "Fit, Class I." X-ray examination revealed extensive areas of infiltration with fluffy outline in the left upper lobe and numerous calcified areas in the upper half of the right lung. A subsequent medical board obtained a history of recurrent pleurisy for the past four years and of cough with blood-stained sputum for one year. The only physical signs detected were a slight hollowing beneath the left clavicle with diminution of intensity of breath sounds. His sputum contained acid-fast bacilli.

A lesion at the left apex was detected by x-ray examination of a recruit in whom no physical signs were discovered at three different medical examinations. The radiological evidence was so definite, however, that the final medical board classified him as unfit. After his discharge from the Forces this man admitted that he had been coughing up blood for three weeks, although he had informed the medical officers on three separate occasions that he had no symptoms and had signed two forms stating that he had never suffered from "spitting of blood."

Nine thousand chest films were personally examined and forty-nine of these were classified as showing "active tuberculosis." Definite cavities were seen in fifteen films, the incidence of cavitation being 30% of the 49 cases of tuberculosis, or 0.17% of the total chests examined. Some of the cavities were quite large, and in some instances cavities were present in both lung fields. Tubercle bacilli have so far been discovered in the sputum or stomach contents collected from 5 of the 15 men in whom x-ray examination revealed cavitation. No physical signs could be detected in 6 of this group of 15, even when the area of the chest involved was known to the examining physicians. In addition to the above 15 recruits with cavitation, 34 chest films showed opacities which were classified as tuberculous parenchymatous lesions of the lung field. Medical boards have subsequently confirmed the diagnosis of active pulmonary tuberculosis in all but one of this group. Direct questioning of the recruits making up the group often disclosed a history of cough, sputum, haemoptysis, or pleural pain.

Besides the above 49 recruits with tuberculous consolidation and cavity there were 22 in whom radiological examination of the chest showed definite lung fibrosis. Thirteen of these were clearly old quiescent lesions, but in 9 there was some doubt as to the degree of activity.

Forty-three of the 9,000 chests examined showed areas of calcification in the lung field that suggested old healed tuberculous infection of the so-called "adult" type. In 14 out of these 43 cases the radiologists referred the recruit to a medical board as the x-ray appearances were not definitely those of quiescent tuberculosis.

In the total of 9,000 chests examined there was evidence of "secondary" "adult" type pulmonary tuberculosis in

120 cases, the incidence of tuberculous infection thus amounting to 1.33% in a selected group of adults. Of this total 49 were regarded as showing radiological evidence of active pulmonary tuberculosis, and 29 had sufficient radiological evidence of activity to justify further examination by a board of two physicians. Of these 29 deferred cases few were regarded by the subsequent medical boards as showing clinical signs of active pulmonary tuberculosis. Thus in a total of 9,000 men examined by microradiography the incidence of active pulmonary tuberculosis was 0.55%.

The Future

The x-ray examination of recruits in Australia is now to be extended to the Permanent Military Forces and the Garrison Battalions. The Royal Australian Air Force has adopted a similar routine procedure. Every member of the Forces will be re-radiographed on his return from abroad. This record will be obtained even if the soldier has not had symptoms of chest disease while on service. A comparison of these post-war films with those taken on enlistment will not only form a basis for a clinical investigation but may make the task of pension authorities a little less arduous.

Extension of routine radiography of the chest to the civilian population is the next step. The removal of a large proportion of the infective members of the tuberculous population can be confidently expected. A mass survey of the whole population is a practical proposition using the modern method of microradiography (Potter, 1940).

This paper must close upon a note of caution. There has been much criticism of the microradiographic method of diagnosis of tuberculosis. An ancient Chinese proverb states that "a gem cannot be polished without friction, nor a method perfected without adversity." It is not the opposition which is to be feared in the future of microradiography; a greater danger is that of the too ardent advocate.

