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MASS RADIOGRAPHY

WITH SPECIAL REFERENCE TO SCREEN PHOTOGRAPHY AND PULMONARY TUBERCULOSIS

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Mass radiography may be carried out in different ways. Many such investigations directed towards the discovery of pulmonary tuberculosis have been conducted in the past on large selected groups of population by ordinary x-ray methods. The work of Opie,⁵⁷ Hetherington,³⁵ Rathbone,⁶¹ and Wakefield⁸⁶ in the United States is well known in this connexion. Wingfield,⁸⁷ and more recently D'Arcy Hart and Morland,²⁵ have undertaken work on similar lines in this country. Mass use of the full-size x-ray film must necessarily have limited application on grounds chiefly of expense, and the fluorescent screen alone has accordingly found favour with many workers, particularly in France. The greatest drawback to screening alone is the absence of any record. In America a method of mass radiography by means of a paper roll cassette has been invented, and this has been further elaborated in Germany, chiefly by Heisig³³ and Schmitt-Grandhomme.⁷⁷ The paper is relatively inexpensive, and a full-sized record which is nearly equivalent in detail to a celluloid film is obtained. The disadvantage of mass investigations is the extent of paper required. This would quickly reach enormous proportions and make developing and storing a matter of almost insuperable difficulty. In the desire to undertake mass radiography without the associated difficulties of expense, lack of record, and time involved, the method of photographing the fluorescent image has been the subject of much experiment.

From the earliest days of x-ray investigation such attempts have been made. Janker⁴³ refers to two Italian workers who proposed screen photography a few weeks after Roentgen's discovery, and Bleyer¹⁹ had actually made the attempt within six months. At the same time McIntyre³² was making similar investigations in this country. The results were disappointing, and Porcher⁶³

eventually abandoned the method as impracticable. Further work was undertaken by Köhler,⁴⁷ Caldwell,²³ Lomon and Comandon,⁵¹ and others, but without success. Russell Reynolds,⁶⁵⁻⁷⁰ working on cineradiography from 1921, was eventually successful in 1934, but it remained for de Abreu to work out the problem of the still fluorograph that provided sufficient definition. It was obvious that success would not be achieved without screens of greater luminescence, more sensitive films, and lenses of greater aperture.

De Abreu¹⁻¹² started to tackle the problem in 1918 and again in 1924, but met with failure. He did not abandon his attempts, and, collaborating with Siemens, he was able, with the technical improvements that had come about, to carry out his first thoracic survey with "collective fluorography" in Rio de Janeiro in 1936. The results for the first time proved to be satisfactory. The method of screen photography was thereby established for mass investigations. Improvements in detail have been carried out subsequently by Holfelder³⁷ and Janker.⁴⁴ By 1939 de Abreu had no fewer than twenty-five complete units working in Brazil, and the method had been put into extensive use in Germany, as is noted from the discussion at the annual congress of the German Roentgen Society in 1939.³¹

Description of Apparatus

The accompanying photograph (reproduced by courtesy of General Radiological Ltd.) illustrates the essential principles of the apparatus used by de Abreu and by Holfelder. The set is seen to consist of an easily adjustable screening stand, the fluorescent screen being coupled by means of a lead-lined pyramid-shaped cone with a miniature camera situated in the apex. The screen-camera unit is further coupled with the x-ray tube so that camera, screen, and tube all move together in the vertical direction. The camera is designed to take 35-mm. film

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of forty to forty-five exposures. It is fully protected against x rays and is easily interchangeable or removable for loading. A counter system is provided to indicate the number of exposures taken on the roll. An electrical interlocking device prevents two photographs being taken on the same film. The camera has a special lens of large aperture, and this is focused on the highly luminous fluorescent screen, measuring 14 by 14 inches, with the interposition of a micro-grid. A 10-kW tube is used. The lens-screen distance is 85 cm.; the x-ray tube-screen distance is 80 cm. The radiographer is seen inserting a card with the index number and name of the patient. These details are optically recorded on the exposed film. The lever movement involved in the insertion of this card also operates the film transport. The radiographer is responsible also for the position of the patient and the adjustment of the screen. The exposure is made either by operating the main switch on the switch table or by means of a remote control switch from the examination stand. The average exposure is 72 kV peak and 80 mA,

Apparatus for screen photography.

time 0.3 second. The milliampere-seconds product is kept constant, whilst the kilovoltage is altered according to the depth of chest. The completed miniature radiographs are projected by means of a suitable projector and enlarged up to the normal x-ray-film size on a white screen.

