Eight decades of ICRP recommendations in medicine: a perspective

3rd International Symposium of the System of Radiological Protection
Seoul, Korea, 20-22 October 2015

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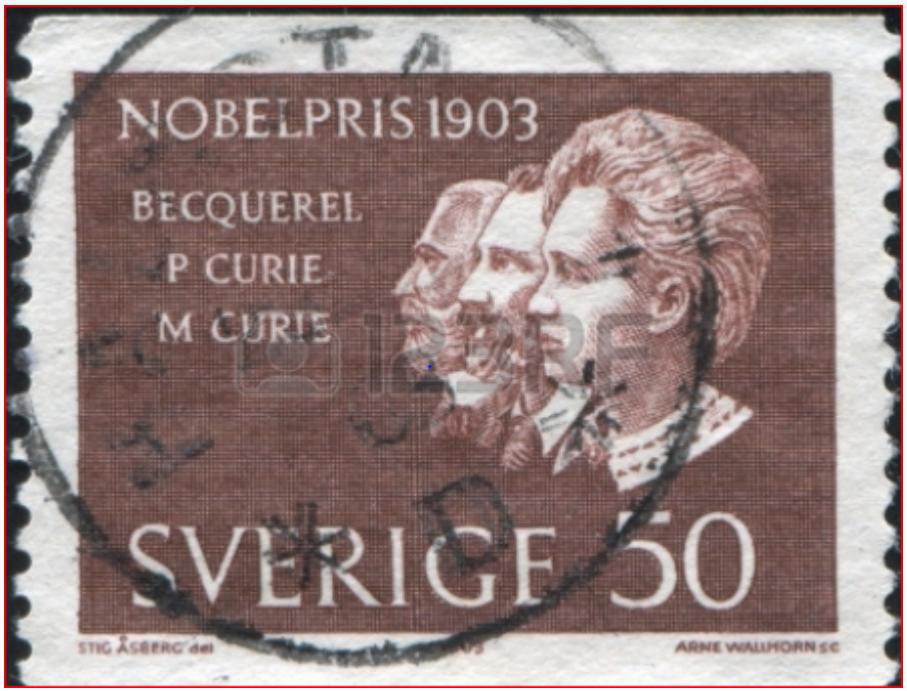
Member of ICRP Committee 3 on Radiological Protection in Medicine

Since the very beginning, ionizing radiation has been has been associated to medical diagnosis and treatment

