THE NEED FOR RADIATION PROTECTION* $\pm$

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No one questions that diagnostic x-ray is one of the most valuable tools of the medical profession. However, many persons do not realize that like most conveniences, luxuries and even necessities of modern society, x-ray exacts a severe price in suffering and human lives. Over 90% of the population exposure to man-made sources of ionizing radiation in the United States derives from medical diagnosis, and, as shown in Table 1, the genetically significant dose from medical diagnosis in the United States is much higher than that in other countries.^(1,2) We are concerned about the GSD to our gonads because it causes some of our children, grandchildren and great-great-grandchildren to be born with birth defects, brain damage, and genetically related diseases and many to die an early genetic death. Likewise, we find that the somatic dose from diagnostic x-ray in the United States is correspondingly higher than that in other countries, and many persons are particularly concerned about this because it increases the chance that they themselves will die of some form of cancer or will die an early death from non-specific diseases and aging.^(3,4) Although there is evidence of some repair of genetic and somatic radiation damage, a certain fraction of this damage appears to persist as irreparable and to accumulate linearly during the life of an individual as indicated in Figure 1. These curves are plotted from data of the International Commission on Radiological Protection,^(3,4) which sets the radiation protection standards at the international level on the prudent assumption that there is no safe threshold dose and that the probability of a person dying of one of these forms of damage increases linearly with the accumulated dose. Eye cataracts and acute forms of radiation damage such as skin erythema, acute radiation sickness and radiation death result only following large doses of radiation. Table 2 summarizes both the types of radiation damage that relate more or less linearly

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Table 1

Genetically Significant Dose (mrem/yr) from Medical Diagnosis
in Various Advanced Countries

United States	95*
Japan	39
Sweden	38
Switzerland	22
United Kingdom	14
New Zealand	12
Norway	10

*Probably value is between 55 and 95 mrem/yr.

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FIGURE 1

Table 2
TYPES OF DAMAGE RELATING MORE OR LESS LINEARLY
TO THE ACCUMULATED DOSE

1. Genetic Mutations (First Generation and Recessive)
2. Cancer (Including Leukemia)
3. Life Shortening
4. Other Biological Changes
 - (a) Chromosomal Aberrations
 - (b) Changes in Blood and Urine Chemistry
 - (c) Areas of Increased and Decreased Bone Density
 - (d) Polynucleated Cells

TYPES OF DAMAGE REQUIRING A THRESHOLD DOSE

1. Eye Cataracts
2. Radiation Sickness
3. Skin Erythema

to the accumulated dose and those which require a threshold dose before they are manifest.

A few persons--some of them radiologists--wish so strongly to believe there is a threshold or safe dose of radiation below which no radiation damage will result in man that they refuse to consider the evidence and at times even resort to unscientific arguments. For example, we often hear such statements as that of the highly respected Dr. Moseley⁽⁵⁾ of the American College of Radiology, "There are no demonstrable deaths from x-rays." This is like saying there has never been a proven case where a person has died of lung cancer from smoking cigarettes. Of course no deaths have been proven because the cancers are identical to those from natural causes, and they occur on a statistical basis. We can show decisively, however, that on a statistical basis diagnostic x-rays as well as cigarettes do cause cancer. Statistical evidence is a basic requirement of all scientific proof. For example, the general gas law applies only to observations on a large number of gas molecules under changes of pressure, volume and temperature. It does not indicate the behavior of a single molecule. One can, of course, refer to the results of many experiments with animals exposed to low doses of x-rays as evidence of radiation damage, but human data in the final analysis must provide the proof we require. Table 3 summarizes some of the more important types of human exposure experiences which are being studied and are lending support to the belief that there is no dose of radiation so low that the probability of its causing a malignancy and life shortening is zero.

Sometimes the data⁽⁶⁾ on bone tumors that have resulted among persons who have ingested large amounts of radium are plotted on semi-log graphs, as shown in Figure 2, which at first glance seem to suggest to the non-scientist proof of the existence of a threshold dose below which no bone tumors will appear. However, if these same data⁽⁶⁾ are plotted on Cartesian coordinate paper, as shown in Figure 3, they seem to support strongly the hypothesis of a linear relationship between radiation dose and effect. Table 4 is a summary of data showing the gradual increase of severity of biological changes as the radium dose is increased from $0.001 \mu\text{c } ^{226}\text{Ra}$ (corresponding to an average skeletal dose of 0.3 rem/yr) to $5.5 \mu\text{c } ^{226}\text{Ra}$ (corresponding to 1650 rem/yr). In this case, $0.1 \mu\text{c } ^{226}\text{Ra}$ (corresponding to 30 rem/yr) is the maximum permissible body burden for the occupational worker.