Enthusiasm for a relatively cheap method of detection of tuberculosis must not be allowed to outstrip caution. With our present technique microradiography can only be regarded as an adjunct to radiography by the well-tried methods of large x-ray films. No one should be labelled tuberculous on the unsupported evidence of a 35-mm. film.

This paper is the result of the work of many willing helpers. To the radiologists, the physicians, and x-ray technicians who assisted one can only say that the survey would not have been possible without their loyal co-operation. To Dr. Cecil Eddy, who in addition to preparing Appendix I gave invaluable assistance in the early stages; to Captain E. R. Crisp, who wrote Appendix II and was responsible for the organization of much of the survey; and to Drs. H. Wunderly and J. O'Sullivan, my thanks are particularly due for assistance freely given.

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APPENDIX I

Equipment for Miniature Radiography

The equipment chosen comprised a high-tension unit by Stanford X-Ray Pty. Ltd. delivering 100 mA at 85 kV and 60 mA at 100 kV, connected by shock-proof cables to a shock-proof 10-kV Eureka self-protected x-ray tube. The tube was mounted on a counterweighted tube stand, the central ray being directed to the centre of the fluorescent screen. The camera unit, also mounted on a counterweighted rigid stand, consisted of a light-tight pyramid-

shaped metal box 30 inches long, closed at the base with a 17 by 13 inch Levy West fluorescent screen. At the other end was fitted a Leica camera, with an F/1.5 lens and auxiliary front lens to permit focusing at 30 inches. The camera was mounted with the lens protruding through a brass plate half an inch thick, which prevented fogging of the spooled film; no evidence was obtained of x rays having penetrated the lens system. The tube and camera unit were connected by an interlocking bar, fixing the focal screen distance of 3 feet; adjustment of the screen to the patient's height automatically adjusted the tube height. All direct radiographs required as a result of the inspection of the miniature radiographs were taken with the same x-ray tube and a vertical cassette holder.

The camera was provided with a special fitting to hold the shutter open immediately each exposure on the film was wound on, 36-exposure film in daylight-loading spools being used. The exposure was controlled by the x-ray timer: there is evidence that a certain amount of "afterglow" in the screen augments the photographic image without causing any difficulty with the next exposure.

With screen photography higher voltages than are possible with direct radiography can be used without producing over-penetration. Using a focal screen distance of 3 feet, 85 kV, 100 mA, a photograph of satisfactory density can be obtained of an average-sized chest with an exposure of approximately 0.2 second. (During the survey, difficulties experienced with electrical supply conditions made it necessary to increase the exposure time for men with large chests.) Although Ilford H.P.2 film was used at first, it was found that the grain size of the faster Kodak Super XX (32 Scheiner) introduced no difficulties. It is necessary to use a fine-grain developer and to develop out as far as possible.

APPENDIX II

Procedure Employed for Miniature Radiography of Chests of Recruits in Camp

Recruits from the units are paraded at times arranged: (i) in single file, graded in height; (ii) stripped to the waist, without hats and with clothes left in the ranks (carrying any articles of clothing definitely slows the procedure); (iii) pay-books in hand. Space is essential to permit a steady forward movement and to provide ventilation—a necessity when dealing with 1,500 daily. X-ray record sheets were prepared beforehand containing columns for (1) Spool No.; (2) Serial No.; (3) Name and Initials; (4) Regimental No.; (5) Rank; (6) Unit; (7) Remarks. The last-mentioned was used for the reports on the small films. A sheet corresponds with one spool, and so has thirty-six spaces on it.

Each man presents his pay-book, and one orderly reads out required facts to a clerk. The recruit is given a small ticket bearing a number corresponding to his serial number on the sheet, and his pay-book is stamped. The ticket-books are made with every thirty-sixth page in red. The red ticket is handed out in turn and is marked "End of Spool No. —," the number being the spool on the sheet just finished. The red ticket signifies "end of spool" to the staff in the second room, and its number is a check on the next spool number to be placed on the camera unit.