Since the discovery…

1895 – Discovery of X-rays

Since the discovery …

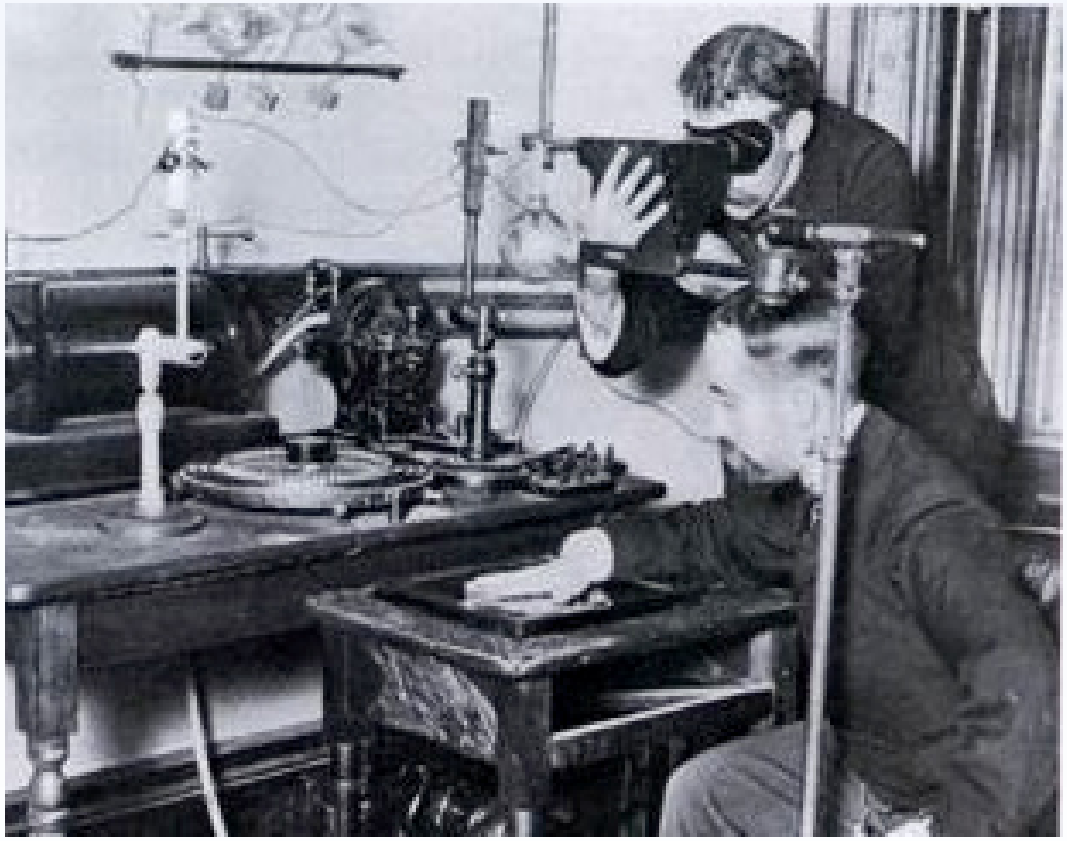


1896 – Discovery of radioactivity

1898 – Discovery of Radium

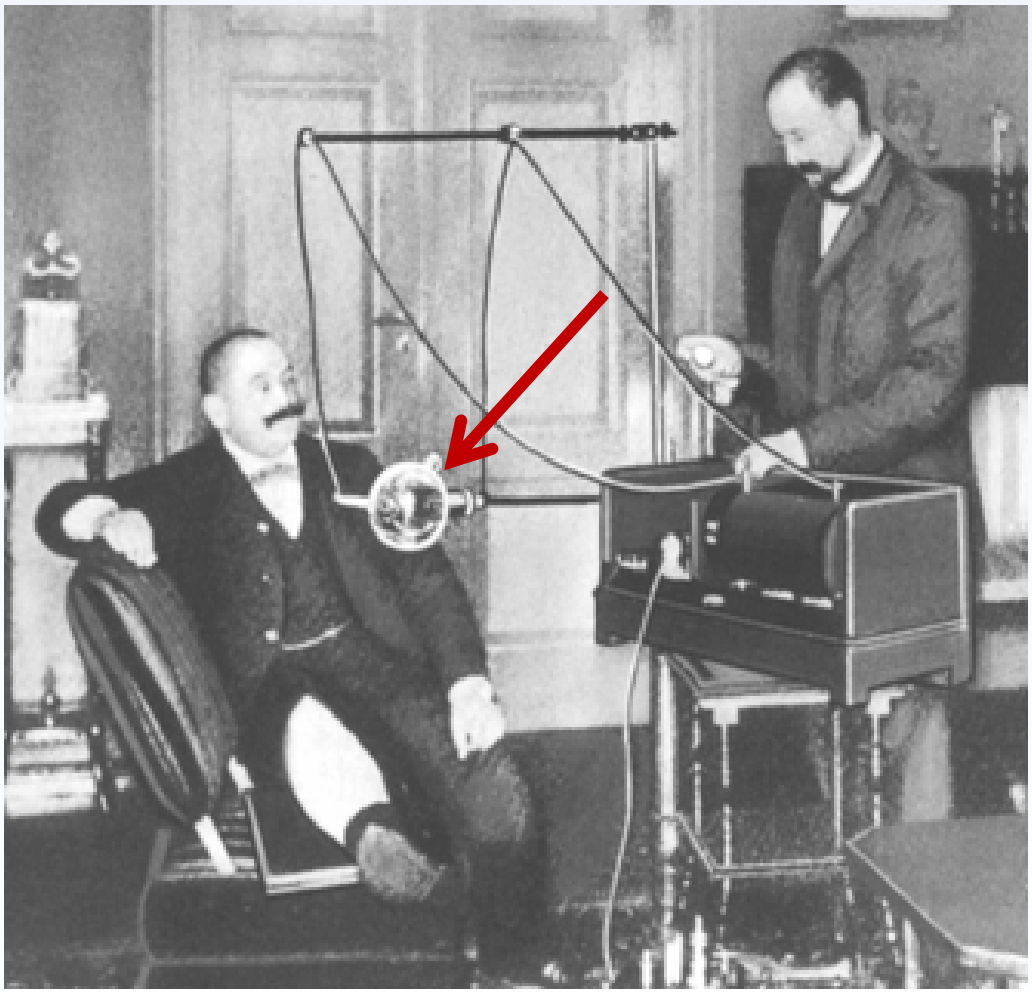
IAEA

Much experimental work placing the hands directly in the beam



Almost every professional working with X rays had to use his own hand very frequently to check the output of the X ray tube

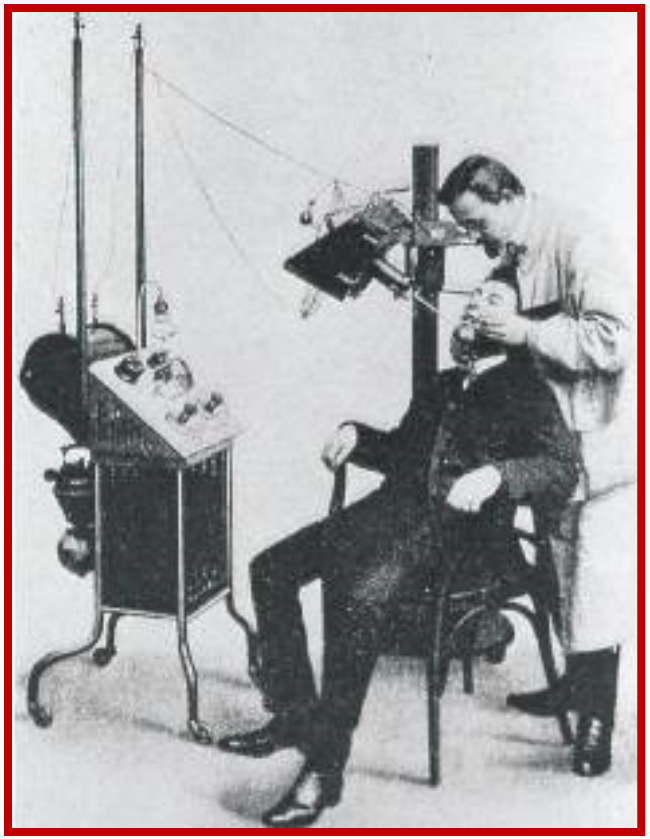
The first X-ray tubes had no shielding



John Daniels letter to the editor of Science, 10 April 1896