Table 3

SOURCES OF HUMAN EXPOSURE CAUSING RADIATION DAMAGE

1. Radium Ingestion-- ^{226}Ra , ^{228}Ra , ^{224}Ra --(Sarcoma and Carcinoma)
2. Thoratrast Ingestion-- ThO --(Hepatic Tumors)
3. Thyroid Diagnoses and Therapy--Isotopes of Iodine and X-Ray--(Thyroid Cancer)
4. Ankylosing Spondylitis X-Ray Therapy--(Leukemia and Other Malignancies)
5. Chest X-Rays of TB Patients (Lung and Breast Cancer)
6. X-Ray Exposure of In Utero Children (Leukemia and Other Malignancies)
7. Prenatal X-Ray Exposure (Leukemia and Other Malignancies)
8. X-Ray and Ra Exposure of Uterus to Induce Artificial Menopause (Leukemia and Other Cancers)
9. Survivors of Atomic Bombing of Hiroshima and Nagasaki (All Forms of Cancer, Cataracts, Brain Damage, Reduction in Organ Size, Change in Sex Ratio)
10. Radiation Accidents--Criticality, Radiographic Sources, X-Rays, High Voltage Accelerators--(Death, Cancers, Cataracts, Radiation Burns)
11. Early Exposures of Radiologists to X-Rays (All Forms of Cancer and Life Shortening)
12. Exposure of Uranium Miners--Radon Daughters (Lung Carcinoma)

Figure 2. The percent incidence of sarcomas and carcinomas plotted separately on a linear scale against the median of the total skeletal dose in rads on a logarithmic scale. For the notation at the top of the figure, 0/42 means zero cancers among 42 persons in this dose range, 2S, 2C/16 means two sarcomas and two carcinomas among 16 persons in this dose range, etc.

Figure 3. The percent incidence of sarcomas and carcinomas plotted separately against the median value of the total skeletal dose in rads in linear coordinates. For the notation at the top of the figure, 13S, 3C/25 means 13 sarcomas, three carcinomas in this dose range, etc.

Table 4

LONG-TERM EFFECTS OF RADIUM IN MAN

Ra Body Burden (μc)	Average Bone Dose (rem/yr)	Biological Changes (%)					
		None	Minimal	Mild	Moderate	Advanced	Malignant*
0.001-0.03	0.3-9	92	8	0	0	0	0
0.03-0-0.1	9-30	83	13	0	4	0	0
0.1-0.3	30-90	69	16	3	6	6	3
0.3-1.0	90-300	12	25	25	16	22	16
1.0-3.2		6	6	14	12	62	32
3.2-5.5		0	0	0	9	91	55

*Those with malignancies were listed also under previous columns.
 (Data from Finkel, Miller and Hasterlik, ICRP No. 11, 1968)

Many studies^(7,8,9) have been conducted which indicate the human fetus is very radiosensitive, and the malignancies produced per rad of x-rays may be five to eight times the rate indicated in Figure 1 for exposure of adults. The data of Stewart and Kneale⁽⁷⁾ in Figure 4 showing a linearly progressive increase in the number of cancers in children as a function of the number of pelvic x-rays received by their mothers during pregnancy is more than "suggestive" of a linear relationship between dose and effect. The estimated average dose per x-ray film was only 0.25 rem. Such studies led the ICRP⁽¹⁰⁾ to recommend that, where practicable, for women in the childbearing age x-rays to pelvic and abdominal regions be given only during the 10-day interval following the beginning of menstruation. Members of the medical profession who have implemented this ICRP recommendation undoubtedly have prevented much misery and suffering and have saved many thousands of lives of young children. In this connection, it is of interest to note that the 1964 USPHS survey indicated the average abdominal x-ray skin dose in the United States is 0.79 rem and that this dose is 0.636 rem if given under the care of a radiologist but 1.253 rem if given otherwise. I believe this does not mean the radiologist carried out these abdominal diagnoses himself at about half the dose delivered by other members of the medical profession for the same examination but rather that on the average the x-ray technologists working in hospitals and private offices of radiologists were more likely to be educated and trained properly and to be certified. I think it is regrettable that proper training and certification of x-ray technologists is required in only three of our states--New York, New Jersey and California--and it is deplorable that only one of our states--California--requires education and training in x-ray and radiation protection of all medical doctors and that there be questions on these subjects on the state board examinations. I am pleased that the American Society of Radiologic Technologists has been working with the Bureau of Radiological Health of the USPHS and other medical organizations in the preparation of model legislation designed to correct these faults and to assure proper legislation that will guarantee eventually that all users of ionizing radiation in the healing arts have proper education, training and certification in its proper use. I am pleased, also, that in these negotiations the ASRT has been insistent that there be as much consistency as possible in the education

