Annals of the ICRP

Published on behalf of the International Commission on Radiological Protection

RADIATION PROTECTION

ICRP PUBLICATION 34

Protection of the Patient in Diagnostic Radiology

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A report of Committee 3 of the
International Commission on Radiological Protection

ADOPTED BY THE COMMISSION IN MAY 1982

This report supersedes ICRP Publication 16

PUBLISHED FOR

The International Commission on Radiological Protection

by

PERGAMON PRESS

OXFORD · NEW YORK · TORONTO · SYDNEY · PARIS · FRANKFURT

UK	Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, England
USA	Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, USA
CANADA	Pergamon Press Canada Ltd., Suite 104, 150 Consumers Road, Willowdale, Ontario M21 1P9, Canada
AUSTRALIA	Pergamon Press (Aust.) Pty. Ltd., PO Box 544, Potts Point, NSW 2011, Australia
FRANCE	Pergamon Press SARL, 24 rue des Ecoles, 75240 Paris, Cedex 05, France
FEDERAL REPUBLIC OF GERMANY	Pergamon Press GmbH, Hammerweg 6, D-6242 Kronberg-Taunus, Federal Republic of Germany

First edition 1982

ISBN 0 08 029797 8

PREFACE

Because of the special relationship that exists between the International Commission on Radiological Protection and the International Society of Radiology, and because of its contacts with the medical profession, ICRP has traditionally provided detailed information on radiation protection in medicine. In 1970 the Commission published "Protection of the Patient in X-ray Diagnosis" (*ICRP Publication 16*). In 1978 it appointed a task group of Committee 3 to prepare a revised version of that report. The members of the task group were:

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The help of J. G. Kereiakes, M. Rosenstein and S. R. Thomas is gratefully acknowledged.

Phototypesetting by Cotswold Typesetting Ltd., Gloucester
Printed in Great Britain by A. Wheaton & Co. Ltd

Annals of the ICRP

Published on behalf of the International Commission on Radiological Protection

Editor: F. D. SOWBY *ICRP, Sutton, Surrey*

Subscription Rates
Annual subscription, including postage and insurance (1983) $190.00
Two-year subscription, including postage and insurance (1983/84) $361.00

Annals of the ICRP is published as 12 issues per year in 3 volumes. Each report will be published as soon as material is received from the ICRP, so that issues will not necessarily appear at regular intervals.

Subscription enquiries from customers in North America should be sent to:
Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, NY 10523, U.S.A.,
and for the remainder of the world to:
Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, U.K.

Microfilm Subscriptions and Back Issues
Back issues of all previously published volumes are available in the regular editions and on microfilm and microfiche. Current subscriptions are available on microfiche simultaneously with the paper edition and on microfilm on completion of the subscription year.

ISBN 0 08 029797 8

Pergamon Press

Headington Hill Hall
Oxford OX3 0BW, England

Maxwell House, Fairview Park
Elmsford, NY 10523, USA

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CONTENTS

INTRODUCTION

Diagnostic x-ray procedures cause the major contribution to man's exposure to ionizing radiation from artificial sources. Work on radiation protection in medical fields has been going on since the beginning of the century. Equipment and procedures have been developed with recognition of the harmful effects that could ensue. Hence, the degree of safety is now so high that an x-ray examination, recommended on the basis of qualified clinical judgment, generally brings a benefit to the patient entirely outweighing the unavoidable radiation risk.

However, there should be no excuse for examinations to be carried out with unnecessary exposure. The Commission's basic principle that all radiation doses be kept "as low as reasonably achievable" should always apply. The Commission has developed principles which allow the assessment of how far it is reasonable to go in cost and efforts to reduce radiation exposures. These methods apply in principle, and should also apply in practice, in the protection of the patient in diagnostic radiology.

The aim of the radiation protection of the patient has gradually shifted from a concern about population exposures and hereditary effects, to the ambition of limiting the risk to the individual patient. The aim is to ensure that the doses are not only low enough to justify the particular diagnostic examination, but are kept even lower when this is reasonably achievable.

The limitation of risk to the individual patient is usually implicit in the medical decision that a particular examination is in the interest of the patient, provided appropriate equipment and examination techniques are employed. The justification of the examination and the optimum use of equipment and techniques then make any explicit limits of radiation dose inapplicable. The Commission's dose limits for exposure of members of the public are therefore not applicable to doses from the medical exposure of patients.