yesterday, 21 days after the experiment, all the hair came out over the space under the X-ray discharge. The spot is now perfectly bald, being two inches in diameter. This is the size of the X-ray field close to this tube. We, and especially Dr. Dudley, shall watch with interest

Dental X rays shortly after X-ray discovery



- Long exposure because of extremely low sensitivity of the photographic plate
- Loss of hair of patients at beam entrance

In sumary: injuries in the fist two decades were

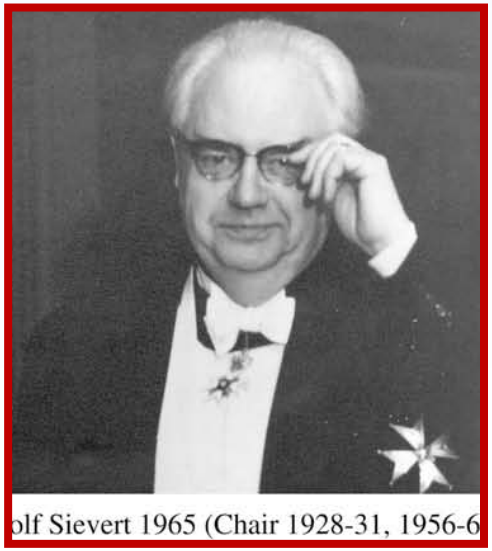
- Primarily, researchers, manufacturers, radiologists and radiation therapists