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NUMBER OF DIAGNOSTIC X-RAY FILMS DURING PREGNANCY
(Data from Alice Stewart and G.W. Kneale, *Lancet*, June 1970)

Figure 4

and training requirements in the various states and that the standards maintained must be equal and preferably superior to those presently enforced by the American Registry of Radiologic Technologists. It is a great encouragement, also, that regional and state organizations of radiologic technologists are beginning to take the lead in forming appropriate state and local legislation in order to maintain high standards in radiologic technology and provide appropriate protection of the patient who is to be x-rayed and of his or her children who could suffer the consequences of unnecessary x-ray exposure for many generations to come. I only wish equal progress was being made by other members of the healing arts to assure appropriate training. I do not believe any doctor should have the right to request an x-ray in an x-ray department (much less give the x-ray himself) unless he has appropriate education, training and certification in the proper use of x-ray.

As mentioned above in Table 3, two important sources of human exposure causing radiation damage and which have been under intensive study are (1) x-ray exposure of in utero children, and (2) survivors of atomic bombings of Hiroshima and Nagasaki, Japan. As often happens in research, the studies of children who received in utero exposure during the atomic bombings at Hiroshima and Nagasaki do not confirm the findings of an unusually high incidence of malignancy as found by Stewart and others among children whose mothers received pelvic and abdominal x-rays while they were in utero. Jablon and Kato ⁽¹¹⁾ pointed out this discrepancy between his studies of Japanese children and Stewart's studies of in utero x-rayed children. I have examined both sets of data and listed in Table 5 some of the principal reasons why there seems to be a difference in the effects of the two types of radiation exposure. First, there was an unusually high abortion and infant mortality rate in Hiroshima and Nagasaki following the atomic bombings, and undoubtedly the children, who otherwise would have died of radiation-induced cancer, had the scales tipped against their surviving more than two years when such malignancies usually appear. Likewise, many studies ⁽¹²⁾ have shown that during times of community disasters it is the young children who suffer most and usually die of causes other than cancer. During such periods, incipient cancers can be mistaken very easily for acute infections. Also, we must not overlook the fact that species difference have been observed ⁽¹³⁾ in

Table 5

REASONS ALICE STEWART'S X-RAY DATA DIFFER FROM JABLON'S JAPAN DATA

1. Only children of age > 2 years have the risk of juvenile cancer. Infant mortality was up 43% among in utero exposed children and a very high abortion rate. In utero initiated cancers tipped scales for early nonmalignant death.
2. In most catastrophic situations (floods, war, disease, starvation), children suffer most and do not survive to die of cancer.
3. Neutron irradiation at Hiroshima and Nagasaki.
4. Japanese children may differ from European children, and/or European children may be uniquely exposed to a co-carcinogen.
5. Jablon data included 33 children who received > 300 rad. Stewart's data do not apply to doses at the far end of the parabola.
6. Incipient cancers during the bomb aftermath were likely mistaken for acute infection.
7. Japanese control group of bomb survivors probably had a greater cancer risk than normal.
8. The average fetal dose in the United Kingdom may have been greater than 500 mrad per examination.
9. Applying Stewart minimum coefficient of 3×10^{-4} c/person-rad to Jablon data, there should have been 5.2 cancers. If the average fetal dose in the United Kingdom (1955-59) were 800 mrad instead of 500 mrad, this becomes 3.2 cancers while one was observed. If the Japanese receiving 49-299 rad were mostly on the far side of the parabola, the 40-500+ rad yielded one cancer, but perhaps none would be expected. The 1-39 rad group yielded no cancers, and only 0.4 cancers would be expected using Stewart data--therefore agreement.

