1960

Gonadal doses in certain routine diagnostic procedures at the University of Nebraska Hospital

Herbert C. Lemon
University of Nebraska Medical Center

GONADAL DOSES IN CERTAIN ROUTINE DIAGNOSTIC PROCEDURES AT THE UNIVERSITY OF NEBRASKA HOSPITAL

A Thesis

Presented To

The Faculty of the College of Medicine

The University of Nebraska

In Partial Fulfillment

Of The Requirements for the Degree

Doctor of Medicine

by

Herbert C. Lemon

April 1960

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

It has long been recognized that radiation constitutes a real and potential genetic hazard to the individual and to whole populations. With the development of apparatuses capable of producing ionizing radiation, it has become possible to subject individuals and whole populations to radiation far in excess to that of naturally occurring background radiation. It has been variously estimated that, from a genetic standpoint, medical radiographic procedures contribute radiation to whole populations amounting to 25 to 100 per cent of that of natural background radiation.[1]

The whole problem of radiation and its hazards has become more acute with the development of atomic energy. This in turn has given impetus to the medical radiologists to re-examine their diagnostic procedures in an attempt to determine the gonadal doses of radiation.

The purpose of this study is to determine the amount of irradiation to which the gonads are subject in certain routine diagnostic procedures at the University of Nebraska Hospital. The data obtained by this study will be presented along with selected data obtained by similar studies conducted elsewhere.

[1]Lars-Eric Larsson, "Radiation Doses to the Gonads of Patients in Swedish Roentgen Diagnostics," Acta Radiologica, Supplementum 157:7-8, 1958.

However, before such data is presented, it would be to advantage to review in a very general fashion what is meant by the term "radiation," its effects upon biological systems, and in particular its effects upon the gonads, with reference to sterilizing and substerilizing doses.

CHAPTER II

RADIATION AND TISSUE RESPONSES

Two forms of energy propagation are recognized by the use of the term "radiation." One of these forms is that of electromagnetic radiation which includes the roentgen and gamma rays as well as others. The second of these forms is that of particulate radiation which includes, among others, the alpha and beta particles, neutrons, deutrons and protons. Electromagnetic and particulate radiation are capable of producing identical biological effects.

Ionizing radiation is a product of either the rays from the electromagnetic spectrum or of the particulate radiation which have sufficient energy to ionize those materials which absorb them. The roentgen is measured in terms of ionization of air and is applicable for both roentgen rays and gamma rays of the electromagnetic spectrum. In order to equate the electromagnetic spectrum to the particulate radiation, a unit known as the roentgen equivalent physical (rep) was devised such that one rep is 83 ergs of energy absorbed. This is roughly that amount of energy absorbed by one gram of air exposed to one roentgen.

In this regard, the shorter the wavelengths, the greater the energy and penetrating powers. Thus, gamma radiation exhibits more penetrating power than ordinary roentgen rays. Very little of the effects upon biological systems are attributable to the primary rays themselves for when radiation is absorbed by tissues most of its energy is scattered by secondary electrons in turn adding their effect in the form of longer waves to the original radiation.

It is generally held that the cellular injury observed is a product of ionizing radiation although there is no uniformity of agreement as to the mechanism of action by ionizing radiation in the production of cellular or tissue injury. Among the theories proposed are: (1) denaturation of nucleoproteins; (2) inactivation of enzyme systems; (3) coagulation and flocculation of protoplasmic colloids; and (4) "direct action." Recently, water has been shown to play an important role in the production of tissue or cellular injury by ionizing radiation through the formation of free hydrogen, hydroxyl groups, and peroxides from the water. These are released into the extra- and intracellular water, causing injury by their interactions with other cellular substances.[1]

Not all cells are equally responsive to a given amount of irradiation. For example, a single dose of irradiation delivered to a number of lymphocytes will not produce identical changes in all the cells thus exposed though one considers that each cell received identical amounts of irradiation. Not only is there a cellular difference in response but also a tissue difference in response. Thus, lymphocytes and germ cells are very sensitive to irradiation while bone and adult nervous tissue is relatively less sensitive. In general, poorly differentiated cells are more

[1]Charles E. Dunlap, "Effects of Radiation," Pathology, W. A. D. Anderson, editor. (Third Edition; St. Louis: C. V. Mosby, 1957), p. 167.

susceptible than well differentiated cells of the same type. Similarly, those cells in an active process of mitotic division are more susceptible than resting cells.