1928 The birth of the ICRP

- In response to growing concerns about the effects of ionizing radiation being observed in the medical community …
- The second International Congress of Radiology, held in Stockholm in 1928, established what is now ICRP under the name of the International X-ray and Radium Protection Committee

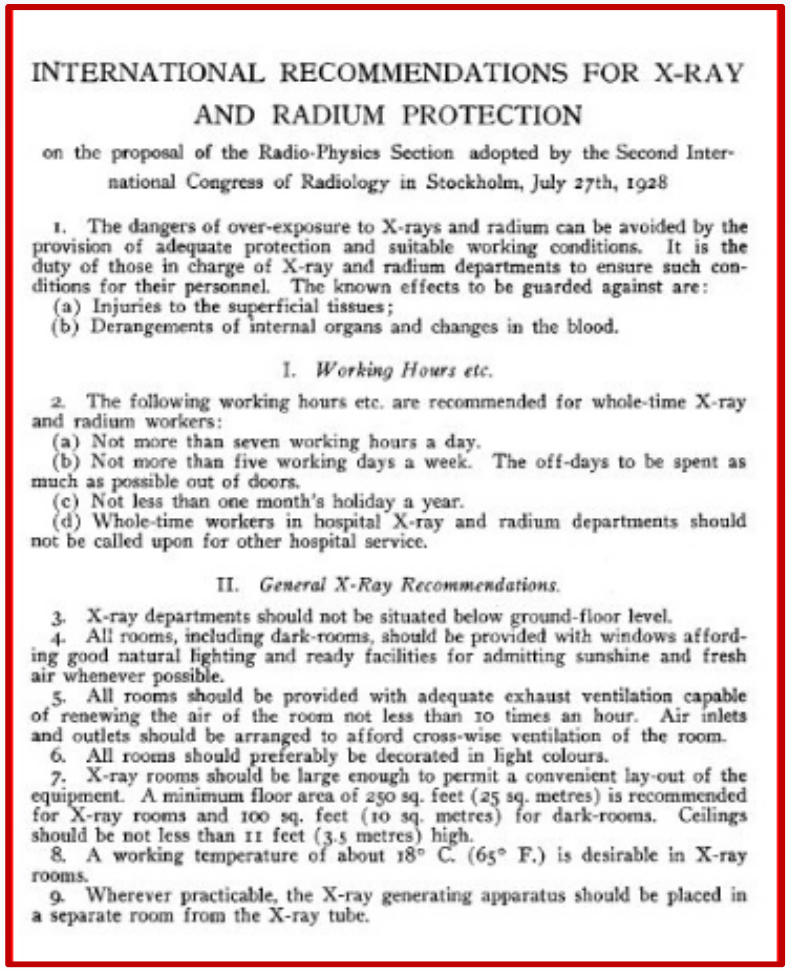
The first Chairperson was the 32 year old Rolf Sievert

Rolf Sievert, 1923 (Chair 1928-31, 1956-62)



olf Sievert 1965 (Chair 1928-31, 1956-6

First set of international recommendations Stockholm July 1928, entirely focused on occupational protection in medicine



INTERNATIONAL RECOMMENDATIONS FOR X-RAY AND RADIUM PROTECTION

on the proposal of the Radio-Physics Section adopted by the Second International Congress of Radiology in Stockholm, July 27th, 1928

1. The dangers of over-exposure to X-rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of X-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are:
(a) Injuries to the superficial tissues;
(b) Derangements of internal organs and changes in the blood.

I. *Working Hours etc.*

2. The following working hours etc. are recommended for whole-time X-ray and radium workers:
(a) Not more than seven working hours a day.
(b) Not more than five working days a week. The off-days to be spent as much as possible out of doors.
(c) Not less than one month's holiday a year.
(d) Whole-time workers in hospital X-ray and radium departments should not be called upon for other hospital service.