If each individual examination is properly justified, the collective risk is by necessity also justified. There is, therefore, no reason to limit the total collective radiation dose from medical exposures below any value that would simply be the sum of the individual doses from appropriately performed examinations.

It is still necessary to assess collective doses from various medical procedures since this gives a useful indication of where protective measures related to design or choice of procedure might have a large impact. In optimizing design of equipment which influences the exposure of a group of patients, their collective dose will be of direct interest.

This report is intended to guide radiologists and others concerned with diagnostic radiology with regard to the factors that influence radiation doses, and hence radiation risks, from different types of x-ray examination. It supersedes *ICRP Publication 16* (I5) on the same subject.*

The welfare of the patient and the population at large will be enhanced if radiation exposures resulting from x-ray examinations can be reduced without reduction of medical benefits. For example, the principal contributors to the annual average per caput dose equivalent are natural background and medical radiation. These two components are respectively 2 mSv and 1 mSv per year. The contribution from all other sources is less than 10% of this value (J1, N4). Consequently, medical exposure is the only category in which large reductions in average dose are possible, and it is therefore highly desirable to reduce applications of medical radiation

* In this report there is no discussion of protection of the patient in nuclear medicine or in radiation therapy since these topics will be taken up in separate publications.

which are of no benefit to the patient and to minimize useless radiation in the course of medical examinations.

In the Commission's recommendations "medical exposure" refers to the intentional exposure of patients for diagnostic and therapeutic purposes. It applies to exposures administered by medical and paramedical personnel. It does not refer to the irradiation of the staff involved in the administration of medical exposures to patients, which is discussed in *ICRP Publication 26* (16) and *ICRP Publication 33* (18).

The material in the first three sections is intended primarily for all those who may take part in the decision to conduct a radiological examination; included in this group are all practitioners associated with medical and dental care. Section 4 is concerned with technical measures and is addressed mainly to persons involved in the performance of the examination.

The establishment of effective measures for patient protection should not impede the continuing scientific and technical development of radiological diagnosis. Such developments contribute to the highest standards of clinical radiological practice.

One factor in the decision to conduct an x-ray examination is the increasing availability of alternative procedures using both ionizing and non-ionizing radiations—e.g. digital radiography, nuclear magnetic resonance and many new applications of computer processing (C2).

1. GENERAL PHYSICAL AND BIOLOGICAL PRINCIPLES

1.1. Introduction

Appreciation of the material in the subsequent sections requires an understanding of the physical and biological phenomena associated with ionizing radiation. These subjects are not covered in detail in this report; broad principles are enunciated.

1.2. Physical Concepts

This report is concerned with x rays, which are one form of electromagnetic radiation. X rays differ from certain other forms of electromagnetic radiation—such as radio waves, infra-red, visible and ultra-violet light—principally in their ability, not only to penetrate matter, but also to produce ionization. When x rays interact with matter, energy is absorbed, mainly by the process of ionization.

It is a feature of ionizing radiation that the energy absorption in the body and its distribution in specific organs and tissues can be determined either by measurement or calculation.

The energy absorbed per unit mass at a point in the human body exposed to radiation is known as the absorbed dose in tissue. The unit of absorbed dose is the gray (Gy). One Gy is an absorbed energy of 1 joule per kilogram (1 J/kg). In terms of the old units 1 Gy = 100 rad.

It had been the established practice for many years to express the quantity of radiation in terms of the "exposure", measured in roentgens (R). The exposure was a measure of the ionization caused by the absorption of x rays in a specified mass of air—at the point of interest. It was used to specify a quantity of x rays, either in the presence or the absence of a patient. In the new international system of units (SI) it can be replaced by the quantity "air kerma", kerma being an acronym for Kinetic Energy Released per unit MAss. In diagnostic radiology, air kerma can be taken to have the same value as the absorbed dose in air, and can be used to describe the radiation field either in the presence or the absence of a patient. An air kerma* of 1 Gy represents a transfer of 1 J of energy from the x-ray beam to air per kg of air. An exposure of 1 R corresponds to an air kerma of 8.7 mGy.