The testes and ovaries are extremely radiosensitive, a single or cumulative dose of 500 roentgens to the gonads usually is sufficient to produce sterility in either males or females. In the ovary, the histological changes produced by irradiation are, in their order of appearance: (1) a degeneration of the granulosa cells; (2) degeneration and disappearance of the ova from the maturing follicles; (3) a gradual, progressive damage to the stromal cells; and (4) a slight effect on the corpora lutea. The net result is an alteration in or a disappearance of the menstrual cycle since follicle maturation, ovulation, and corpus luteum formation all cease.[2]

In the testes, one observes the following: (1) a degeneration or destruction of the germinal epithelium; (2) a destruction of the intermediate stages of spermatogenesis; (3) a destruction of the spermatogonia or mature spermatozoa; (4) a destruction of the interstitial cells. Here, the net result is that the testes become smaller and softer with the production of sterilization.[3]

While the effects of sterilizing doses of radiation to the gonads are readily observed histiologically, an evaluation of the effects of substerilizing doses is difficult. Irradiation will

[2] *Ibid.*, p. 176.

[3] Loc. cit.

injure chromosomes and thus increase the rate of genetic mutations because of its effect on desoxyribose nucleic acid upon which genetic factors are formed.[4] The result may be the death of the cell or an alteration in chromosomal pattern to produce a hereditary defect the emergence of which may or may not be observed in subsequent generations. If the defect is of sufficient magnitude, the offspring may not survive. On the other hand, a lesser defect may be masked or lost unless combined with a similar chromosomal alteration from the second parent. It has been shown that the frequency of mutations can be a function of radiation dose and that these mutations express themselves in linear proportions.[5] Theoretically, then, any dose of irradiation regardless of its magnitude may be considered mutagenic.

However, in higher forms of life, this genetic effect is difficult to observe. These effects may manifest themselves as slight reductions in life expectancy, as a decrease in fertility, as increased susceptibility to ordinary illnesses, or other non-specifics. In a study of 65,431 infants born to Japanese parents between the years 1948-53, no differences were observed between the children of irradiated parents and of control parents.[6]

[4]Bentley Glass, "The Genetic Basis for the Limitation of Radiation Exposure," American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 78:955, December, 1957.

[5]Ibid., p. 956.

[6]James V. Neel, "The Delayed Effects of Ionizing Radiation," Journal of the American Medical Association, 166:910-11, February 22, 1958.

However, the genetic effects of radiation are cumulative and delayed. Therefore, future studies of the progeny of these children may evidence clear differences.

Methods of assaying "permissable" radiation doses are approached with difficulty. As it has been suggested, any radiating dose is mutagenic. An attempt has been made to quantitate the "spontaneous mutations" to those artificially produced by irradiation, such that those of the latter would be double the number of the former after a number of generations. This is the so-called "doubling dose." If all of the "spontaneous mutations" were due to background irradiation, then the "doubling dose" would be equal to the background radiation (3.1 rem).[7] However, this does not seem to be the case for with Drosophila not more than 1/1000 of the "spontaneous mutations" are attributed to background irradiation.[8] For man, then, the "doubling dose" would have to be in the range of 40-80 r delivered to the gonads per generation.[9]

To utilize this range as a "permissible" dose would be unrealistic in view of present-day knowledge, for it has recently been demonstrated that mice are approximately fifteen times more sensitive to the production of radiation induced mutations than are Drosophila.[10] Thus, where man is concerned, neither Drosophila

[7] Glass, op. cit., p. 958.

[8] Loc. cit.

[9] Loc. cit.

