MINISTRY OF HEALTH
DEPARTMENT OF HEALTH FOR SCOTLAND

RADIOLOGICAL HAZARDS TO PATIENTS

Interim Report of the Committee

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COMMITTEE ON RADIOLOGICAL HAZARDS TO PATIENTS

INTERIM REPORT

I. INTRODUCTION

Constitution and Terms of Reference

1. The Committee was appointed by the Secretary of State for Scotland and the Minister of Health at the end of 1956, with terms of reference " To review the present practice in diagnostic radiology and the use of radiotherapy in non-malignant conditions, having regard to the report of the Committee on the Hazards to Man of Nuclear and Allied Radiations[1], and to make recommendations ". A list of members is given in Appendix I. The Committee first met on 10th January, 1957.

Present State of Knowledge

2. It has been known for more than 50 years that living cells may be damaged by ionizing radiation, and that excessive exposure may cause serious injury to man. In recent years attention has been drawn to two less obvious hazards which may perhaps be produced by relatively low levels of radiation dosage. Experimental work has shown that ionizing radiations can induce mutations in reproductive cells and so cause genetic damage to future generations in the species studied. In mankind such damage could lead to a variety of inherited defects.

3. Secondly there is a problem concerning the individual—the somatic hazard—which is mainly the risk of leukaemia arising from exposure of the bone marrow to ionizing radiations. It is known that this disease can result from very heavy exposure. It is not known for certain whether it ever follows slight exposure or whether there may not be some threshold of appreciable size which must be reached before any risk arises.

4. The report of the Medical Research Council on the Hazards to Man of Nuclear and Allied Radiations[1] described the sources of ionizing radiations to which the human race is subjected, and assessed the contribution made by each source to the total radiation to which the population of this country is exposed. It found that of all the man-made sources, medical and dental radiology contributed much more than any other. The calculation of this contribution had to be based on a relatively small amount of data but subsequently both the report of the United Nations Scientific Committee on the Effects of Atomic Radiation[2(a)], and the statement on this report by the Medical Research Council[3] confirmed this finding.

Work of the Committee

5. The Committee has set itself a twofold task: (*a*) We have undertaken a nation-wide survey of radiological procedures in order to estimate the present level of radiation to which the population is exposed. (*b*) At the same time we are considering the particular diagnostic and therapeutic procedures in present use, with the object of eliminating all unnecessary irradiation of the gonads and of the body generally. For this purpose we have set up eight specialist panels, a list of which is given in Appendix I.

6. Under (*a*) we have surveyed during a selected week the numbers and types of X-ray examinations, the number of films used and the apparatus available in all hospitals, chest clinics, dental surgeries and other institutions in Great Britain. A second census taken at a different time of the year was made on a random selection of a quarter of the National Health Service hospitals and chest clinics. This section of the work which provides part of the basis for assessing the radiation dose is now completed. At the same time measurements have been made of the dose received by patients under the varied circumstances of different types of radiological examination. These measurements comprise some 5,000 examinations in 140 hospitals and chest clinics chosen to give a representative selection of radiological work throughout all the 19 hospital regions of Great Britain. Because each examination on the average requires 3 X-ray exposures, some 15,000 measurements have been made by hospital physicists all over the country. There remains the very considerable task of computation before the final population dose can be derived and before relationships between dose and technique can be studied. A separate investigation is being carried out, including a three months' survey, to estimate the contribution from radiotherapeutic procedures.

7. The results of surveys of this magnitude were not available to the Medical Research Council's Committee when making their report in 1956. The plan on which our surveys are being made follows recommendations laid down by the International Commissions on Radiological Protection and on Radiological Units and Measurements[4] and a technical account of this plan has already been published under the auspices of the Committee[5].

8. The tasks outlined in paragraph 5 (*a*) and (*b*) are not yet completed but our work has been brought to a conclusion for one particular part of the total field of review, namely the use of X-rays for mass miniature radiography. Detailed investigations of this form of diagnostic radiology have given us new data on the amount of exposure involved and we have completed a review of the subject in the light of these figures.

9. The Committee considered it advisable to produce an interim report without waiting until investigations over the whole field are completed. We do so because the hazards of ionizing radiation have been widely publicized and there is some danger that radiological examinations and radiotherapy of every kind will be viewed with unnecessary suspicion by the public at large so that the individual patient may come to harm through his reluctance to be X-rayed. In particular the value of mass miniature radiography is so great that it must not be curtailed without good cause and we think it important therefore to state now that these examinations, properly conducted, make a negligible contribution to the total radiation to which the population is exposed.