Kerma can be defined for any absorbing material. For x rays used in diagnostic radiology, soft-tissue kerma is approximately equal to air kerma (the difference is of the order of 10%) and for the purposes of radiation protection they can be considered equal. Thus the value of the air kerma is interchangeable with that of the absorbed dose in soft tissue, to the same extent that, previously, exposure measured in roentgens was interchangeable with the absorbed dose measured in rad.

Dose equivalent is a quantity used for radiation protection purposes. It takes into account both the absorbed dose and the biological effectiveness of different types and energies of ionizing radiation. The special name of the SI unit of dose equivalent is the sievert (Sv) (1 Sv = 100 rem). For x rays, the dose equivalent is numerically equal to the absorbed dose.

For practical purposes in x-ray diagnosis, a kerma in air of 1 Gy can be regarded as delivering to a small mass of soft tissue an absorbed dose of 1 Gy and a dose equivalent of 1 Sv. Numerical values of radiation doses can be meaningful only if the particular body organs or tissues to which they refer are specified. For example, as discussed later in this report, radiation doses to the skin,

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* Unless specified otherwise, the term Kerma in this report is taken to mean the air kerma in air

bone, gonads, active bone marrow, lung, thyroid, female breast and embryo are of particular importance.

1.2.1. *Radiation exposure from diagnostic x-ray procedures*

Any attempt to assess the possible deleterious effects on individuals, or on entire populations, from diagnostic x-ray procedures requires a knowledge of the doses and dose distribution in the body. In addition, the population effects will depend on the frequency of radiological examinations in the population. In comparing the possible hazards to different populations, an important factor is the average number of examinations per caput and the frequency of certain types of examinations. Thus, reduction of the potential harm associated with diagnostic x-ray examinations may be achieved by reducing the level of dose in the directly irradiated tissues, restricting the volume of body tissue irradiated or reducing the frequency of examinations. Such reduction is sensible only if the benefit to the patient is not compromised.

The radiation risk to the individual patient associated with a diagnostic examination cannot be accurately estimated from the risk factors recommended by the Commission for purposes of radiation protection (see Table 1). However, they do provide an approximate estimation of the magnitude of the risk of fatality. Table 1 gives an example of risk evaluations for a typical dose distribution within the adult human body resulting from a chest examination. Under these irradiation conditions the genetic risk is small compared with the somatic risk. The somatic risk results mainly from those organs or tissues which are in the direct beam (lung, female breast, bone marrow).

Risk analysis of this type can be used to provide some guidance for the comparison of the risks with the benefits to the patient from diagnostic procedures.

1.2.2. *Radiation dose per examination*

The dose received in a given examination will vary widely throughout the body, the maximum being to the skin in the primary beam of radiation. The tissue doses are highly dependent on the technical factors employed in radiography and fluoroscopy, the characteristics of the equipment, the number of films taken, and the fluoroscopy time per examination. The doses delivered in a particular kind of examination will, therefore, vary between countries, between institutions within one country, and even between different x-ray machines and techniques in a single institution. Although physical methods of measuring dose can be performed routinely with an accuracy of about $\pm 10\%$, it has been found that the dose to patients, from a given type of examination, may vary, between hospitals, by a factor of 2–10. The range for gonad exposures is as much as three orders of magnitude (B6, T1, W1).

Table 1. An example of typical tissue doses and of the age-averaged radiation risk for x-ray chest examinations of adult females

Organ, tissue	Mean absorbed dose (mGy) (from Table A 1)	Risk coefficient (I6) (10^{-4} Sv^{-1})	Radiation risk (deaths per 10^6 individuals)
Lung	0.20	20	0.40
Breast	0 14	50	0.70
Bone marrow	0.03	20	0.06
Thyroid	0.07	5	0.04

Doses to other organs are negligible.

The average radiation dose received per examination or per exposure has been estimated in many countries, for certain specified tissues and organs. Examples are shown in Tables 2 and 3. The dose received by an individual patient in a particular examination may vary widely from these illustrative values, depending on equipment and physical factors used.

The incident skin dose gives an indication of the maximum dose received by any cell population of the body, and ranges from less than 100 μGy for a large-film examination of the chest to as high as 1 Gy for cardiac catheterization. There is evidence in some countries that significant reductions in skin dose for various examinations are being achieved. Table 4 shows typical skin doses in the primary beam in diagnostic x-ray examinations classified in three groups according to the magnitude of the dose. Many common examinations, including those of the heart, chest and extremities, deliver gonadal doses of less than 100 μGy. In examinations of the lower trunk in which the gonads are directly irradiated the dose is usually greater than 5 mGy and may, occasionally, be as high as 20 mGy. Large doses may also be given to the foetal gonads in abdominal examinations of pregnant women.