many animal experiments, and it should not be surprising to find different radiation responses in children in Japan, the United Kingdom and the United States. Most importantly, Jablon included in his study children who had received in utero very high doses of radiation, and very probably at these high doses one should expect a sharp decrease in the number of childhood malignancies. Marinelli⁽⁶⁾ and many others have shown that at high doses of ionizing radiation the malignancy curves such as those plotted in Figures 1-3 drop off to form a parabola-shaped curve, i.e., the number of malignancies reaches a maximum at some large dose and then declines at higher doses. Finally, the Japanese fetuses were exposed to both neutrons and γ -rays, and some of the differences may be due to the fact that the study groups in the United Kingdom and the United States were exposed only to x-rays. When all these factors plus the possibility that the average United Kingdom dose may have been somewhat greater than the 0.25 rem estimate are taken into account, all discrepancies in the data from the two types of in utero exposure disappear.

One of the earliest sources of human exposure that has been studied extensively is that of occupational exposure of the early radiologists. Table 6 summarizes some of the data collected by Seltser and Sartwell.⁽¹⁴⁾ Here it is observed that these early radiologists in the age group 50-64 had over seven times as many leukemias as the control group, and death from all causes in the age group 65-79 was considerably greater than for the control group. In the second part of Table 6, it is noted the early radiologist's expected life was shortened by 4.8 yr in the period 1935-44, 4 yr in the period 1945-54 and 2.9 yr in the period 1955-58. Studies of Warren⁽¹⁵⁾ indicate that beginning about 1960 when radiologists conformed more nearly with the maximum permissible occupational exposure levels recommended by ICRP and, more importantly, when most of the diagnostic x-ray exposures were delivered to patients by the x-ray technologist (and not the radiologist), there apparently has been no detectable lifeshortening of radiologists. This, of course, suggests immediately the question, "What about the x-ray technologist?" Unfortunately, we do not have an answer to this question. Certainly unless technologists heed the warning of the experience of the radiologists who operated the diagnostic x-ray machine in the early period, they can expect similar damage. Of even greater importance, unless technologists avoid unnecessary radiation exposure of their patients, many thousands of these patients will suffer consequences as indicated in Table 6.

Table 6

RATIO OF DEATHS AMONG RADIOLOGISTS TO NUMBER EXPECTED FROM THE EXPERIENCE OF OPHTHALMOLOGISTS AND OTORHINOLARYNGOLOGISTS, BY CAUSE: 1935-1958*

Age Group (yr)	Leukaemia	Cause of Death		
		Other Malignant Disease	Cardiovascular Renal Disease	Other Causes
35-49	1.0	1.2	1.0	1.7
50-64	7.3	1.7	1.1	1.4
65-79	1.9	1.5	1.4	2.0

*These data indicate the increased death rate among radiologists compared to the control groups or leukemia, other malignancies, cardiovascular and renal disease and other causes of death. The increased death rate of radiologists is thought to be the consequences of x-ray exposure. As a matter of explanation, in the age group 50-64 there were 7.3 times as many leukemic deaths and 1.7 times as many deaths from other malignancies among the radiologists between 1935 and 1958 as among the control group that did not receive occupational exposure to x-rays.

MORTALITY OF MEMBERS OF SPECIALIST MEDICAL SOCIETIES:
DEATH RATE PER 1000 MEN PER YEAR, STANDARDIZED FOR AGE

Period	Age (yr)	Death Rate		
		Radiologists	Specialist Physicians	Ophthalmologists and E. N. T. Surgeons
1935-44	35-49	6.6	4.6	3.3
	50-64	19.5	16.1	17.1
	65-79	57.6	51.7	38.9
		(71.4)*		(73.4)*
1945-54	35-49	3.5	3.8	3.5
	50-64	17.8	14.9	12.9
	65-79	57.9	45.6	39.0
		(72.0)		(74.8)
1955-58	35-49	2.1	2.1	2.7
	50-64	12.1	11.6	9.4
	65-79	59.3	44.0	42.8
		(73.5)		(76.0)
				(76.4)

*The values in parentheses are mean ages at death.