II. *General X-Ray Recommendations.*

3. X-ray departments should not be situated below ground-floor level.
4. All rooms, including dark-rooms, should be provided with windows affording good natural lighting and ready facilities for admitting sunshine and fresh air whenever possible.
5. All rooms should be provided with adequate exhaust ventilation capable of renewing the air of the room not less than 10 times an hour. Air inlets and outlets should be arranged to afford cross-wise ventilation of the room.
6. All rooms should preferably be decorated in light colours.
7. X-ray rooms should be large enough to permit a convenient lay-out of the equipment. A minimum floor area of 250 sq. feet (25 sq. metres) is recommended for X-ray rooms and 100 sq. feet (10 sq. metres) for dark-rooms. Ceilings should be not less than 11 feet (3.5 metres) high.
8. A working temperature of about 18° C. (65° F.) is desirable in X-ray rooms.
9. Wherever practicable, the X-ray generating apparatus should be placed in a separate room from the X-ray tube.

- Basically three rules
  - Distance
  - Shielding
  - Limitation of working time
  - In addition, there were a set of recommendations on electrical safety

Distance

11. An operator should place himself as remote as practicable from the X-ray tube. It should not be possible for a well rested eye of normal acuity to detect

15. In the case of X-ray treatment the operator is best stationed completely outside the X-ray room behind a protective wall of a minimum lead equivalent

Shielding

12. The X-ray tube should be surrounded as completely as possible with protective material of adequate lead equivalent.

13. The following lead equivalents are recommended as adequate:

X-rays generated by peak voltages	Minimum equivalent thickness of lead
Not exceeding 75	1 mm.
» » 100	1 1/2 »
» » 125	2 »
» » 150	2 1/2 »
» » 175	3 »
» » 200	4 »
» » 225	5 »

14. In the case of diagnostic work, the operator should be afforded protection from scattered rays by a screen of a minimum lead equivalent of 1 mm.

Time

I. *Working Hours etc.*

2. The following working hours etc. are recommended for whole-time X-ray and radium workers:

(a) Not more than seven working hours a day.

(b) Not more than five working days a week. The off-days to be spent as much as possible out of doors.

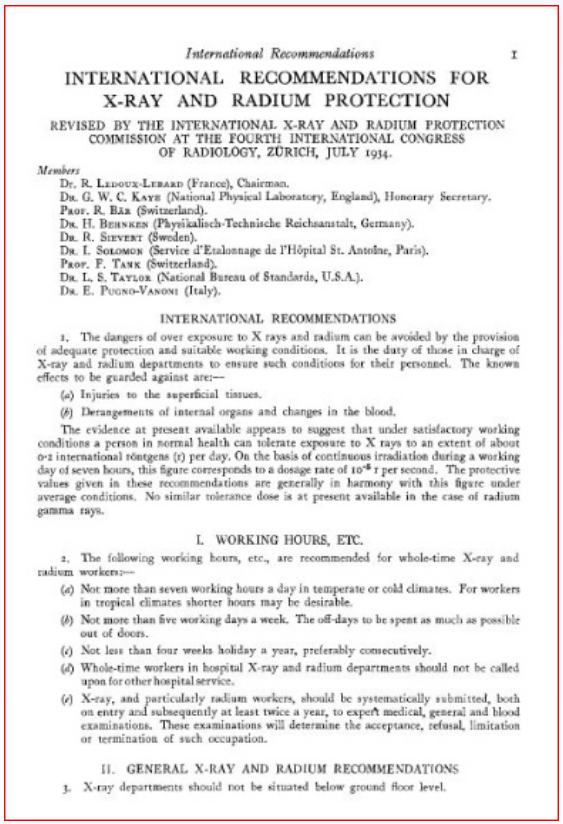
(c) Not less than one month's holiday a year.

(d) Whole-time workers in hospital X-ray and radium departments should not be called upon for other hospital service.

16. Screening examinations should be conducted as rapidly as possible with minimum intensities and apertures.

Successive recomendations continued to focus on occupational protection in medicine

1934 1937 1950



International Recommendations 1

INTERNATIONAL RECOMMENDATIONS FOR X-RAY AND RADIUM PROTECTION

REVISED BY THE INTERNATIONAL X-RAY AND RADIUM PROTECTION COMMISSION AT THE FOURTH INTERNATIONAL CONGRESS OF RADIOLOGY, ZÜRICH, JULY 1934.