From the previous paragraphs it is apparent that differences of up to three orders of magnitude can occur in organ doses from examinations performed at different institutions. These differences depend on the number of films used as well as on the technical factors. Because of these large variations, tables which give organ doses per unit exposure are a practical method of determining the actual dose. Direct measurements, though accurate, are not generally practicable on a wide scale. (For estimation of organ doses resulting from commonly-used diagnostic procedures see Appendix 1.)

1.3. Biological Concepts

Radiation energy absorbed in living tissues initiates physical and chemical reactions, resulting in biological changes. Some diagnostic x-ray equipment, particularly fluoroscopic equipment when improperly operated, is capable of delivering radiation doses that may be high enough to produce cellular reactions which will be manifested as acute radiation reaction or injury. However, in properly-conducted diagnostic x-ray examinations, these acute radiation effects do not occur because the radiation doses are well below the threshold for such effects. Nevertheless, there may be no lower limit of dose for the initiation of some deleterious biological changes. Even a small dose of radiation may increase the risk of development of neoplasia and small doses of radiation absorbed in the gonads may induce mutations or chromosomal changes leading to hereditary effects. This type of action is known as stochastic, i.e. only the probability of occurrence of the effect depends on the dose of radiation absorbed whereas the severity of the effect is independent of dose.

It therefore has to be assumed that every increment of x-ray dose to an individual may carry some risk, even though the risk for a particular examination is small. Given that the quantitative relationships between risk and dose can be established, such factors as the distribution of energy absorbed in the body, the dose rate, the tissues exposed, the cumulative dose, and the age of the patient are relevant to estimating this risk.

In its current recommendations, the Commission revised certain earlier concepts concerning risk. The detrimental effects against which radiation protection is required are known as *hereditary* if they affect the exposed individual's descendants and *somatic* if they become manifest in the exposed individual.

In previous reports, ICRP used the concept of critical organ—i.e. the dose limit to the individual was determined by the dose-equivalent limit for a particular tissue or organ, depending on the dose distribution within the body. In *ICRP Publication 26* the combined

Table 2. Average organ doses in various diagnostic x-ray examinations in Sweden (from Bengtsson *et al.* (B6))

Examination	Testes	Ovary	Active bone marrow	Breast	Lung	Thyroid
			mGy			
Hip and femur (upper third)	15.00	3.70*	2.50	<0.05*	<0.10*	<0.01*
Pelvis	3.10	1.90	1.90	<0.05*	<0.10*	<0.01*
Pelvimetry		4.60	6.80*	<0.10*	<0.50*	<0.10*
Lumbo-sacral	1.00*	1.80*	1.00*	<0.05*	<0.10*	<0.01*
Lumbar spine	1.80	6.20	4.10	1.20	<1.00	0.16
Urography	3.30	8.80	2.40	5.40	<1.00	0.38
Retrograde pyelography	13.00*	8.00*	3.00*	5.00*	<1.00*	0.50*
Urethrocystography	20.00*	15.00*	3.00*	0.20*	0.20*	0.05*
Stomach and duodenum	0.16	0.56	4.20	1.00	<0.50	0.29
Small intestine	1.00	1.80	3.50	0.11	<0.20*	0.03
Colon	5.30	7.00	9.40	0.27	<0.20	1.10
Abdomen	2.00*	2.00*	3.00*	0.11*	<0.20*	0.03*
Abdomen (obstetrical)	—	1.50*	2.20*	0.08*	<0.15*	0.02*
Hysterosalpingography	—	5.90	1.70	<0.05*	<0.10*	<0.01*
Cholecystography, cholangiography	0.06	0.24	1.50	0.15	<0.10	0.03
Thoracic spine	<0.20*	<1.00	4.70	1.70	8.00	13.00
Lungs (full size), ribs	<0.03*	<0.03*	0.29	0.55	0.80	0.17
Lung (photofluorography)	<0.10*	<0.10*	0.90	2.00	3.50	1.00
Lung plus heart	<0.05*	<0.05*	0.54	0.61	1.20	0.24
Cervical spine	<0.01	<0.01	0.38	<0.10	<0.10*	1.40
Shoulder, clavicle, sternum	<0.01*	<0.01*	0.60*	<0.50*	<0.10*	<0.50*
Head, sinus	<0.01	<0.01	1.22	<0.10*	<0.10*	7.90
Cerebral angiography	<0.10	<0.10	15.00	<0.10*	<0.10*	3.00
Dental (intraoral single exposure)	0.0001	0.0001	0.01	0.005	0.001	0.03
Femur (middle and lower third)	4.00*	0.50*	0	<0.01*	<0.01*	<0.01*
Lower leg, knee	<0.01	<0.01	0	<0.01	<0.01	<0.01
Arm	<0.01	<0.01	0	<0.01	<0.01	<0.01