The films can be stored in completed rolls or they may be cut into short strips and arranged between cellophane in books. Large numbers of chest radiographs can thus be stored in a small space. The great importance of such documented fluoroscopy in dealing with large numbers of cases is obvious. In viewing the films the immediate object is to pick out the abnormalities and not to attempt to arrive at a diagnosis on the spot. All patients with suspect films should be sent for and investigated again as completely as may be necessary, by clinical as well as by ordinary radiological methods. The final diagnosis in any case should only be arrived at by a physician who has had careful regard to the individual patient; and in considering pulmonary tuberculosis it is to be hoped that the mere finding of a dubious pulmonary shadow would not, without supporting evidence, condemn the patient at once to the process of notification and sanatorium treatment.

As to cost, Thomas⁵² recently stated that a satisfactory installation could be bought for about £650, and that while the cost of films for radiographing 1,000 chests

by ordinary means would be £100 this would be reduced to about £2 8s. by using screen photography with 35-mm. film. It is thought that the average price of a complete machine to-day is in the region of £1,000, and most radiological firms are now producing screen-camera units. It should be noted here—it is also referred to later—that, particularly if rapid work is to be undertaken, the number of clerical and other assistants needed is considerable, and this wage bill must be taken into account. A word of warning is thought advisable with regard to the necessity for standardization of technique. Disappointment and confusion are likely to be the result if an attempt is made to photograph the screen image without a full knowledge of all the detailed requirements. With a screen-camera x-ray unit built with the knowledge and experience already accumulated there should be no difficulty. But it should not be thought that the only requirements are a first-class camera, a tolerably good x-ray set, and a lot of enthusiasm. Shanks⁵⁰ has drawn due attention to this aspect and has made a strong plea for standardization and unified control.

Results of Mass Investigations

It is of interest to consider the extent to which tuberculosis has been brought to light by mass radiography. In England Wingfield, using a portable x-ray apparatus, examined over 2,000 secondary-school children and adolescents at work and ascertained that between 0.65 per cent. and 1.08 per cent. showed important lung lesions, the former figure relating to very definite pathological changes indicating tuberculous lesions of adult type. Wingfield thought that a definite proportion of adult clinical cases must be the end-results of latent adolescent disease such as he discovered. D'Arcy Hart and Morland, using full-sized celluloid films in photographing medical students at University College Hospital, have demonstrated that 6 per cent. out of 400 showed important lesions in the chest, and about one-third of the 6 per cent. were advised sanatorium treatment. Dormer and Collender^{26 27} and Robinson Thomas have described methods of screen photography but show no statistics of results. Shanks is a strong advocate of screen photography at the present time in all recruits for the fighting Services.

NORTH AND SOUTH AMERICA

In the United States of America, according to Wingfield, Hetherington and McPhedran found practically 4 per cent. of lesions of adult type in the lungs of university students. Wingfield also quotes Soper and Wilson⁵¹ as finding about 2 per cent. in similar investigations. Latterly screen photography has been introduced, and Lindberg⁵⁰ and Hirsch⁵⁶ have used the method with success.

De Abreu's enthusiasm has led to considerable use of screen photography in South America, the method being adopted in Uruguay and Argentina in addition to Brazil. Barreto,¹³ Cabello Campos,²² Coelho,²⁴ Mazzei,⁵⁵ de Paula,⁵⁸⁻⁶⁰ and de Paula and Benedetti^{61 62} are all enthusiastic. De Abreu's full statistics will be studied with great interest when available; meanwhile he has published his first investigations, mentioning 14,000 cases, out of which he found 3.78 per cent. to be tuberculous. A further series of over 10,000 persons occupied in the food trade revealed 3.4 per cent. of tuberculosis cases. Following de Abreu's work legislation has been introduced in Brazil making it compulsory for every entrant into the food trade to undergo screen photography of the chest, and further legislation is contemplated to

make this investigation obligatory in domestics, teachers, hairdressers, school children, pregnant women, soldiers, sailors, and members of sports clubs.