The man proceeds to the x-ray room, where his progress is regulated by another orderly, who also checks the ticket numbers and makes sure the men are in their correct order. The recruit then passes before two orderlies seated at a table, where are prepared strip metallic figures on adhesive strapping, the numbers corresponding with the serial number on the record sheets and in addition the recruit's regimental number. A technician takes the man's ticket, checks it against the prepared number, and if correct the adhesive number and the man are ready to follow on to the camera unit.

Each man is told to watch the man in front and do what he does; it is arranged that he has the opportunity of seeing three people radiographed before being done himself. Each man is placed in position by a sergeant-technician, and an exposure made with the chest in full inspiration. As the recruit leaves the hut an N.C.O. from his unit marks a nominal roll. The adhesive numbers are placed on the top left-hand corner of the screen unit, the spool number in the

right-hand corner. The camera unit and tube are adjusted to the height of each man—a movement greatly facilitated by accurate grading and height. After each exposure the camera film is moved on and the shutter reopened by the special attachment.

The importance of adequate protection of personnel must be stressed, for the scattered radiation is very great when doing large series of men in a short time. Heavy lead screens are used, and the staff have blood examinations at frequent intervals.

APPENDIX III

Recruits examined by microradiography	9,000
No. of 14 by 17 inch films ordered	541 (6%)
No. of microradiographs showing evidence of hilar calcification suggestive of a healed primary tuberculous infection	4,830 (54%)
No. of films showing evidence in lung fields of past or present tuberculous infection of the secondary adult type of tuberculosis	120 (1.33%)
No. of recruits showing radiological evidence of active pulmonary tuberculosis	49 (0.55%)
No. of recruits showing fibrotic or calcified areas in lung fields in which the radiological appearances, while suggestive of a quiescent lesion, were not definitely those of a non-active tuberculous lesion	29 (0.3%)
No. of men showing fibrotic or calcified areas in the lung fields suggesting a healed or quiescent lesion	43 (0.47%)
No. of films showing cavities in the lung fields	15 (0.17%)
No. of recruits in whom radiological examination suggested tuberculosis of the lungs, and of whom subsequent examination of the sputum and stomach contents showed tubercle bacilli in smear or culture	16 (0.18%)

SERUM AND PLASMA IN TREATMENT OF HAEMORRHAGE IN EXPERIMENTAL ANIMALS

BY

J. W. MAGLADERY, M.D.Toronto, D.Phil.Oxon.

Research Associate in Physiology, University of Toronto

D. Y. SOLANDT, M.D.Toronto, Ph.D.Lond.

Associate Professor of Physiology, University of Toronto

AND

C. H. BEST, M.D.Toronto, D.Sc.Lond., F.R.S.

Professor of Physiology, University of Toronto

(From the Departments of Physiology and Physiological Hygiene, University of Toronto)

The stability of serum or plasma, and the growing body of evidence that pooled samples of them can be safely used in human patients of any blood type, prompted us to reinvestigate the extent to which these fluids could replace whole blood in the treatment of animals suffering from acute haemorrhage.

Although Rous and Wilson (1918) had stressed the importance of the fluid in contrast to the cellular elements in the treatment of haemorrhage, whole-blood transfusions have until recently been considered the only satisfactory treatment for blood loss. Bond and Wright (1938), however, reported the successful use of "lyophilized" serum in the treatment of haemorrhage in experimental animals, but the conditions of these trials were not described in detail. Since we began our experiments Levinson, Neuwelt, and Necheles (1940) and Strumia, Wagner, and Monaghan (1940) have published interesting papers bearing on this subject. Strumia and his co-workers report the successful treatment, with relatively small doses of plasma, of patients suffering from surgical shock and haemorrhage. Levinson *et al.* adopted the experimental method of Blalock (Johnson and Blalock, 1931) and subjected dogs to repeated bleedings. The efficacy of the replacement therapy was gauged by the time of survival of the animals. These