* Crude estimates, the uncertainty of which might exceed a factor of 2.

Table 3. Average organ doses in x-ray examinations in Poland (J2)

Examination	Ovary	Testis	Active marrow		Thyroid		Breast	Lung
			F	M	F	M		
	mrad	mrad	mrad		mrad		mrad	mrad
Mass miniature radiography	1	1	43	49	19	21	11	70
Chest radiography	1	1	11	11	5	4	3	18
Chest tomography	1	2	210	190	2600	2400	4600	1600
Stomach, upper GI tract	290	90	510	780	30	80	110	490
Urography	590	1500	340	320	21	23	230	970
Cervical spine	1	1	73	62	1400	1300	520	210
Dental	1	2	7	8	1	1	1	1
Humeral joint	1	1	2	2	28	33	71	8
Hip joint	81	920	47	47	1	1	9	44
Cholecystography	190	3	300	250	1	2	20	150
Lumbo-sacral spine	160	310	83	81	3	2	85	260
Cholangiography	180	5	370	350	3	1	34	220
Sinuses	1	1	160	160	55	28	3	18

Data quoted from a published reference are expressed in the units used in the original paper.
1 mrad = 10 μGy.

Table 4. Typical skin dose in the primary beam in diagnostic x-ray examinations (UNSCEAR) (rad*)

Dose group	Per exposure		Per examination	
	Median value	Range of average values	Median value	Range of average values
High skin dose				
Barium swallow R			1.4	
Barium swallow F	6.4[1]		8.5	
Barium meal R	0.9	0.9 2.2	1.7	
Barium meal F	4.4[1]		2.1	6 25
Barium enema R	0.7	0.4 1.0	1.5	
Barium enema F	4.9[1]		20.0	5 26
Whole chest R	0.02	0.006 0.09	0.14	0.07 0.15
Whole chest F	2.0[1]		12.0	3 22
Mammography			6.0	0.2 7.8
Pelvimetry	2.0	0.8 3.8	8.0	6 10
Lumbosacral spine	2.7	0.5 2.9	5.0	5 6
Lumbar spine	1.5	0.7 2.9	4.5	
Cardiac catheterization			47.0	
Medium skin dose				
Head	0.4	0.3 1.5	1.5	1.4 1.9
Cervical spine	0.3	0.03 0.8	1.5	0.6 1.9
Clavicle and shoulder	0.9		0.3	0.3 0.4
Dorsal spine	1.8		2.8	2.0 4.7
Thorax	0.4		0.8	0.6 0.9
Cholecystography	0.8	0.2 1.2	2.2	1.5 2.8
Abdomen	0.2	0.15 1.3	1.2	1.0 1.4
Abdomen (obstetric)	2.0	0.4 3.9	3.2	2.7 3.8
Urography (descending)	1.2		3.2	1.7 5.0
Urography (retrograde)			2.9	1.4 2.4
Salpingography R			1.2	
Salpingography F			3.4	
Placentography			3.0	
Cystography	0.2		3.1	
Pelvis	1.4	0.4 1.7	3.3	2.1 4.5
Hip and upper femur	1.1	0.4 1.7	1.4	1.1 3.0
Dental	0.4		2.5	1.6 3.4
Angiography (head)			1.0	
Angiography (abdomen)			3.3	
Tomography (chest)			1.1	0.8 1.4
Mass survey chest	0.9		1.0	0.6 1.4
Low skin dose				
Arm and hand	0.1		0.3	0.1 1.7
Chest	0.02	0.006 0.09	0.14	0.07 0.15
Femur (lower two thirds)	0.03		0.4	
Leg and foot	0.1		0.4	0.3 0.4

Note: R = radiography; F = fluoroscopy.