Members

Dr. R. Ledoux-Lebard (France), Chairman.
Dr. G. W. C. Kaye (National Physical Laboratory, England), Honorary Secretary.
Prof. R. Bär (Switzerland).
Dr. H. Behnken (Physikalisch-Technische Reichsanstalt, Germany).
Dr. R. Sievert (Sweden).
Dr. I. Solomon (Service d'Etalonnage de l'Hôpital St. Antoine, Paris).
Prof. F. Tank (Switzerland).
Dr. L. S. Taylor (National Bureau of Standards, U.S.A.).
Dr. E. Pugno-Vanoni (Italy).

INTERNATIONAL RECOMMENDATIONS

1. The dangers of over exposure to X rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of X-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are:—

(*a*) Injuries to the superficial tissues.

(*b*) Derangements of internal organs and changes in the blood.

The evidence at present available appears to suggest that under satisfactory working conditions a person in normal health can tolerate exposure to X rays to an extent of about 0·2 international röntgens (*r*) per day. On the basis of continuous irradiation during a working day of seven hours, this figure corresponds to a dosage rate of 10^{-6} *r* per second. The protective values given in these recommendations are generally in harmony with this figure under average conditions. No similar tolerance dose is at present available in the case of radium gamma rays.

I. WORKING HOURS, ETC.

2. The following working hours, etc., are recommended for whole-time X-ray and radium workers:—

(*a*) Not more than seven working hours a day in temperate or cold climates. For workers in tropical climates shorter hours may be desirable.

(*b*) Not more than five working days a week. The off-days to be spent as much as possible out of doors.

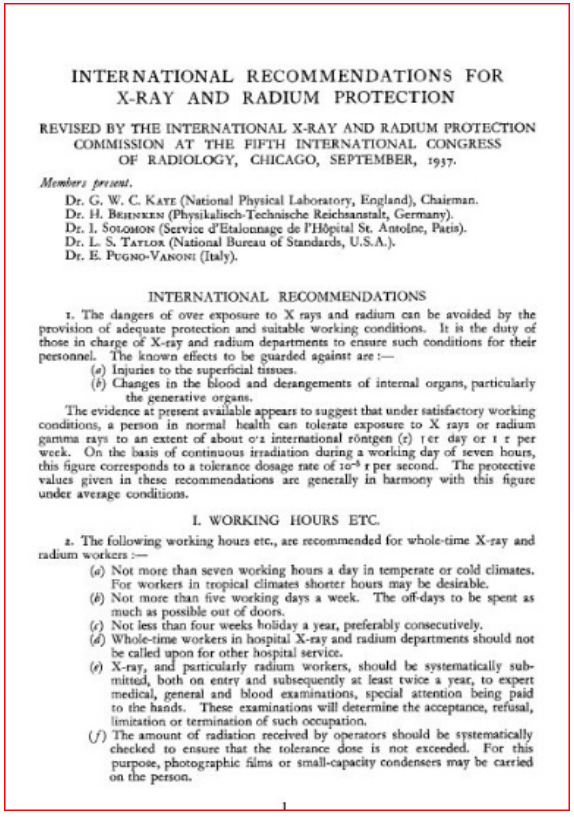
(*c*) Not less than four weeks holiday a year, preferably consecutively.

(*d*) Whole-time workers in hospital X-ray and radium departments should not be called upon for other hospital service.

(*e*) X-ray, and particularly radium workers, should be systematically submitted, both on entry and subsequently at least twice a year, to expert medical, general and blood examinations. These examinations will determine the acceptance, refusal, limitation or termination of such occupation.

II. GENERAL X-RAY AND RADIUM RECOMMENDATIONS

3. X-ray departments should not be situated below ground floor level.



INTERNATIONAL RECOMMENDATIONS FOR X-RAY AND RADIUM PROTECTION

REVISED BY THE INTERNATIONAL X-RAY AND RADIUM PROTECTION COMMISSION AT THE FIFTH INTERNATIONAL CONGRESS OF RADIOLOGY, CHICAGO, SEPTEMBER, 1937.

Members present.

Dr. G. W. C. Kaye (National Physical Laboratory, England), Chairman.
Dr. H. Behnken (Physikalisch-Technische Reichsanstalt, Germany).
Dr. I. Solomon (Service d'Etalonnage de l'Hôpital St. Antoine, Paris).
Dr. L. S. Taylor (National Bureau of Standards, U.S.A.).
Dr. E. Pugno-Vanoni (Italy).