Another type of malignancy--thyroid carcinoma--likewise appears to increase more or less linearly with the dose of ionizing radiation. Hempelmann⁽¹⁶⁾ after examining the incidence of thyroid cancer among children at Ann Arbor and Rochester who had received x-ray treatment for thymic enlargement and children in the Marshall Islands whose thyroids were irradiated by ^{131}I fallout concluded, "The incidence of thyroid and extra-thyroid tumors in the Rochester series is dose dependent, and the frequency of thyroid neoplasms is age dependent until age 18. Some evidence is presented suggesting that (1) the dose response to thyroid tumors is linear in the lower dose range, and (2) there is no threshold or at least the threshold is below 20 rad." Incidentally, Lewis⁽¹⁷⁾ points out after examining data of Saenger et al⁽¹⁸⁾ that in the case of medical exposure to ^{131}I delivering rather low doses of 7 to 13 rad to bone marrow, there is a significant increase in leukemia among persons between ages 50 and 79. Other studies also have indicated an increased radiosensitivity in older age groups as well as among fetuses and children, so the rule for technologists should be to avoid all unnecessary radiation exposure regardless of the age of the patient.

As pointed out above, we are concerned not only about somatic damage from ionizing radiation but genetic damage which can manifest itself in congenital defects and deaths among our children and children yet to be born for many generations. From the early genetic studies by Muller⁽¹⁹⁾ of drosophila (flies), it was thought that genetic damage increased linearly with dose, and there could be no dose rate dependence. More recent mouse studies of Russell⁽²⁰⁾ (the results of which are plotted in Figure 5) indicate rate independence when the dose rate is above 5000 R/hr, but as the dose rate drops below 5000 R/hr, the mutation frequency for both oocytes (female) and spermatogonia (male) drop off rapidly. The rate for the oocytes drops down to background levels where, presumably, there is complete genetic repair. However, for the spermatogonia, there is a drop-off by a factor of about 3 where at about 50 R/hr there is a return to dose rate independence of mutation frequency at lower dose rates. Since there are the two sexes in every mating and assuming a drop to zero mutation frequency for the oocyte and a drop by a factor of 3 for the spermatogonia, we conclude that at least in the case of the mouse, genetic damage below a dose rate of about 50 R/hr is 1/6 that at higher dose rates. From this, however, we must not jump to the conclusion

Rate Dependence of Point Mutations in Mice. (Data from W. R. Russell, Nucleonics, 1965)

Figure 5

that genetic damage is zero at very low dose rates. At very low dose rates, it is 1/6 as great as previously considered and as at high dose rates, but at high dose rates such as are ordinarily used in medical diagnosis and therapy, there is no reduction below previous estimates and genetic damage is dose-rate independent.

If one takes the coefficient of radiation damage as given by ICRP^(3,4) and as plotted in Figure 1 and applies them to the estimates of dose to the U.S. population from medical diagnosis as given by the USPHS,⁽²⁾ the number of deaths/yr from medical diagnosis in the U.S. can be obtained as summarized in Table 7. The lower estimate of 1,100 genetic deaths/yr includes only the first generation deaths while the higher figure of 44,000 genetic deaths/yr includes those that will be introduced into future generations/yr as a result of recessive mutations. For comparison, estimates of risk are given for the nuclear energy industry. Although much has been said recently in the public press concerning this risk, it is to be observed it is very small by comparison.

In terms of the risks from diagnostic x-ray exposure as estimated from population exposure data reported by the USPHS in 1964 and as I have summarized in Table 7, it is perhaps discouraging to note that, as shown in Figure 6, the number of x-ray visits by members of the U.S. population was much greater in 1970 than in 1964. One encouraging observation of this latest 1970 USPHS survey,⁽²¹⁾ however, is that, as indicated in Figure 7, the mean ratio of beam area to film area has shown a great amount of improvement (reduction) in every area except there has been only slight improvement in private offices of radiologists and among public health agencies and other groups. One of the most promising developments recently is that a number of radiologists, technologists, dentists, and other members of the healing arts are beginning to speak out and criticize their own profession for its failure to give appropriate attention to reducing unnecessary diagnostic exposure of the patient. Perhaps the most frank and informative article of this type was by McClenahan.⁽²²⁾ Table 8 summarizes the main points of this article, and Table 9 lists a number of other reasons for excessive patient exposure that I have added for good measure. I have listed some 63 ways^(23,24) by which the average medical diagnostic dose to persons in the U.S. can be reduced at least to 1/10 the present values. Most of these can be summarized