[10] James F. Crow, "Genetic Considerations in Establishing Radiation Doses," Radiology, 69:18, July, 1957.

nor mice can serve as an adequate index toward "permissible" radiation doses. The National Academy of Sciences of Washington, D. C., recommends that radiation doses to the gonads from conception to the age of 30 years not average more than 10 r in addition to background radiation.[11]

It has been estimated that approximately 40 per cent of the total radiation which the gonads of persons living in the United States receive during a 30 year period is derived from background radiation. Fallout, at the rate of testing during the 1951-1955 period, provides another one per cent. The remaining 59 per cent is contributed by medical radiographic diagnostics and radiotherapeutics, 52 per cent due to diagnostic procedures alone, the other 7 per cent to radiotherapy. In total (100 per cent) this amounts to 7.8 r delivered to the gonads over a 30 year period.[12] If one subtracts from the total (7.8 r) that due to background radiation (3.12 r), the remainder (4.68 r) is a product of man-made radiation. Of this, 0.1 r (or 2 per cent) could be attributed to fallout, 0.5 r (or 10 per cent) could be attributed to radiotherapy, and 4.1 r (or 87 per cent) due to diagnostic radiology. This evidence alone offers sufficient reason to undertake a study of the amount of radiation delivered to the gonads from diagnostic procedures in any given institution and to examine these doses in accord with similar reports of other institutions.

[11] _Loc_. _cit_.

[12] Neel, _op_. _cit_., p. 911.

CHAPTER III

REVIEW OF SELECTED STUDIES

It was implied in the preceding chapter that given a known gonadal dosage one might easily compare this with the reports of gonadal dosages from similar institutions. Unfortunately, this is hardly the case for the reports to not lend themselves to direct comparison. There are numbers of techniques used in determining the amount of irradiation which the gonads receive. To compound this confusion, there are numbers of variables in any given procedure which will further alter the results. In the course of the following discussion many, but not all, of these techniques and variables will be mentioned. The studies presented here do not constitute the whole of those found in the literature but rather are selected because of the particular type of the study, their relative completeness, or their applicability to comparison with this study.

Ardran and Crooks[1] obtained their data on male gonadal dosage by applying small ionization chambers on the scrotum. This they supplemented with the application of intensifying screens and screen-type films applied near the scrotal region. In certain procedures, they utilize lead rubber protection to the testes, resulting in marked decrease of testicular dose. In determining

[1] G. N. Ardran and H. E. Crooks, "Gonad Radiation Dose from Diagnostic Procedures," British Journal of Radiology, 30:295-6, June, 1957.

female gonadal dosage, these authors used a Mix D phantom 9 inches thick in which it was assumed that the ovaries were one-half the distance between the front and the back of the body.

Billings et al[2] obtained their data on male gonadal dosage by measuring the ionization on a tissue equivalent phantom where the testes were considered at a caudal mid-point 2.5 cm. beneath the anterior surface. This was further supplemented by direct measurements on male patients undergoing chest examinations. In the case of the female, they utilized a tissue equivalent phantom in which the ovaries were assumed to be 9 cm. below the anterior surface, 8.5 cm. above the inferior margin of the symphysis pubis, and 4.5 cm. from the midline on each side.

Stanford and Vance[3] determined testicular dose by direct measurements upon male patients. In determing the ovarian dose, they made use of an indirect method utilizing conversion factors of ovarian dose to the skin dose. These conversion factors were obtained by placing ionization chambers in contact with ovaries of cadavers and exposing them to radiation much as one would a patient. This was also supplemented with examinations of Mix D and water phantoms. The results reported represent the average

[2] M. S. Billings, A. Norman and M. A. Greenfield, "Gonad Dose During Routine Roentgenography," Radiology, 69:37, July, 1957.

[3] R. W. Stanford and J. Vance, "The Quantity of Radiation Received by the Reproductive Organs of Patients During Routine Diagnostic X-Ray Examinations," British Journal of Radiology, 28:266-7, May 1955.

quantities of radiation in milliroentgens received per film as measured on 1,500 patients. The skin dose which is presented in this study is a measure of that in the center of the beam.

Martin[4] obtained his data on testicular doses by applying ionizing chambers to the scrotum. In the female, to determine ovarian doses, the data presented was variously obtained by placing ionizing chambers in the posterior formix of the vagina in some cases, by calculating the depth doses in the direct beam in other cases, and with the use of phantoms in still other cases. It is assumed by this writer that the dosages given are averages obtained from these three techniques.

Ritter _et al_[5] derived their data by measuring air-dose rates. Skin and depth doses were computed by combining air dose rates, the data on half-value layers and data on percentage back-scatter and percentage depth dose. The values obtained employing Ritter's curves are admittedly high so as to be the maximum dosage received. Actual measurement, according to Ritter, might be as much as 33.3 per cent less than the computed value.