INTERNATIONAL RECOMMENDATIONS

1. The dangers of over exposure to X rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of X-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are:—

(*a*) Injuries to the superficial tissues.

(*b*) Changes in the blood and derangements of internal organs, particularly the generative organs.

The evidence at present available appears to suggest that under satisfactory working conditions, a person in normal health can tolerate exposure to X rays or radium gamma rays to an extent of about 0·2 international röntgen (*r*) per day or 1 *r* per week. On the basis of continuous irradiation during a working day of seven hours, this figure corresponds to a tolerance dosage rate of 10^{-6} *r* per second. The protective values given in these recommendations are generally in harmony with this figure under average conditions.

I. WORKING HOURS ETC.

2. The following working hours etc., are recommended for whole-time X-ray and radium workers :—

(*a*) Not more than seven working hours a day in temperate or cold climates. For workers in tropical climates shorter hours may be desirable.

(*b*) Not more than five working days a week. The off-days to be spent as much as possible out of doors.

(*c*) Not less than four weeks holiday a year, preferably consecutively.

(*d*) Whole-time workers in hospital X-ray and radium departments should not be called upon for other hospital service.

(*e*) X-ray, and particularly radium workers, should be systematically submitted, both on entry and subsequently at least twice a year, to expert medical, general and blood examinations, special attention being paid to the hands. These examinations will determine the acceptance, refusal, limitation or termination of such occupation.

(*f*) The amount of radiation received by operators should be systematically checked to ensure that the tolerance dose is not exceeded. For this purpose, photographic films or small-capacity condensers may be carried on the person.

JANUARY 1951

INTERNATIONAL RECOMMENDATIONS ON RADIOLOGICAL PROTECTION

Revised by the International Commission on Radiological Protection at the Sixth International Congress of Radiology, London, July 1950.

INTRODUCTION

DEVELOPMENTS in nuclear physics and their practical applications since the last International Congress have greatly increased the number and scope of potential hazards. At the same time biological research has led to an extension of our knowledge of the dangers associated with ionizing radiations. This increase of biological knowledge has not only brought a realisation of the importance of certain effects, particularly carcinogenic and genetic effects, but has also provided more information as to the permissible levels of radiation. The International Commission on Radiological Protection has therefore adopted new radiation safety standards with more rigid criteria. Such standards must, in view of the still limited experience of the effects of radiation, be kept continually under review.

It appears that the effects to be considered are:
(1) Superficial injuries.
(2) General effects on the body, particularly the blood and blood-forming organs, *e.g.*, production of anæmia and leukæmias.
(3) The induction of malignant tumours.
(4) Other deleterious effects including cataract, obesity, impaired fertility, and reduction of life span.
(5) Genetic effects.

While it is still fundamental to express whole-body exposure in terms of a single number, it is not practicable, in general, in view of the complexity of circumstances now arising, to express the maximum permissible hazards in terms of a single parameter. It is, for example, highly desirable to derive values of maximum permissible concentrations of radioactive materials in the air or in drinking water, taking into account the metabolism of the materials concerned, and assuming standard anatomical, physiological, and chemical data. Furthermore, the previously accepted value of 1 r per week for maximum permissible exposure to external radiation itself needs revision in the light of the nature of the radiations to which workers are now exposed. There is the added difficulty that the röntgen is not an acceptable unit of dose for all ionizing radiations. Accordingly, the following recommendations are based on considerations of the equivalent energy absorbed in tissue coupled with the appropriate relative biological efficiency.

Whilst the values proposed for maximum permissible exposures are such as to involve a risk which is small compared to the other hazards of life, nevertheless in view of the unsatisfactory nature of much of the evidence on which our judgments must be based, coupled with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposures to all types of ionizing radiations to the lowest possible level.