TABLE 7

Comparison of Consequences of X-Ray Diagnostic Exposure Presently Received by the U.S. Population with the Consequences of a Continuous Exposure from all Nuclear Industries of 0.5% of the Allowed 170 mrem/yr (0.85 mrem/yr)

Types of Radiation Damage	Consequences of Medical X-Ray Diagnostic Exposure Presently Received by U.S. Population	Consequences of Hypothetical Exposure of 0.85 mrem/yr to U.S. Population from Nuclear Industries
	deaths/yr	deaths/yr
1. Genetic	1100* to 44,000**	3* to 120**
2. Leukemia	500	3
3. Thyroid Cancer		0.2*** to (2)
(a) from dental x-rays	16*** to (160)	
(b) from thorax x-rays	2*** to (20)	
4. Other Cancer	500 (2000) [†]	3 (13) [†]
5. Life Shortening	1200	8.5
Total Deaths	~ 3300 to 46,000	~ 18 to 140
	~ (5000 to 50,000) [†]	~ (28 to 150) [†]

* This includes only first generation genetic deaths and assumes the factor of 1/6 does not apply to the high dose rates ordinarily used in medical x-ray diagnosis but does apply at the very low dose rate of 0.85 mrem which would be delivered during the year.

** This includes genetic deaths in 40 subsequent generations and assumes the genetic recovery factor of 1/6 does not apply in the case of man for medical diagnostic exposure but does apply at the very low dose rate of 0.85 mrem/yr.

*** This is assuming 90% of thyroid cancers are cured by medical treatment and so are not included in this number. The numbers in parentheses include all thyroid cancers.

[†] The values in parentheses are estimates making use of ICRP Publication 14. All other estimates are made using data from earlier ICRP Publication 8. All estimates of deaths from medical diagnostic exposure make use of the medical doses reported by the U.S. Public Health Service in 1964. Probably these values would be much higher if the dose estimates from the U.S. Public Health Service 1970 survey were available.

ESTIMATED ANNUAL NUMBER OF X-RAY VISITS IN MILLIONS U.S., 1964 and 1970

TOTAL VISITS 143 MILLION FOR 1964
AND 179 MILLION FOR 1970

ESTIMATED MEAN RATIO OF BEAM AREA TO FILM AREA FOR RADIOGRAPHIC EXAMINATIONS by Type of Facility, U.S., 1964 and 1970

-21-

Table 8

SOME PRACTICES CAUSING EXCESSIVE PATIENT EXPOSURE

1. Easier to order an x-ray than think.
2. Exercise "ruling out," i.e., order x-rays when accurate diagnosis has been made with the naked eye.
3. Heavy legal penalties for failure to x-ray but no penalties for unnecessary exposure of patient.
4. Insurance covers most x-ray costs.
5. More films per diagnosis now required than formerly.
6. Shortage of trained workers leading to hasty, hazardous techniques.
7. Folkways and traditional rites.

Table 9

OTHER REASONS FOR EXCESSIVE PATIENT EXPOSURE

8. X-rays add to income of doctors or the medical institution.
9. Patient ignorance. Patient judges medical competence in terms of number of x-rays.
10. X-rays required for certain jobs (nurses, teachers, restaurant workers, etc.).
11. X-ray surveys where little need (mass chest x-ray program).
12. Required pelvimetries sometimes a routine for first pregnancy.
13. Failure to use x-rays already in files of patient.
14. Failure to use tape and computer equipment for storing and retrieving x-ray data.
15. X-rays used for psychotherapy (neurotic patients).
16. X-rays as a financial drain on Medicare and Medicaid.
17. Failure to observe special x-ray requirements for children and infants.
18. Use fluoroscopy where dynamic information is not required.
19. Lack of education and certification requirements for all who own, operate, supervise or request diagnostic x-rays.
20. Some medical x-rays of questionable and bizarre benefit to patient, e.g., practice of some chiropractors.
21. Radiology not practiced as a profession -- radiologist takes orders from others and fails to exercise professional judgment. Radiologist lacks proper motivation to maximize ratio of diagnostic information to radiation damage to patient.
22. Failure to establish professional rank of "senior technologist."
23. Medical x-rays used by insurance companies and lawyers to verify claims of injury.
24. Failure to maintain patient dose records.
25. Failure to avoid exposure to critical tissue such as CNS, active bone marrow, lens of eyes, thyroid, etc.
26. Use of mass production and cookbook procedures in radiology.
27. Lack of appropriate state or federal legislation.
28. Medical diagnostic exposure of the population should be included as part of the population dose limit of an average of 170 mrem/yr.