FRANCE AND BELGIUM

In France fluoroscopy has been the most commonly used method, and out of 25,000 candidates for employment in the French State railways more than 1 per cent. were discarded as a result of the radiological finding after being passed as sound by physical examination.¹⁸ Jalet¹² relates his experiences with routine screening in the North African Army (Algeria) since 1935. The examination takes place not among the recruits but only when, after two preliminary medical inspections, they have become young soldiers living in or near barracks. The point is important when considering the application of similar methods in England. Carrying out between sixty and one hundred screenings an hour, Jalet examined 19,000 soldiers, about one-quarter of whom were French, the remainder natives. He found that 4.6 per cent. either had definite lesions or were suspect. As a result approximately 1 per cent. of the French soldiers were discharged on grounds of tuberculosis, and of these 0.12 per cent. were discovered to have a positive sputum. Similar discoveries in England would have happier results than in Algeria, where Jalet deplors the lack of facilities for treatment, as the result of which the public health service has given up the attempt to follow up cases referred by the military authorities. Fournié and Frezouls^{28, 29} introduced screen photography into the French Army, while Jullien, Sieur, and Dutrey⁴⁵ have made extensive use of routine fluoroscopy in French soldiers since 1926. They report results of over 200,000 examinations, giving much interesting detail and subdivision. It is sufficient here to refer to the largest tabulation, which deals with 145,213 young soldiers at the time of incorporation, as a result of which 265 (0.18 per cent.) were found to have pulmonary tuberculosis with positive sputum. The importance of such discovery of hitherto unsuspected disease needs no emphasis. Ronneaux and others⁷¹⁻⁷⁵ have done much work with screen photography in Paris and advocate the method, as do also Maingot⁵⁴ and Saye and Caubarrère.⁷⁶

Toussaint,⁸³ after considerable experience with routine screening, now advocates screen photography in the Belgian Army, as in his view no fewer than 1 per cent. of soldiers developed pulmonary tuberculosis during service. Toussaint quotes Franz and Mueller as having a similar experience of tuberculosis morbidity in the German Army.

GERMANY

In Germany Holfelder and Berner,⁴⁰ using screen photography, examined over 10,000 men at Nuremberg in 1938 at the rate of 300 to 400 an hour (2,000 to 2,500 a day). They stress the necessity for a well-trained staff, which should consist of ten men for each screen-camera unit, in addition to clerks; the inspection of films needs four more men and two doctors. Holfelder claims that, after an experience of viewing 1,000 films to become accustomed to the method, it is possible to examine 500 films an hour effectively. Berner¹⁸ included these original cases in a further communication which gives results of over 55,000 examinations comprising about 32,000 military men, the rest being mainly industrial workers. Many of the soldiers were picked men, already examined and screened and under supervision in barracks, yet even these yielded their quota of cases with definite cavitation. The summary of Berner's findings is worth giving in full.

Total number examined		55,666
Negative findings		88.79%
Transitory conditions and artefacts		0.22%
Calcified foci		2.82%
Unhealed and recent tuberculosis		1.36%
Tuberculosis with cavities		0.15%
Cardiac abnormalities		2.27%
Aortic abnormalities		0.56%
Various findings (thickened pleura, azygos lobe, dextrocardia, skeletal abnormalities)		1.93%
Lung tumours		0.005%
Technically spoiled films		1.90%

It will be seen that 1.5 per cent. of cases showed x-ray evidence of active pulmonary tuberculosis, while nearly twice as many pointed to heart conditions needing further investigation. Holfelder states with regard to the 10,000 men investigated at Nuremberg that all the abnormalities found at screen photography were examined clinically and by full-sized radiography by an independent worker, whose findings "completely coincided" with his own.

Holfelder and Berner have recently published⁴¹ an atlas of screen photography based on an experience of over 900,000 examinations. These examinations include the entire population of the province of Mecklenburg (over 650,000 persons), and this part of the work was carried out in four months. It is stated that the statistics will not be available for some considerable time.

Schulz,⁷⁹ an army doctor, advises caution with regard to speed of operation in screen photography. Schulz considers, despite Holfelder, that anything over 300 pictures an hour cannot be obtained satisfactorily. He investigated the Condor Legion on its return from Spain, examining 4,300 men in one and a half working days—that is, thirteen hours—an average of 330 an hour. He managed this with sixteen assistants, but does not think it feasible as a routine to undertake more than 200 an hour. The difficulties at greater speed include vibration of the tube, incorrect adjustment of the screen, patient still breathing, etc. Böhme,²⁰ Griesbach,³² Ulrici,⁸⁵ Cramer,³¹ and Knothe⁴⁶ have all used screen photography, and speak favourably of the method. Franke,³⁰ Schorr and Willbold,⁷⁸ and Schopper³¹ have all carried out improvements in technique. Bräuning²¹ is also impressed with screen photography, but points out that the method is not infallible, as in his experience occasional slight cases of proved pulmonary tuberculosis fail to be demonstrated.