[1] R min^{-1}.

* Data quoted from a published reference are expressed in the units used in the original paper. 1 rad = 10 mGy.

risk resulting from all irradiated tissues is considered. The critical organ concept has been replaced by the total risk concept.

Initially, the hazards of radiation exposure of most concern have been those arising from relatively high radiation doses received by a few people. Currently there is increasing concern that deleterious effects could be expected from the exposure of large numbers of people to low doses of radiation. The harmful effect to be anticipated is mainly a very small increase in the

incidence of neoplasms. Quantitative assessment of such "whole-population" hazards is based on two assumptions about the dose–effect relationship, namely that the risk of deleterious effects is proportional to dose, and that there is no threshold below which biological effects do not occur. From these assumptions concerning radiation risks, a system of balancing competing risks and benefits has been developed. This is achieved by making judgments, not only about the radiation hazard itself, but also about all other consequences of using or not using radiation in particular circumstances. These kinds of benefit–risk judgments are not fundamentally different from those made in other fields of human activity, but they have been given particular attention in radiation protection.

Over the past 20 years, a number of estimates of risk of radiation effects have been developed: BEIR 1972 (N5); BEIR 1980 (N4); UNSCEAR 1972 (U1); UNSCEAR 1977 (U2); ICRP 1966 (I3); ICRP 1969 (I4); ICRP 1977 (I7). These risk estimates are taken from many sources—medical irradiation (mostly therapeutic), atomic bomb survivors, and occupational sources. Although each of these cited reports presents the risk estimates in a somewhat different form, it is important to note that, when they are expressed in the same units, there have been no substantive changes during the past decade. The quantity "effective dose equivalent" is based on the risk estimates for each organ or tissue, taken to extend over about 25 years for somatic effects and two generations, or about 50 years, for hereditary effects. UNSCEAR 1977 presents a detailed analysis of all available human data and finds essentially the same risk. The most recent risk estimates have been presented in the 1980 BEIR report. Some of the cancer risk estimates from these sources are given in Table 5.

Hereditary effects of ionizing radiation have not been observed in human beings and therefore the genetic risk estimates are based on laboratory animal data (O1). Developmental effects have been observed in human beings and their nature and frequency depend on the stage of growth at which exposure occurs and on the dose received.

Since the late effects ascribed to low doses of low-LET radiations are not exclusively characteristic of ionizing radiations, and because these effects may not occur for many years after irradiation, the correlation between exposures and effect is difficult to establish. Risk factors

Table 5. Cancer mortality risk estimates by site

Site of cancer	Mortality risk (10^{-4} Sv^{-1}) ICRP 1977 (I6)	UNSCEAR 1977 (U2)
Red bone marrow	20	15–25
Lung	20	25
Breast	25	~30
Bone	5	2–5
Gastrointestinal tract	*	25
Thyroid	5	5–15
Remainder	50	~25
Total	125	120

* Included in remainder.

Note: The comparisons are of cancer mortality risks to specific sites as estimated by ICRP in its Publication 26, and by UNSCEAR in its 1977 report. Data are averaged for sex and age; in the case of breast cancer this means that the female risk has therefore been divided by two. For ICRP and UNSCEAR, the total was derived independently of site specific data, and so is not equal to their sum.

have been developed by linear extrapolation from exposures of persons at doses far higher than those encountered in diagnostic radiology and will vary somewhat, depending on the dose-effect model used, the prevalence of the disease under consideration and the population with which the irradiated group is compared.

Despite the fact that no hereditary abnormalities have been noted in human beings as a result of either high or low doses of radiation, hereditary changes remain a major concern. The risk of major hereditary disease in future generations as a result of the exposure of a potential parent, is $2\ 10^{-2}\ Sv^{-1}$ ($2\ 10^{-4}\ rem^{-1}$).

In addition to the induction of hereditary abnormalities, two other possible effects of radiation on the developing embryo or foetus need consideration, namely developmental abnormalities, and the cancers which will be expressed during childhood or in adult life. The type and frequency of such effects depend upon the stage of gestation at which the exposure occurs.