10. Before considering the evidence in this particular field we have some general observations to make. The present evidence on the genetic and somatic effects of ionizing radiations has been discussed in the reports of the Medical Research Council and of the United Nations Scientific Committee. This evidence suggests that any genetic effects which are produced by radiation will be on the whole harmful and that perceptible damage would certainly arise if the radiation dose was enough to double the mutation rate in the whole population; this dose is estimated to be probably greater than 10 rad* per generation and less than 100 rad. According to earlier estimates the dose due to medical radiology does not exceed 3 rad per generation even in countries where it is in most general use. The preliminary results of our survey do not suggest a higher figure.

11. It is therefore unlikely that we shall have to recommend a drastic re-assessment of the place of diagnostic radiology in medicine and dentistry. We do not, however, know enough about the effects of very small doses, and in stating that the danger of a particular form of examination is negligible we mean that the potential harm is negligible in comparison with the benefits. Clearly, however, the potential harm must be kept to a minimum in every form of examination. In mass miniature radiography as in all other diagnostic procedures, there must be no unnecessary radiation. Thus in the following sections our conclusion that the dangers are negligible has not prevented us from emphasising the precautions which should be taken to reduce dosage even further.

II. MASS MINIATURE RADIOGRAPHY OF THE CHEST

12. In mass miniature radiography an X-ray image of the chest is formed on a fluorescent screen and this is photographed on 35 or 70 mm. strip film. The film is developed as a roll with up to 200 consecutive exposures and is read by projection or direct viewing. The advantage of this method is that it permits the X-ray examination of large numbers of people in a short time and at low cost.

13. The importance of mass miniature radiography in Britain may be briefly illustrated by the following statistics. In 1957 a total of 3,451,060 mass miniature radiography examinations were carried out in England and Wales and during the same year an intensive mass radiography campaign was held in Scotland and 1,319,867 examinations were made. For the whole of Great Britain these examinations led to the discovery of 17,835 cases of pulmonary tuberculosis requiring supervision. Over 63,000 other abnormalities were detected and these

* The *roentgen* is a commonly used unit of dose which is defined in terms of the electrical charge set free by radiation in a prescribed mass of air; it is equivalent to an absorption of radiation energy by soft tissues of between 88 and 97 ergs per gram, depending on the quality of the radiation. The *rad* is defined simply as a unit of absorbed dose equal to 100 ergs per gram

In some cases it is necessary to include in a statement of dose some factor to allow for the "relative biological effectiveness" of the radiation. The physical dose in rad when multiplied by this factor is then said to be the dose in *rem* ("rad-equivalent-man"). This unit is used for the sake of generality in the statement in paragraph 20 taken from the Report of the United Nations Scientific Committee. For radiations considered in this report, however, the factor for the relative biological effectiveness is unity and the dose in rem is numerically the same as the dose in rad and very nearly equal to the dose in roentgen.

included 2,362 cases of lung cancer, nearly 12,000 cardiac abnormalities and 9,400 cases of pneumoconiosis. It is clear that the hazard, if any, of this particular form of radiation exposure must be balanced against the undoubted benefits.

Dose Measurement

14. The Medical Research Council's report in 1956 gave figures for the gonad dose from mass miniature radiography based on work by Stanford and Vance[6] which had been carried out in 1952. According to these figures mass miniature radiography contributed less than 0·1 per cent of the gonad dose received by the population from diagnostic radiology. The report of the Medical Research Council therefore concluded that mass miniature radiography in common with a number of other ancillary medical and dental uses of X-rays represented a " relatively unimportant source of radiation to the gonads ".

15. In order to obtain an up-to-date assessment of the gonad dose a new programme of measurements was undertaken. More than 600 observations were made on four different types of unit typical of those used throughout the country. Further research to estimate the ovary dose was undertaken by experimental irradiation of a specially constructed model. A short account of this work, of the techniques used and of the method of computing results, is given in Appendix II. Table I of this Appendix shows the results of this survey in terms of gonad doses and compares them with those contained in the earlier survey used in the Medical Research Council report.

16. A study of the present measurements shows a male gonad dose from a single examination that is appreciably less than the figure reported by Stanford and Vance in 1952 using the same type of unit. For females the present figures approximate those previously published. The new experimental work on the model has however shown that the figures presented by Stanford and Vance must be adjusted. In Appendix II it will be seen that after making this adjustment, the doses found in the present survey are in all cases lower than those previously reported.