Practicability of Screen Photography

It seems clear that mass radiography yields immensely important findings and that by means of screen photography the method has now come within the range of practical politics. Findings will differ according to the group examined, place, age, sex, and social status, but a method that is practicable and can pick out approximately 100 hitherto unsuspected cases of tuberculosis, about ten of which are likely to show actual cavities, from every 10,000 persons examined can surely be made the basis of a great new step forward in the anti-tuberculosis campaign. Other abnormal conditions in the chest will be found at the same time, and will enhance the value of the investigations, but considerations of tuberculosis are paramount.

Experienced tuberculosis workers have long deplored the lack of early cases of disease. The proportion of adult pulmonary patients treated by the L.C.C. who are early sputum-positive cases or those in which bacilli have not been demonstrated (A+B1 groups) is still only 20 per cent. Approximately four out of every five patients are still moderately or hopelessly advanced (B2 and B3 groups) when first coming under treatment. The ultimate result of treatment in this latter group is naturally disappointing: of those who were discharged from residen-

tial treatment during 1931 only one-third survived five years. If we can get our cases earlier the results obviously will be better; 77.3 per cent. of the patients falling into the earlier groups—that is, A and B1—in 1931 being alive five years later.⁴⁹ Screen photography should prove of great help in a renewed search for favourable cases.

Screen Photography and the Armed Forces

Considerable prominence was given last year⁴⁸ to the death of a militiaman from pulmonary tuberculosis after having been placed in Grade 1 by a medical board. One of us (F. J. B.) recently made arrangements for further residential treatment for thirteen ex-sanatorium patients who had just been discharged from the armed Forces on account of tuberculosis. Some of these were gross positive-sputum cases before enlistment. Such patients must have withheld vital information and consequently, one assumes, will not receive pensions. But if such florid cases can leak through into the armed Forces one wonders how many cases of slight hitherto unsuspected disease are being similarly admitted. In many ways this is much the most serious aspect of the problem. Many of these unknown sufferers will inevitably break down with frank disease under service conditions, and the State may be called upon to pay millions in pensions, as in connexion with the 1914–18 war. There is also the question of infection. This problem of tuberculosis pensioners cannot be put aside. In the last war, according to Sir Arthur MacNalty, the number of men invalided out of the Services on account of tuberculosis attributable to or aggravated by conditions of service amounted to approximately 35,000.⁵³ During 1920 more than 3,000 ex-service pensioners for tuberculosis contracted during the war of 1914–18 were admitted to residential treatment under the London scheme alone, and it was not till 1925 that the number of yearly admissions fell below the 1,000 mark. That the effect of contracting tuberculosis during war service is a prolonged social and economic problem can be seen from the 1937 report of the L.C.C., in which it is noted that there were still seventy ex-service tuberculosis pensioners for whom residential treatment had to be arranged during the year.

It is not suggested that screen photography will abolish tuberculosis from the Services, but it would eliminate a sensible proportion of tuberculosis subjects who should not be allowed to serve. It is thought the saving in pensions alone would more than outweigh the cost of the investigation. The administrative problems concerned in the possible application of screen photography now to the armed Forces can only be considered properly by the appropriate authorities. The great difficulties of organization in time of war with everything pressing for attention at the same moment can only be appreciated fully by those with a large administrative experience. It is suggested for consideration that if advance is to be made on these lines the difficulties may be less if the examination is carried out as soon as possible *after* enlistment than if it is attempted before or in conjunction with examination by the medical boards. As the search is for early disease there will be found a great many shadows which need careful watching before a definite decision can be reached as to their significance. It is doubtful if, in addition to difficulties of sheer arrangement, sufficient control could in many instances be kept over the suspect to enable satisfactory assessment to be carried out before enlistment. Apart from the Army, it is understood that the method is to be used in the Navy. Numbers here are smaller, fewer centres are concerned, and consequently organization is less of a problem.

Application to the Community in Peacetime

It seems clear that by the time peace is restored much practical experience in screen photography is likely to have been gained in this country. The application of the method then may well have a striking effect in medical science, from both a diagnostic and a research point of view.

In due course other systems will doubtless come under survey, but the obvious immediate use of screen photography will be in diseases of the chest, and particularly in pulmonary tuberculosis. The theoretical ideal is to take a picture of the screen image of the chest in every member of the community and to repeat this annually. Even with screen photography, however, this task would prove too immense; nor can it be said to be essential so far as tuberculosis is concerned. The spearhead of the attack should be directed towards the still awful toll that tuberculosis takes among young adults, in whom it remains the captain of the men of death.