As noted earlier, not only are there many techniques utilized in an attempt to measure gonadal doses, but also there are many variables within any given technique, all of which serve to alter the results obtained.

[4] J. H. Martin, "Radiation Doses to the Gonads in Diagnostic Radiology and Their Relation to the Long-term Genetic Hazard," _Medical Journal of Australia,_ 2:806, November 12, 1955.

[5] Vern W. Ritter, S. Reid Warren and Eugene P. Pendergrass, "Roentgen Doses During Diagnostic Procedures," _Radiology,_ 59: 238-9, August, 1952.

The first of these variables is the effect of filtration. Here there is seemingly contradictory evidence as to the effect of filtration. Martin[6] states that, all other variables being constant, changing of the filter from zero to one millimeter of aluminum will reduce the skin dose by 33 per cent and the ovarian dose by 16 per cent. Stanford and Vance[7] on the other hand contend that while filters in the primary beam cause significant decreases in skin dose, there is little effect upon the quantity of radiation reaching the gonads as a result of scatter. These authors point out that the utilization of filtration necessitates the use of longer exposure time to produce the same amount of blackening on an X-ray film. They conclude that if an ovary is in the direct beam, the dose received by it may be increased slightly.

The second variable serving to alter gonadal dosage within a given technique is that of kilovoltage. It is generally believed that an increase in kilovoltage will permit greater penetration of the beam with a consequent dose reduction by virtue of a lowering of mA and mAs figures. Martin[8] states that changing the kilovoltage from 85 to 130, for a beam filtered with one millimeter of aluminum, will reduce the skin dose by 78 per cent while effecting a reduction in ovarian dose of 45 per cent. Stanford and Vance[9]

[6] Martin, op. cit., p. 809.

[7] Stanford, op. cit., p. 272.

[8] Martin, op. cit., p. 809.

[9] Stanford, op. cit., p. 270.

The first of these variables is the effect of filtration. Here there is seemingly contradictory evidence as to the effect of filtration. Martin[6] states that, all other variables being constant, changing of the filter from zero to one millimeter of aluminum will reduce the skin dose by 33 per cent and the ovarian dose by 16 per cent. Stanford and Vance[7] on the other hand contend that while filters in the primary beam cause significant decreases in skin dose, there is little effect upon the quantity of radiation reaching the gonads as a result of scatter. These authors point out that the utilization of filtration necessitates the use of longer exposure time to produce the same amount of blackening on an X-ray film. They conclude that if an ovary is in the direct beam, the dose received by it may be increased slightly.

The second variable serving to alter gonadal dosage within a given technique is that of kilovoltage. It is generally believed that an increase in kilovoltage will permit greater penetration of the beam with a consequent dose reduction by virtue of a lowering of mA and mAs figures. Martin[8] states that changing the kilovoltage from 85 to 130, for a beam filtered with one millimeter of aluminum, will reduce the skin dose by 78 per cent while effecting a reduction in ovarian dose of 45 per cent. Stanford and Vance[9]

[6] Martin, op. cit., p. 809.

[7] Stanford, op. cit., p. 272.

[8] Martin, op. cit., p. 809.

[9] Stanford, op. cit., p. 270.

are in agreement with Martin in that an increase in kilovoltage will produce a reduction in skin dose by as much as one-third. However, these authors (Stanford and Vance) state that the depth dose may be increased by four to five times and that the amount of scatter may be increased by 50 per cent, the net result being an increase in gonadal doses for both male and female patients where high kilovoltage is utilized.

Ardran and Crooks,[10] in a well controlled study, give added support to Martin's observations. These authors report substantial reductions in depth dose (as well as surface dose) while maintaining equivalent emergent doses with the addition of 3 mm. of aluminum filtration. The presence of the filter necessitated increasing the mAs from 200 to 300 at 65 kV. Even further reductions in surface and depth doses were noted when the kVs were increased from 65 to 90. This permitted them to decrease the mAs. The emergent doses remained comparable throughout. Similar results were noted in measuring male gonadal doses in the presence of added filtration and increased kilovoltage.[11]

Another variable altering gonadal dosage within a given technique is that of field size. Stanford and Vance[12] note that when the beam diameter is increased from 5 inches to 12 inches, there is a 10 fold increase in radiation dosage.