17. As the measurements made on mass miniature units can be regarded as typical for all examinations of this type, we have concluded that the radiation dose to the gonads per examination arising from mass miniature radiography is now less than half of that reported by Stanford and Vance in 1952. Even allowing for the increased numbers examined in recent years, the population gonadal dose from this source remains below that calculated in 1952. In the light of our more representative and extensive data we can therefore endorse the Medical Research Council's conclusion that mass miniature radiography examinations are a relatively unimportant source of gonadal radiation exposure.

18. A separate survey was undertaken to obtain information about the dose to the skin of the area directly exposed in mass miniature radiography. In this survey 318 measurements were made on 12 X-ray units of three different types and in widely distributed populations. Details of this work are also given in Appendix II with results shown in Table II and Figure I. Using the arithmetic mean, the average skin dose was found to be 0·63 roentgen per examination.

19. The figure for the mean marrow dose derived from the skin dose of 0·63 roentgen is 74 milliroentgens per individual examination, or approximately 7 milliroentgens per head of the population of Great Britain per annum. This measured annual per capita dose for Great Britain compares with an estimated

value of 10 milliroentgens per year given by the United Nations Scientific Committee for a population, in which 10 per cent are examined by mass radiography each year.[2(b)]

20. The Report of the United Nations Scientific Committee emphasises that " any present attempt to evaluate the effects of sources of radiation to which the world population is exposed can produce only tentative estimates with wide margins of uncertainty ".[2(c)] Nevertheless, the Report includes a calculation of what is considered an upper limit to the number of leukaemia cases produced by a given radiation exposure, on the basis that " the increased incidence per rem would be 1·5 per 1 million per year for the rest of the lives of the exposed individuals ".[2(d)] This calculation is a generalisation from observations on leukaemia following high doses, and evidence is as yet lacking that the calculation is equally applicable to the very low doses associated with mass radiography. Indeed, as the United Nations Scientific Committee has stated, there may be no addition at all from this source to the incidence of leukaemia.

21. Nevertheless, applying these same calculations to the mean marrow dose per year in Great Britain, leads to the conclusion that indefinite continuation of mass miniature radiography at the present rate could produce annually at the most 20 cases of leukaemia additional to the present annual incidence from all causes of about 2,500 cases, but might produce none at all. Similar considerations show that an individual who has ten mass miniature radiography examinations over a series of years would have his chance of developing leukaemia in any year increased—if at all—from 50 in a million to at most 51.

22. We are satisfied that the somatic risk of doses at these levels is on any interpretation far outweighed by the benefits of mass miniature radiography.*

Review of the Use of Mass Miniature Radiography

23. The Committee in the course of its review concluded that modifications of mass miniature radiography units might be made which would reduce still further the radiation dose to the patient. Details of the modifications which were recommended for immediate implementation are given in Appendix III.

24. Also in the course of our work some incidental observations on persons in the queue awaiting their turn for examination showed that those lined up close to the side of the apparatus might sometimes receive radiation during the waiting period. We have not investigated this matter further because we are informed that steps were immediately taken to prevent this occurring in future. (Appendix III (iv).)

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* Our measurements show that the gonadal dose is less than that calculated in 1952. In that year it was estimated to be less than 0·02 mr per head of population per year. From natural sources the annual dose received by an individual would increase by about 20 mr on going from a stone house in a limestone district to a granite house in a granite area (local gamma ray increment), or going from sea level to live at an altitude of 5,500 feet (cosmic ray increment). A per capita dose of 7 mr (the measured annual marrow dose in our Mass Miniature Radiography survey) would be equivalent to the increased dose after some 4 months residence in a granite district or at 5,500 feet.

It is possible that an amount of radiation given in a single brief exposure at high intensity may be more damaging than the same amount given at a low intensity over a long time, but there is insufficient evidence on which to assess the effect of dose rate on these comparisons. The calculations in paragraph 21, however, are based on observations of leukaemia induction at about the same order of dose rate as in Mass Miniature Radiography. The uncertainties here lie in assumptions which are made in extrapolating from high doses to doses some 10,000 times smaller.

25. The Committee have considered the problems which arise in the mass miniature radiography of children and concluded that the method is a less suitable one than for adults because the size of the field with present apparatus means proportionately greater surface irradiation of the child. Where an X-ray of the chest of a child is considered necessary, mass miniature apparatus should not be used and recourse should be had to normal radiographic procedures with strict limitation of field size. Similar conditions apply to small adults unless the field size can be limited to the chest.

26. So long as the incidence of tuberculosis in pregnant women continues at its present level, radiological examination of the chest is desirable. A single examination during pregnancy should normally be sufficient and should be made by the use of full sized films with stringent limitation of field size. This will minimise the irradiation of the mother and foetus.