Table 9 (con't)

29. Poor equipment and techniques:
- (a) use of insensitive films (slow speed)
 - (b) poor developing techniques
 - (c) edges of x-ray field not showing on film
 - (d) overexposure and underdevelopment of film
 - (e) target-skin distance too short
 - (f) improper voltage
 - (g) poor coning and diaphragming
 - (h) poor timing devices
 - (i) improper filters
 - (j) insufficient shielding
 - (k) poor calibration of equipment
 - (l) some imported equipment does not indicate voltage and current
 - (m) failure of radiologist to dark adapt eyes
 - (n) use of substandard photofluorometric equipment
 - (o) lack of adequate beam centering devices
30. 1964 report of USPHS indicated the genetically significant dose from diagnostic x-rays was 55 mrem/yr. The 1970 estimate may turn out to be considerably higher.

under three headings, (1) better and more extensive education, training and certification of all members of the medical profession, (2) better use of modern equipment, and (3) the application of better diagnostic techniques. Adrian⁽²⁵⁾ gave strong evidence that medical diagnostic exposure in the United Kingdom could be reduced when he said, "If all radiological departments in the United Kingdom employed the techniques already in use in 25% of the departments in 1958, the population gonad dose from diagnostic radiology would probably be reduced by a factor of 7." This would mean, for example, a reduction of the GSD in the United Kingdom from 14 mrem/yr to 2 mrem/yr. Why then can't we in the U.S. reduce our GSD from the 1964 value of 55 mrem/yr to 5 mrem/yr? Present forecasts are that the 1970 survey, when the final compilations are complete, will indicate the GSD is now greater than 55 mrem/yr. Much of the success we seek in reversing this trend depends on the radiologic technologist. I am counting very much on him and the independent progressive thinking of leaders in his professional societies to take the necessary steps in reducing the genetic and somatic dose of the U.S. population.

Another strong incentive for reducing unnecessary diagnostic exposure of the patient is that almost every measure suggested for reducing this dose provides the opportunity for better radiograms and more meaningful diagnostic information. As indicated at the beginning of this lecture, there is no doubt that x-ray is one of the most valuable of all medical tools. We do not know how many lives it saves each year in the U.S., but we might assume arbitrarily this number is 100,000. Some might contend that there is no cause for alarm if diagnostic x-ray is causing 5,000 to 50,000 deaths/yr while it is saving 100,000 lives. Our argument, however, is that by better use of x-ray and the elimination of all unnecessary x-ray exposure of the patient we might reduce the radiation deaths by a factor of 10 (i.e., to 500 to 5,000) while at the same time the benefits of x-ray might be doubled (i.e., save 200,000 lives each year instead of 100,000).

I believe the radiologic technologist must play a major role in bringing about these improvements in diagnostic x-ray. We hear a great cry these days about the hundreds of millions of dollars the U.S. taxpayers should spend to train more radiologists. Although a sufficient supply of well trained radiologists is vital to an adequate medical program,

I do not believe there is such an urgent need for additional radiologists. Rather, I believe we must recognize the situation that exists and has existed for a long time; namely, the senior radiologic technologist has become of stature and matured to a senior member of the medical profession. He takes most of the diagnostic x-rays and knows more about the use and maintenance of the x-ray machine than the radiologist. Why then not officially recognize this grade of senior radiologic technologist? Why not require that technologists qualifying for this rank complete a carefully planned four-year program of education and training, pass a special certification examination and then be moved into the higher medical ranks? Here he would be given complete responsibility for the operation, maintenance and use of the diagnostic x-ray machine and would be paid at a rate becoming of his professional rank. He would make his own decisions commensurate with his responsibilities and plan and carry out his own program of providing the best possible diagnostic radiography with the minimum dose to the patient. Such an arrangement would relieve the need of expanding the number of radiologists and would set the radiologist free to work more closely with other members of the healing arts, to specialize on reading and interpreting the x-ray films and to concentrate most of his efforts and specialized skills on x-ray and radioisotope therapy. I believe such a working team could provide cheaper and better radiology of higher professional quality and with much less population exposure to ionizing radiation.

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