[10] Ibid.

[11] Ardran, op. cit., p. 296.

[12] Stanford, op. cit., p. 270.

The anode to film distance is still another factor. According to Stanford and Vance[13] an increase in this distance will result in a decrease in skin dose but still increase the volume of tissues radiated with a corresponding increase in scatter. The net result is about the same so that dosage to the gonads is not a function of anode-film distance.

There are still other factors which alter the results. These include the response of radiation detectors to different qualities of radiation,[14] differences in dose rates between roentgen apparatuses and errors in kV and mA-meters. The technician also plays a role in altering dosages.

In summary, the number of techniques and variables give use to varied results. This, in turn, makes a direct comparison between studies very difficult, if not impossible. Therefore, when such a study as this is undertaken, it will be of most value to the institution at which the study was made, for it serves as a measure of current radiation doses and establishes a base line for other studies within the institution.

[13] *Loc. cit.*

[14] J. S. Laughlin et *al.*, "Bone, Skin and Gonadal Doses in Routine Diagnostic Procedures," *The American Journal of Roentgenology, Radium Therapy and Nuclear Medicine*, 78:962, December 1957.

CHAPTER IV

EXPERIMENTAL METHODS AND COMMENTS ON THE DATA OBTAINED AT THE UNIVERSITY OF NEBRASKA HOSPITAL

1. Instruments

A PICKER full wave rectifier served as the radiation source in all measurements recorded at the University of Nebraska Hospital. KELEKET ionizing chambers with a range of 0 to 200 milliroentgens were utilized in determining the gonadal doses. VICTOREEN ionization chambers with a range of 0 to 25 r were utilized in determining the skin doses. The doses reported with the latter meters were not corrected for temperature or humidity.

2. Techniques

The ovarian doses were determined by inserting a KELEKET ionization chamber about which had been placed a rubber sheath into the vaginal fornix. The testicular dose was determined by taping a KELEKET ionization chamber to the medial aspect of the upper thigh. The patient was then subjected to certain routine diagnostic procedures as conducted at the University of Nebraska Hospital. The positioning of the patients and adjusting of the equipment was performed by two technicians employed in the hospital. After each examination, the chambers were removed and the dosages observed and recorded by this writer. The ionization chambers were again recharged and replaced in their respective positions for the next procedure.

Skin doses were measured with the VICTOREEN chambers. These chambers were placed on a phantom in such a fashion that the upper half of the chamber was exposed to air and the lower half was imbedded in the phantom in the longitudinal plane. The anode-skin distance, the kV, mAs, and filtration were adjusted according to the type of examination. The doses thus obtained were noted and recorded.

The KELEKET ionizing chambers were known to record within ± 10 per cent accuracy with the tendency to record elevated levels. The chrome-plated shaft VICTOREEN and meter were stable. Correction factor (.997) for temperature and barometric pressure was not applied to doses recorded.

In the following tables, the data obtained at the University of Nebraska Hospital is presented along with similar data from other institutions noted in the literature. This data is arranged according to the type of examination.

TABLE I

RADIATION DOSE (mr) IN EXAMINATION OF THE SPINE

TYPE OF EXAMINATION	SOURCE	kV	mas	Filter	Skin Dose	Testes	Ovaries	Comments
Spine, Cervical								
A. P.	Stanford & Vance	58	100	0	1500	0.27	0.06	
	Univ. of Nebraska	60	50	3	*	*	*	* = dosage below recording level of ionizing chamber
Lateral	Stanford & Vance	70	150	0	1100	0.92	0.20	
	Univ. of Nebraska	76	40	3	*	*	*	* = dosage below recording level of ionizing chamber
Spine, Dorsal								
A. P.	Ardran & Crooks	75	80B	3	480	1.0	1.3	B = Bucky
	Stanford & Vance	62	200	0	4700	8.0	11.0	
	Univ. of Nebraska	68	70	3	600	5.0	10.0	

TABLE I (CONTINUED)