III. GENERAL COMMENTS ON DIAGNOSTIC RADIOLOGY

27. We are not yet ready to make an assessment of the total gonad dose to the population from all forms of diagnostic radiology but we have no reason to doubt the conclusions of the Medical Research Council Committee that the major contribution to it comes from a few types of examination. It is already recognised by radiologists that these call for special precautions. There are however certain obvious measures for reducing the total radiation which we think it important to emphasise.

28. These are, as regards the technical aspects of radiology, measures for reducing the exposure by attention to such details as the use of fast films, appropriate filters, minimum timing and smallest reasonable field size, and by the use of gonad shields. The Committee would like to draw attention to the difference between fluoroscopy and radiography. It is not generally realised even among the medical profession that the dose per examination in fluoroscopy is considerably higher than that from radiography. The dose in fluoroscopy should be minimised by adequate dark adaptation on the part of the observer and by the routine use of timing devices. The development and use of image intensification will also contribute to this end. The rigorous application of the recommendations in the Code of Practice[7] for the protection of persons exposed to ionizing radiations would play a considerable part in reducing the dosage received by patients.

29. There should be clear cut indications before an X-ray examination is requested. Wherever possible there should be consultation between the clinician and the radiologist before any examination involving a considerable dose to a young individual. In women of child bearing age the clinician requesting the examination should consider the possibility of early pregnancy. Precise information should always be given about the nature of the examination as this will help to reduce the total number of exposures.

30. Strict control of progress or repeat X-rays is essential. It should be normal practice to investigate the patient's previous radiological history. The forms on which requests are forwarded to radiological departments should be designed to include this information. If it is known that relevant X-ray films exist, whether at the same hospital or elsewhere they should always be made available, and the ready and prompt transfer of X-ray films should be facilitated in every way.

31. Particular attention should be paid to X-ray examinations of pregnant women. Obstetric X-rays for pelvimetry, determination of placental site or foetal maturity for example, are of proven value in conserving the lives of mother and child but should not be undertaken as a routine procedure in every case. When specifically indicated, however, there should be no hesitation about their employment.

32. We would stress that all means should be taken continually to ensure that radiation exposure is kept at a minimum. We believe that the level may be reduced appreciably without prejudice to the interest of the patient. At the same time we would strongly urge that a reasonably balanced view be adopted in this field of endeavour. Diagnostic radiology by the part that it plays not only in diagnosis but in the correct treatment of the patient renders immense service to medicine and dentistry. There is no doubt that much individual suffering would follow any unnecessary curtailment of those services.

IV. SUMMARY

(i) A survey has been made of exposure to radiation produced by mass miniature radiography. The doses to the gonads have been found to be less than those previously reported. It is concluded that properly conducted examinations of this kind make a negligible contribution to the total radiation to which the population is daily exposed. Even on the most pessimistic assumptions our measurements have shown that indefinite continuation of the present rate of mass miniature radiography could add no more than 20 cases of leukaemia to the annual incidence of 2,500 cases of this disease. On the other hand, mass miniature X-ray examinations in 1957 led to the discovery of nearly 18,000 cases of pulmonary tuberculosis and some 63,000 other abnormalities which included lung cancer, heart disease and pneumoconiosis.

(ii) On the principle that all unnecessary exposures should be prevented, the Committee endorse the steps already recommended to reduce even the present small dose and further recommend that mass miniature radiography should not be used as a case-finding procedure in children or in pregnant women.

(iii) The Committee have set out some general principles towards the reduction of unnecessary exposures in other forms of diagnostic radiology.

Acknowledgments

The Committee's thanks are due particularly to Professor C. B. Allsopp and Mr. Stanford for their work on mass miniature radiography, and to all those physicists who helped with the collection of measurement data from units in different parts of the country and to the co-opted members of the various panels.

Signed on behalf of the Committee,

Adrian. (Chairman)

14*th February*, 1959.

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APPENDIX I

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APPENDIX II

The quantity of Radiation received by Patients during routine Mass Radiographic examinations of the Chest

by

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A. Dose received by the Reproductive Organs

1. It has been estimated that during 1955 Mass Miniature Radiography accounted for nearly one fifth of all diagnostic X-ray examinations in England and Wales. The contribution made by these examinations to the genetically significant radiation resulting from diagnostic radiology has been reported as being negligibly small, that is, less than 0·1 per cent of the total in each sex (Medical Research Council, 1956). This conclusion was based on some 1,300 measurements made in 1952 and published by Stanford and Vance in 1955 (British Journal of Radiology **28**, 266–273). All but 200 of these measurements, however, were made on one particular 35 mm Mass Radiography Trailer Unit. It was considered that a more extensive investigation was necessary, as many more units, some of different types from those of 1952, are now in general use.