Figures have already been given which show that the great majority of cases of pulmonary tuberculosis dealt with by public medical schemes are moderately or hopelessly advanced when first coming under treatment and that the results of such treatment are in consequence disappointing. In this connexion an authoritative statement⁵⁶ has recently deplored the fact that a greater number of cases are not diagnosed in the earlier stages of the disease. This is thought to be due probably to a continued reluctance of those suffering from the disease in its early stages to seek medical advice in good time. It has always been difficult to persuade even contacts to attend dispensaries. The reluctance of young adults who are not contacts and are not obviously ill is greater still. The apparently healthy do not like going to doctors, hospitals, or dispensaries, and it will need much careful thought, organization, and propaganda to obtain a fair trial for screen photography in peacetime. It has already been suggested that compulsion to undergo screen photography should be introduced.⁵⁴ We are absolutely against this. Compulsion is alien to the traditions of this country. It should be unnecessary during times of peace in matters of this nature.

In the past, mass radiography of school children in London has been opposed.¹⁴ Screen photography would seem to bring the subject more into the realm of practical effort. It is still considered that, so far as tuberculosis requiring treatment is concerned, the findings would be slight even with school-leavers; nevertheless it would obviously be a good plan if it were possible to put all children leaving school before the screen camera and try to re-examine them annually till, say, 30 years of age. This should be the main plan towards which future work should be directed.

To begin with, centres would be started in densely populated areas. At these centres school-leavers would have to pass through the screen camera. Year by year they would be invited to come again, and in the early years all young adults who cared to present themselves should be accepted with the least possible formality. No medical recommendation should be required, but the name of each individual's doctor would be noted and all radiological suspects would be referred to him. Where tuberculosis is suspect the suggestion would be made that the local tuberculosis officer should be consulted. The suspect would be followed up to make sure that he had attended for further investigation. The others would be invited to attend again at, normally, yearly

intervals. Young adult contacts of positive-sputum cases of tuberculosis would be invited to attend for re-examination every six or even three months. Attendance of such contacts could easily be linked up with dispensary supervision. It is quite impossible without some such help as this for the present dispensary organizations to examine and re-examine annually the total number of people in close contact with all known cases of the disease. In London alone this problem is immense. Here there are approximately 10,000 positive-sputum cases on the dispensary registers, and it is thought that if all house contacts of all notified cases in London were followed with yearly examinations for five years approximately 60,000 examinations annually would have to be undertaken.¹⁵ Tuberculosis officers would, it is thought, welcome the new method as a valuable help in their work, providing all lung suspects were referred to them without delay.

This help in the more complete supervision of contacts than has been possible hitherto is considered important, as in the age group 16-30 no fewer than 21 per cent. of new male positive-sputum cases and 24 per cent. of similar female cases arise from families in which there has been a recent previously known case of the disease.¹⁶ It is an important public health measure, therefore, to supervise contacts over a considerable period of time, especially—having regard to the frequency of the disease at this period of life—young adult contacts of living positive-sputum cases or of those recently dead from the disease.

Another suggestion is that all young people recovering from "influenza" or "debility," or who have frequent "colds" or persistent coughs, should be encouraged by their doctors to undergo screen photography if it is not thought that their cases are of sufficient import to merit direct reference to the tuberculosis officer. Screen photography following such conditions would yield a fair crop of early cases of pulmonary tuberculosis.

Investigation of Special Occupational Groups

Considerations of research would no doubt indicate from time to time other special groups of the population for investigation. Campaigns could be carried out to investigate particularly susceptible occupational groups. For instance, in London, out of 682 cases of pulmonary tuberculosis in single girls between the ages of 15 and 25 it was found that 50 per cent. were occupied as clerks, domestics, dressmakers, or shop assistants.¹⁷ These groups should well repay routine investigation by screen photography. Investigations might also be conducted on an occupational basis by examining all employees in particular factories or other commercial organizations, and some large employers of labour might find it well worth while to undertake screen photography of all new workers. Philips of Eindhoven already do this. This aspect of the matter would have to be approached in England with great caution, as the means of livelihood of the individual may immediately be called into question, and there would have to be suitable safeguards for adequate treatment (if necessary) and subsequent reinstatement, or rehabilitation elsewhere.

Those who favour the method of screen photography as a possible means of x-raying very widely, at slight cost, in order to separate the abnormals quickly will have their own conception as to the proper direction of future work. Enough has been said, it is hoped, to indicate that the scope is wide and the possibilities fascinating.

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