TYPE OF EXAMINATION	SOURCE	kV	mas	Filter	Skin Dose	Testes	Ovaries	Comments
Lateral	Stanford & Vance	68	200	0	10,700	13.0	2.1	
	Univ. of Nebraska	82	70	3	*	8.0	2.0	* = dosage below recording level of ionizing chamber
Spine, Lumbar A.P.	Ardran & Crooks	75	80B	3	480	0.5*	95	B = Bucky * = lead rubber protection
	Stanford & Vance	68	200	0		24	227	
	Univ. of Nebraska	72	370	3	2600	20	180	
Lateral	Ardran & Crooks	85	300B	3	2000	2.25	270	
	Stanford & Vance	72	500	0	12400	26.6	86	
	Univ. of Nebraska	80	300	3	3500	24.0	96	

TABLE II

RADIATION DOSE (mr) IN EXAMINATION OF THE CHEST

TYPE OF EXAMINATION		SOURCE	kV	mas	Filter	Skin Dose	Testes	Ovaries	Comments
Chest									
	A. P.	Ardran & Crooks	90	3(nA)	3	8	0.01	0.02	
		Billings et al.	62	13	3	15			
		Stanford & Vance	68		0	160	0.36	0.07	mA = 300 sec. = AT
		Univ. of Nebraska	97	200	3	*	*	*	200 mas = 10x normal; * = dosage below recording level af ionizing chamber.
	Lateral	Univ. of Nebraska	97	200	3	*	*	*	200 mas = 10x normal; * = dosage below recording level of ionizing chamber.

TABLE III

RADIATION DOSE (mr) IN EXAMINATION OF ABDOMEN

TYPE OF EXAMINATION	SOURCE	kV	mas	Filter	Skin Dose	Testes	Ovaries	Comments
Abdomen								
A. P.	Ardran & Crooks	75	60B	3	360	0.5*	75	* = lead rubber shield
	Billings et al	62	100	3	460		155	
	Stanford & Vance	72	100	0	2200	69	200	
(Stomach)	Martin					180	150	One film
	Univ. of Nebraska	83	40	3	400	4	20	
(Cholecystography)	Martin					3	90	
	Univ. of Nebraska	66	100	3	*	2	87	* = dosage below recording level of ionizing chamber

TABLE IV

RADIATION DOSE (mr) IN EXAMINATION OF THE PELVIS

TYPE OF EXAMINATION		SOURCE	kV	mas	Filter	Skin Dose	Testes	Ovaries	Comments
Pelvis									
	A. P.	Ardran & Crooks	75	80B	3	480	20.0*	80	* = lead rubber protection
		Billings et al	66	100	3	500	500	200	
		Stanford & Vance	65	100	0	4700	1100	210	
		Ritter et al	58	420	1	5300		600	
		Univ. of Nebraska	73	70	3	500	200+	80	Testicular dose greater than range of ionizing chamber
	Lateral	Ritter et al	74	750	1	21000		2800	
		Univ. of Nebraska	93	200	3	3000	142	200+	Ovarian dose greater than range of ionizing chamber

3. Comments on Data

The difficulties encountered in measuring radiation doses which range from fractions of a milliroentgen to thousands of milliroentgens are many. To do so adequately would require a number of ionizing chambers of various ranges. Only a limited number of such chambers were available for this study and in many instances these chambers were not within the radiation range to be measured. The lowest gonadal dose reported in this study was 2 mr. When one considers that the ionizing chamber's range was from 0 to 200 mr the value of 2 mr can only be held in question. The next highest gonadal dose reported is 4 mr. If all those doses not recorded in the study were below 4 mr, the study would still be of significance.

Similarly, in measuring the skin doses, an ionizing chamber with a range of 0 to 25 r was employed. Here, the lowest dose reported is 400 mr. This value can be similarly held in question. The next highest value is 500 mr. Again, if all doses not recorded were below 500 mr, the study is still significant.

It should also be noted that the radiation doses reported are not true gonadal doses. Rather, it is a measure of the radiation in the region of the gonads.

Perhaps the most outstanding thing one observes from examining the preceding tables is the wide range of doses reported. When one recalls the several techniques utilized in measuring gonadal doses, along with the several variables (kV, filtration, field size, etc.) alluded to earlier, and other difficulties encountered during the course of the experiment, then one develops some tolerance and appreciation for these wide ranges. It is readily observed that there is no uniformity in practical application of roentgenographic procedures.