Scope of the survey

2. Investigations were therefore made under conditions representative of normal practice on the following four units:

35 mm Mass Radiographic Unit (Trailer mounted),
35 mm Mass Radiographic Unit (Temporary static installation),
70 mm Mass Radiographic Unit (Trailer mounted),
100 mm Mass Radiographic Unit (Static installation).

No attempt was made to select patients at any of these units but other selection factors did in fact operate in so far as the nature of the establishment at which the unit was working varied, e.g. at a University, a Hospital Out-Patient Department, or at Government Offices, etc.

Method

3. The technique of measurement and the apparatus used were the same as those described by Stanford and Vance (1955). It was thought desirable to check the ratio of the ovary dose to skin dose* which was quoted by them as 0·10 for chest radiography. For this purpose a phantom (see Section D) was constructed from Neoprene sheet in the shape of a female figure measuring 37, 28 and 39 inches and filled with water. Provision was made for inserting an ionisation chamber into the pelvic cavity in the mid-line to a distance of 5 inches above the perineum. It was not possible to insert ribs, spine and pelvic bones into the container but the lungs were simulated by an inflated football bladder in the thoracic cavity. Subsidiary measurements (see Section D) indicated that the model was sufficiently accurate for the purpose in hand. The results showed that when a 17 × 17 inch field at 36 inches was used the ratio of the ovary dose to the skin dose varied with kV as shown in Table I. In the Mass Miniature units examined, the average kV varied from 61 to 76 for women. For calculation of the ovary doses given in Table I the ratio 0·10 has been used for 61 and 63 kV and the ratio 0·18 for 74, 75 and 76 kV (this covering the normal range of kilovoltages used in mass miniature radiography).

Accuracy of the measurements

4. When patients are fully clothed as in this type of work it is not always possible to be certain that the ionisation chamber is in contact with the male gonads or that

* In this context the term " skin dose " is used in a particular sense and refers to the dose at a point on the surface of the abdomen anterior to the ovary.

it is accurately positioned on the abdomen in the case of women. It is estimated that errors of this nature could cause the stated figure of dose for males to vary by a factor of five times. In females the variation is likely to be smaller and the factor is estimated to be three times. This same factor operated in respect of the figures quoted in the M.R.C. Report and does not invalidate the conclusions reached in the present work.

Results

5. Gonad doses received by males and females at each of the four types of M.M. unit are set out in Table I, the last line of which also shows the figures obtained by Stanford and Vance (1955) on a trailer-mounted 35 mm Unit, which were subsequently used in the M.R.C. Report. Comparing these M.R.C. figures with the new observations for *males* made on a 35 mm unit suggests that the male gonad dose per examination may actually be less than was indicated in the M.R.C. report.

6. A similar comparison for *female* patients of observations made on a 35 mm unit shows that the present figures are also less than those in the M.R.C. Report. Moreover, in the light of the new measurements on the phantom, the ovary dose/skin dose ratio which should have been used by Stanford and Vance (1955) is 0·23, which would have made the ovary dose in the M.R.C. Report 0·35 mr (as shown in brackets in Table I). The new values are not more than a third of the 1952 value.

7. In the case of the 100 mm Unit both male and female patients receive a dose which is somewhat greater than that delivered by the standard 35 mm unit, but even so the doses are no greater than reported by Stanford and Vance (1955).

8. The 70 mm unit delivers a dose to women that is about twice that from the 35 mm unit. By comparison with the figure of 0·15 mr quoted in Table 2K of the M.R.C. Report, which dose was shown in Table 3K as giving rise to a genetically significant dose less than 0·1 per cent of the total, it is clear that the present figure of 0·23 mr cannot give rise to a contribution greater than 0·15 per cent of the total. It is unlikely that the female gonadal dose from the comparatively few 70 mm units in present use could make an appreciable increase in the contribution to the genetically significant dose arising from Mass Miniature practice. This increase is probably due to the particular configuration of the female patient and of the screen in relation to the position of the dosemeter for the unit examined. For male patients on the same unit the dose was in the same range as from the 35 mm unit.