Ovulation occurs typically at about the midpoint of the menstrual cycle, and rarely takes place earlier than ten days after the first day of the preceding menstrual period.

In the human species the conceptus begins to implant in the uterine wall at 5 or 6 days after fertilization, but its subsequent development is relatively slow. Extra-embryonic tissues are the first to develop, and formation of the primitive streak begins only at 15 days after fertilization. Organogenesis begins a few days later and, in the case of most organs, continues for the next month. The development of the forebrain, however, begins later still, at 7–8 weeks after fertilization.

Loss of a proportion of the cells from extra-embryonic tissues would not be expected to influence subsequent development of the conceptus. The first four weeks from the first day of the last menstrual period, during which organogenesis is unlikely to be occurring, is not therefore a critically radiosensitive period for induction of malformations in the human species.

In the following month, during which general organogenesis is occurring, an increased sensitivity must be expected, since malformations are induced by radiation in laboratory animals at corresponding stages of development. Such malformations have not in fact been shown to be induced in man by radiation at this stage of gestation. The relatively slower development of organs in the human embryo as compared with laboratory animals would be expected to reduce sensitivity to their induction by a brief exposure to radiation.

The development of the human forebrain occurs during the further period of 2 or 3 months, starting at about 2 months from the first day of the last menstrual period. Evidence from atomic bomb survivors now indicates an excess of severe mental impairment in children who received a brief radiation exposure in utero during the period of 10–17 weeks after the last menstrual period (O2). At later stages of gestation the excess was smaller and there was none at 28–38 weeks.

Sensitivity to the developmental effects of radiation, as expressed in the live born, therefore, is likely to start at or soon after the time of the first missed menstrual period, in women with periods of 28 days or less, and to continue during the ensuing 3 or 4 months (see also Section 5.2).

2. CLINICAL JUDGMENT AND ADMINISTRATIVE PRACTICES

2.1. Clinical Judgment

In discussing medical exposure the Commission states in *ICRP Publication 26*, paragraph 195:

"The term medical exposure refers to the exposure of individuals subject to medical examination or treatment involving radiation."

In paragraph 196 it states:

"The objectives of the medical procedures are:
examinations or treatments directly associated with illness;
systematic examinations undertaken for mass screening purposes or for periodic health checks;
examinations forming part of the medical surveillance of workers or carried out for medico legal or insurance purposes;
examinations or treatment forming part of a medical research program."

See also paragraphs 203, 204 of *ICRP Publication 26*.

It then becomes necessary to discuss the optimal way in which these goals may be achieved.

2.2. Indications for the Use of Diagnostic Radiology

Three major developments in diagnostic imaging have occurred recently: these include computed tomography, ultrasonic techniques and nuclear medicine procedures. Computed tomography has provided a major step forward in the ability to visualize certain organs and lesions, and can often replace invasive procedures. Ultrasonic diagnosis, which appears to have minimal or no risk, provides a method of visualizing certain organs not easily seen by radiographic techniques and provides information without the potential hazards of diagnostic doses of ionizing radiation. These facilities are not uniformly distributed throughout the world, so that available imaging equipment covers a broad spectrum from the very simplest to the most complex.

A more careful evaluation than in the past is being made concerning risks, the relationships between costs and benefits so as better to determine the indications for each radiological procedure. Cost–benefit analysis as described by *ICRP Publication 26* includes all individuals and societal and environmental considerations, including the direct cost of a particular procedure weighed against the benefit to a given patient. The concept of the term justification of a practice, in relation to its benefits, was developed in *ICRP Publication 26*. The professional judgment of the referring physician and radiologist, singly or jointly, that a proposed medical radiological procedure may be of net benefit to the recipient patient, will normally constitute "justification" vis-à-vis the individual patient's exposure. Methods of making such evaluations are improving, and new techniques have been developed to improve efficacy and decision making (L3, M4, S1).

More specific criteria are steadily being developed for the use of diagnostic radiology, both as regards indications and contraindications. A few examinations which have been of low yield are discussed below. Obviously, the definition of "low" and "yield" varies with the health costs of missing a diagnosis and with the health costs of making an incorrect diagnosis. Thus, for example, a much lower yield of case-finding might be acceptable in the search for a disease which is treatable but fatal if untreated, rather than for a disease on which treatment has little impact.