In the data presented, it would seem that the addition of a filter markedly reduces skin dose and, to a lesser extent, gonadal dose. The relationship of kilovoltage to skin and gonadal dosage is not apparent from the limited data presented.

It will be noted that the skin and gonadal doses reported at the University of Nebraska Hospital are well below those of Stanford and Vance. It will be recalled, however, that Stanford and Vance did not employ filtration and that the ovarian doses which they report are derived from the conversion factors which they had developed.

From the preceding tables it can be observed that Ardran and Crooks report the lowest radiation doses to the skin and to the gonads of those selected studies presented. They employed direct measuring techniques for testicular doses and a Mix D phantom for ovarian doses. The kV, mAs, and filtration which they utilized were similar to those reported for the University of Nebraska Hospital. It can be seen that the skin doses reported at the University of Nebraska Hospital were consistently greater than those reported by Ardran and Crooks. The testicular doses at the University of Nebraska Hospital are consistently higher than those reported by Ardran and Crooks. However, these authors employed a lead rubber shield to protect the male gonads. This shield served to reduce significantly the radiation dose to the male gonads. The ovarian doses reported at the University of Nebraska Hospital are, in most instances, below those of Ardran and Crooks. In oné instance, the dose level is identical (Pelvis, A. P.). In another (Dorsal Spine), the University of Nebraska Hospital reporting dose is greater. However, it should be noted that the "ovarian dose" as measured at the University of Nebraska Hospital does not, by virtue of the ionizing chambers position, truly represent the gonadal dose, but rather that amount of radiation in the region of the female gonads.

A direct comparison between the data reported by Billings et al. and that reported at the University of Nebraska Hospital cannot be made. Generally, that data obtained at the University of Nebraska Hospital was based upon higher kVs and lower mas. than that obtained by Billings et al. Billings et al. record higher values for gonadal doses than that observed at the University of Nebraska Hospital. The difference in values is great enough to suggest that factors other than kV and mas. are operating.

CHAPTER V

METHODS IN REDUCING GONADAL DOSES

Several methods for reducing gonadal doses have been previously mentioned. These included: (1) the use of higher kilovoltage which, with the greater penetration of the beam, made it possible to reduce the mA and the mAs; (2) the use of filtration; and (3) reducing the field size, particularly in male examinations of the lumbar and sacral spine, the hip and others, which will serve to lower gonadal doses by factors of 10 to 100.

Other approaches to the reduction of gonadal doses would include periodic checks of the apparatuses for their output, tube leaks, and for cone leaks. More direct approaches might include lead-rubber protection to the scrotum in certain types of examinations.

It is almost trite to suggest that before a particular examination be undertaken that there be good indications for this examination. However, this is a very sure means of reducing gonadal dosage. This is particularly true when it involves examinations of the pelvic region. While such examinations represent only 2 to 4 per cent of all roentgenographic examinations, they contribute between 60 and 70 per cent of the total amount of radiation received by the reproductive organs. In marked contrast, examinations of the skull, chest and extremities constitute eighty per cent of all examinations yet contribute only about one per cent of the average amount of radiation received by the reproductive organs.[1] In the case of obstetric examinations, it has been shown that in 90 per cent of all such examinations the findings are normal.[2]

There are two special examinations which deserve additional mention. The first of these, the obstetrical examination, has already been noted. What has not been noted, is that, from a genetic point of view, the gonadal dose to the fetus may be extremely high. The second special examination is that of young children and infants. Here one approaches total body irradiation in many types of examinations.

[1] R. W. Stanford and J. Vance, "The Quantity of Radiation Received by the Reproductive Organs of Patients During Routine Diagnostic X-Ray Examinations," British Journal of Radiology, 28:271, May 1955.

[2] Lars-Eric Larsson, "Radiation Doses to the Gonads of Patients in Swedish Roentgen Diagnostics," Acta Radiologica, Supplementum 157:119, 1958.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. Summary

Radiation constitutes a real and potential genetic hazard to the individual and to whole populations. The increased use of medical radiographic procedures plus the development of and the use of atomic energy have served to increase the amount of radiation to which man is subjected to ranges far in excess of that of naturally occuring background radiation. It has become necessary for medical radiologists to re-examine their diagnostic procedures in an attempt to determine the amount of irradiation to which the gonads are subject during such procedures.