Conclusion

9. The Mass Miniature Units which have now been examined can be regarded as typical of those in common use, and, with the single exception of that for female patients radiographed with the 70 mm unit, the gonadal dose per examination arising from Mass Miniature Radiography is now less than when it was computed in the earlier work reported in 1955. The contribution of Mass Radiography of the chest to the total radiation received by the population as a whole was considered to be negligible in the M.R.C. Report of 1956; it may be safely concluded that it is still negligible.

B. Dose received by the Posterior Skin Surface at the Centre of the Field

10. The second consideration concerned the somatic risk and in order to assess this the bone marrow dose must be computed from data on the dose delivered to the skin where the X-ray beam enters the body.

Scope of the Survey

11. With the co-operation of other Hospital Physicists measurements of skin dose were made on 318 patients at 12 centres over England and Scotland. The numbers and types of X-ray apparatus were:

35 mm Mass radiographic units	9
100 mm Mass radiographic units	2
Unit with 35 mm camera	1

With the exception of one 100 mm unit all other units had no external filter fitted to the tube.

Method

12. Observations were made by placing an ionisation chamber over the clothing of the patient at the centre of the field. Since in most cases the chamber used was that provided for the general survey of gonad dose the size of the chamber was such that its mid-point was about 1 inch from the clothing. It is likely that the clothing might be up to ½ inch from the skin. Thus the chamber was in fact closer to the tube than the skin and the recorded dose might therefore be greater than the actual skin dose. The factor of increase is unlikely to be in excess of that calculated from the inverse square law, i.e., of the order 10 per cent. Thus the figures quoted in this paper may be up to 10 per cent greater than the actual skin dose.

Results

13. The results of the survey are given in Table II. A histogram for the observations is given in Fig. 1, which shows a distribution of doses sufficiently uniform to justify the use of a simple arithmetic mean. The value of this mean dose is 0·63 r per examination.

Conclusion

14. For the purpose of estimating the somatic risk the best available figure for the skin dose is 0·63 roentgens delivered with radiation having an average quality of 72 kV. The range of skin dose is from 0·17 to 1·9 roentgens and the range of quality from 50 kV to 90 kV.

C. Additional Observations made during the Survey

15. In addition to the measurements of the actual doses received by patients undergoing mass X-ray investigations, we also made a number of observations on apparatus or techniques which we consider should be reported to the Committee. These, however, were not made systematically; in the case of patients they were not numerous; and we do not attach any *statistical* significance to them. They are intended more as a guide in framing recommendations relating to procedure in Mass X-ray Units.

Limitation of the X-ray beam

16. All the X-ray tubes were provided with pre-set lead diaphragms restricting the beam so that only the fluorescent screen in the camera unit was irradiated. In each case film was used to establish that the periphery of the beam did not exceed the area of the screen. Measurements made with a dosemeter showed that the intensity just within the beam was always more than two hundred times the intensity 2 inches outside the beam.

Dose received by children

17. No provision was made on any of the apparatus for independently limiting the vertical dimension of the beam to less than the full height of the screen. The design of the camera unit was such that the patient's chin must rest on the upper edge of the screen. With small adults and with children this necessarily resulted in the X-ray beam extending well below the lower edge of the lung field and in very young children as low as the head of the femur. A girl aged 10 radiographed on the 100 mm unit received an ovary dose of 0·28 mr despite the reduced exposure of 62 kV and 22 mAs. In this case the ovary was not in the direct beam but had it been so the phantom measurements suggest that the dose would have been increased by a factor of 20 times. Similar results were observed with boys of about the same age.

Recommended improvements in apparatus

18. A reduction in the dosage currently received can be achieved by three simple measures:—

(*a*) An adjustable protective shield should be attached to the apparatus so that it can protect the individual's abdomen from the direct beam, i.e. provide a means of limiting the field size.

(*b*) Mobile lead screens should be used to prevent scattered X-rays from reaching any person required to wait in the vicinity of the apparatus when the unit is used in the static arrangement.

(*c*) Some device should be fitted to indicate to the Radiographer the size of the diaphragm in position on the X-ray tube.

D. Measurements made on the Phantom

Equivalence of the phantom to a patient

19. The use of the phantom was restricted to determining the ovary dose/skin dose ratio. On a number of patients measurements were made first with the dosemeter on the anterior surface of the abdomen and then on the lower region of the back at the same level. In each case the measurements were made with the chamber unscreened and with lead screening so placed as to permit only scattered radiation emerging from the patient to reach the chamber. The ratios of the doses with and without screening were established and similar measurements were made on the phantom. These results are shown in Table III. There was agreement between the phantom measurements and patients' measurements to better than a factor of 2 and this was considered sufficient to justify the subsequent use of the phantom.