The purpose of this study was to determine the amount of irradiation to which the gonads are subject in certain diagnostic procedures at the University of Nebraska Hospital and to compare these results with those obtained by other investigators.

Also presented was a brief introduction into the definition of and types of radiation along with their effects upon the gonads. A distinction was made with respect to sterilizing doses and their histological effects as contrasted with substerilizing doses and their mutagenic components.

Selected articles from the literature were reviewed as to the techniques employed in measuring gonadal doses. Also, the effects of certain variables such as filtration, kilovoltage and field size were discussed with respect to their alteration of skin and gonadal doses.

The experimental portion of this study was outlined with respect to instruments used and the techniques employed. The experimental data were presented along with critical comments about the experiment. The data were then compared with that obtained by other investigators.

Several methods for reducing gonadal dosage were mentioned. Special attention was directed toward certain types of examinations which inherently produce high gonadal doses.

2. Conclusions

Within the limitations of the experimental data, it was shown that the gonadal doses delivered by certain radiographic procedures at the University of Nebraska Hospital compared very favorably with those observed by other investigators and were, in most instances, less than those observed at other institutions. However, this should not lead to complacency and every effort should be made to keep the gonadal doses to a minimum.

It is admitted that the mutagenic effects of irradiation upon man are not well known. What is known is that irradiation is mutagenic and that the future promises higher rather than lower environmental radiation. It is imperative, therefore, that medical radiologists know the gonadal doses in their diagnostic procedures and that strong efforts be made to reduce this dosage. The fact that there is no uniformity of agreement as to the amounts of irradiation which the gonads receive during such procedures means only that future study is indicated.

SELECTED BIBLIOGRAPHY

Ardran, G. M. and H. E. Crooks. "Gonadal Radiation Dose from Diagnostic Procedures," British Journal of Radiology, 30:295-7, June 1957.

Billings, M. S., A. Norman and M. A. Greenfield. "Gonad Dose During Routine Roentgenography," Radiology, 69:37-41, July 1957.

Chamberlain, Richard H. "A Summary: Today's Problems in Radiation Hazards and What is Being Done to Control Them," The American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 78:1000-2, December, 1957.

Crow, James F. "Genetic Considerations in Establishing Maximum Radiation Doses," Radiology, 69:18-22, July 1957.

Dunlap, Charles E. "Delayed Effects of Ionizing Radiation," Radiology, 69:12-17, July 1957.

_______, "Effects of Radiation," Pathology, W. A. D. Anderson, editor. (Third edition; St. Louis: C. V. Mosby, 1957), pp. 161-183.

Glass, Bentley. "The Genetic Basis for the Limitation of Radiation Exposure," American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 78:955-60, December 1957.

Larsson, Lars-Eric. "Radiation Doses to the Gonads of Patients in Swedish Roentgen Diagnostics," Acta Radiologica, Supplementum 157:1-127, 1958.

Laughlin, J. S., et al. "Bone, Skin and Gonadal Doses in Routine Diagnostic Procedures," The American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 78:961-982, December 1957.

Lincoln, Thomas A., and Edwin D. Gupton, "Radiation Dose to Gonads from Diagnostic X-Ray Exposure," Journal of the American Medical Association, 166:233-9, January 18, 1958.

Martin, J. H. "Radiation Doses to the Gonads in Diagnostic Radiology and Their Relation to Long-Term Genetic Hazard," Medical Journal of Australia, 2:806-810, November 12, 1955.

Neel, James V. "The Delayed Effects of Ionizing Radiation," Journal of the American Medical Association, 166:908-16, February 22, 1958.

Ritter, Vern W., S. Reid Warren and Eugene P. Pendergrass. "Roentgen Doses During Diagnostic Procedures," Radiology, 59:238-251, August 1952.

Stanford, R. W., and J. Vance. "The Quantity of Radiation Received by the Reproductive Organs of Patients During Routine Diagnostic X-Ray Examinations," British Journal of Radiology, 28:266-273, May 1555.