Ovary dose/skin dose ratio

20. A large number of measurements were made simulating conditions likely to obtain in practice. The figures given in Table I derive from this work.

Other conclusions

21. During these measurements on the phantom the following conclusions were also reached:—

(*a*) If the beam is correctly defined then the presence of a lead rubber apron placed posteriorly from the waist down has no effect on the ovary dose.

(*b*) The dose measured on the anterior surface comprises a component due to scatter emerging from the abdomen and a component due to scatter from the chest approximately in the proportion 1:2·5; if the scatter from the chest is excluded by placing a lead rubber apron over the anterior surface of the abdomen and thus over the chamber the measured dose is in very close agreement with the ovary dose.

(*c*) The skin dose measured at various points over the anterior surface of the abdomen can vary by a factor of up to 3 times; if the surface is covered with a lead rubber apron the variation is reduced to a factor of 2 times.

References

STANFORD, R. W. and VANCE, J. *Brit. J. Radiol.*, 1955, xxviii, 266.

The Medical Research Council Report on the Hazards to Man of Nuclear and Allied Radiations, H.M.S.O., June, 1956.

TABLE I

The Gonad Doses derived from Mass Miniature Radiography

Type of Unit	Female							Male					
	Mean kV	Exp. mAs	Age Range	Number of observations	Surface† Dose range mr.	Mean Surface Dose mr.	Mean Ovary Dose mr.	Mean kV	Exp. mAs	Age Range	Number of observations	Gonad Dose Range mr.	Mean Gonad Dose mr.
70 mm.	76	17	24–66	12	0·55–3·5	1·26	0·23	80	18	23–58	24	0·01–0·33	0·07
100 mm.	74	27	18–70	53	0·24–2·4	0·83	0·15	74	28	17–75	22	0·08–0·20	0·16
(1) 35 mm. Trailer	75	24	18–47	66	0·10–2·7	0·65	0·12	75	21	16–36	15	0·03–0·11	0·07
(2) 35 mm. Trailer	63	29	15–63	101	0·04–0·36	0·20	0·02	65	27	22–64	118	0·02–0·72	0·05
(3) 35 mm. Static	61	42	15–60	93	0·16–2·8	0·98	0·10	69	40	17–70	98	0·02–0·48	0·13
35 mm. Trailer ...	83	24	Stanford and Vance, 1955 ... ... (Revised, 1959‡				0·15* 0·35)	83	24				0·25

* Committee of the Medical Research Council Report, 1956, on the Hazards to Man of Nuclear and Allied Radiations, London, H.M.S.O.
† Dose to Anterior Surface of Abdomen.
‡ See Appendix II, paragraph 6.

TABLE II

Mass Miniature Radiography
Skin dose measurements

Type of Apparatus	Place	Female kV mean and range	Female mAs mean and range	Female Mean skin dose r.	Female No. of obsns.	Male kV mean and range	Male mAs mean and range	Male Mean skin dose r.	Male No. of obsns.
35 mm. ...	Cambridge ...	65 61–72	22 21–26	0·61	21	—	—	—	—
,, ...	Aberdeen ... P.A.	70 65–72·5	20 18–24	0·47	5	73 70–77	22 20–24	0·62	10
	Aberdeen ... A.P.	70 65–72·5	20 18–24	0·49	4	74 70–79	20 18–24	0·50	9
,, ...	Hull... ...	60 52–66	24 16–48	0·47	32	65 52–70	30 18–58	0·47	45
,, ...	Southampton	76 70–85	25	0·94	9	84	25	1·06	1
,, ...	Sheffield ... P.A.	60 58–61	30 20–40	0·57	12	66 61–73	20 16–38	0·59	20
	Sheffield ... A.P.	64 61–73	30 22–42	0·76	7				
,, ...	Bradford ...	65 61–77	24 20–30	1·00	13	69 65–75	20 19–22	0·79	11
,, ...	Maidstone ...	79 75–84	34 22–40	1·10	14	80 73–86	34 22–40	1·00	8
100 mm....	London* (Middlesex)	74 70–78	21 17–29	0·23	13	78 75–86	30 19–44	0·48	7
,,	Southampton	72 59–85	25 20–33	0·90	7	66–80	17–24	0·64	3
35 mm. ...	Southampton	70–85	25	0·94	9	84	25	1·06	1
,, ...	Leeds† ...	60 52–66	32–5 12–74	0·70	40				
,, ...	London† ...	79 69–88	23 16–40	0·47	17				

* Unit fitted with 1 mm. aluminium filter.
† Figures refer to males and females.

TABLE III

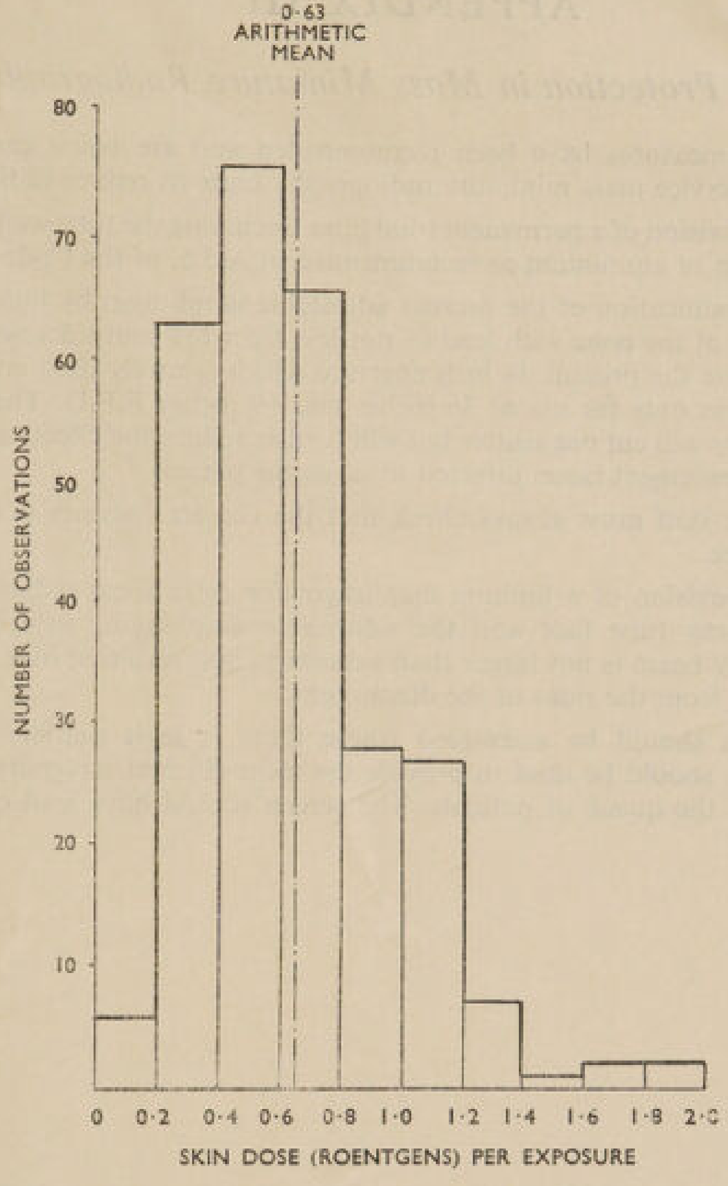
	Dose with chamber unscreened / Dose with chamber screened	
	Anterior	Posterior
	Range of Readings	
Patients ...	1·75 2·60	10·9 5·0
Phantom ...	1·43	8·9

TABLE IV

Ovary Dose/Surface Dose Conversion Factors

Ovary dose / Surface dose	kV
0·10	60
0·14	70
0·23	80
0·26	90
0·26	100

NOTES: (1) Surface dose measured on anterior abdominal surface.
(2) Each of these ratios is the mean of 3 measurements made on the phantom.



Histogram for 318 observations made on 12 different mass miniature radiography units.

APPENDIX III

Radiological Protection in Mass Miniature Radiography Units

The following measures have been recommended and are being carried out in National Health Service mass miniature radiography units to reduce radiation doses.

(i) The provision of a permanent total filter (including the tube wall) equivalent to 2 mm of aluminium as recommended in A.5.5. of the Code of Practice.

(ii) The modification of the present adjustable diaphragm by lining the inner section of the cone with lead of not less than 1·5 mm thickness. This will eliminate the present 48 inch aperture which is rarely used and leave two apertures only for use at 36 inches and 60 inches F.F.D. The lead lining not only will cut out scatter but will further reduce the effective dimensions of the emergent beam directed towards the patient.

The staff must always check that the correct aperture is used for the film size.

(iii) The provision of a limiting diaphragm for extra focal radiation between the X-ray tube face and the adjustable diaphragm, ensuring that the primary beam is not larger than necessary, and resulting in a reduction in scatter from the sides of the diaphragm.

(iv) Queues should be assembled where there is least scatter, and mobile screens should be used to provide the most efficient screening of the staff and of the queue of patients. The screen should have lead equivalent of 1 mm.

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