EXPOSURE TO EXTERNAL RADIATION

1. *Exposure of individuals to X, γ, and β radiation*

(*a*) *Whole-body exposure*

A careful consideration of the deleterious biological effects enumerated in the Introduction, in the light of observations on man and of the experimental data on animals, has led to the conclusion that, in so far as the well-being of the individual is concerned, the most dangerous effects of external radiation are probably those on the blood-forming organs. Although the dose to these organs is regarded as a fundamental quantity, for practical reasons the maximum permissible exposure is best stated in terms of the surface dose per week. The figure of 1 r per week previously adopted by the International X-ray and Radium Protection Commission seems very close to the probable threshold for adverse effects, particularly for radiations of high energy which are more frequently encountered than formerly. A reduction of surface dose is therefore called for. For these reasons and for those previously outlined in the Introduction, it is recommended that:—

(i) *In circumstances under which the whole body may be exposed over an indefinite period to X or γ radiation of quantum energy less than 3 MeV, the maximum permissible dose received by the surface of the body shall be 0·5 röntgen in any one week. This dose corresponds to 0·3 r per week measured in free air.*

(ii) *In the case of high energy β rays, the maximum permissible exposure of the surface of the body in any one week shall be the energy flux of β radiation such that the absorption per gramme of superficial tissues is equivalent to the energy absorption from 1·5 röntgen of hard γ rays.*

For purposes of calculation, the superficial tissues concerned shall be assumed to be the basal layer of the epidermis, defined conventionally as lying at a depth corresponding to 7 mg/cm.²

(*b*) *Critical tissues*

The recommendations relating to exposure to external radiation are primarily framed in relation to exposure of the whole body. Nevertheless, a greater

These ICRP recommendations were published as papers in various scientific journals in the fields of medicine and physics

By 1950, the scope of radiation protection had expanded

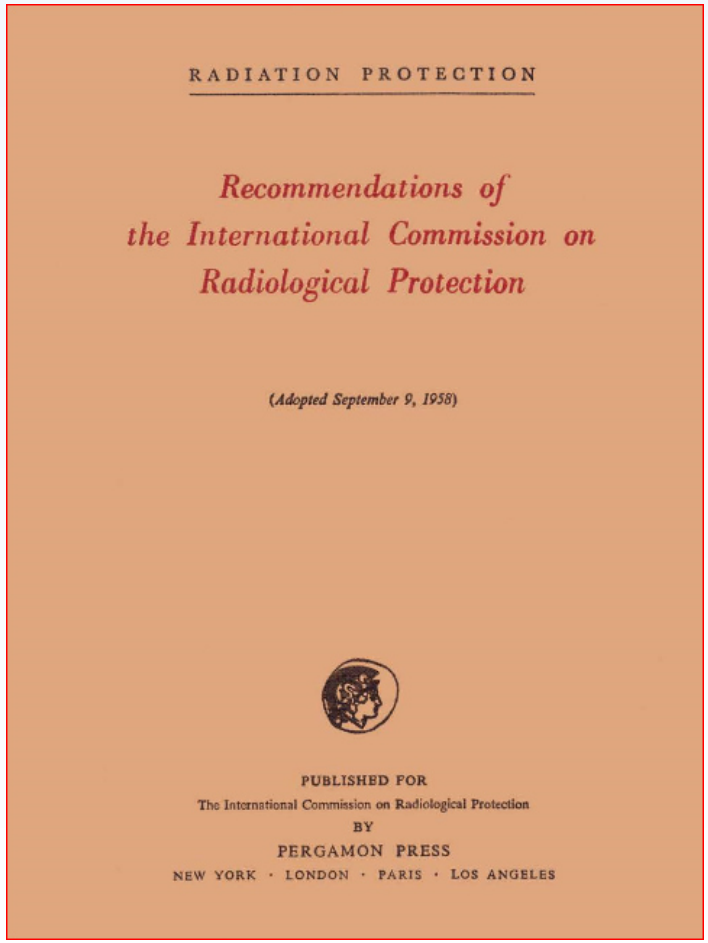
- The field of radiological protection had widened from protection in medical radiology (X rays and radium) to embrace all other aspects of protection against ionising radiation.
- The organization was renamed in 1950, taking its current name, International Commission of Radiological Protection
- The parent organization continues to be the International Society of Radiology

The following Committees were appointed

1. permissible dose for external radiation;
2. permissible dose for internal radiation;
3. protection against X rays generated at potentials up to 2 million volts;
4. protection against X rays above 2 million volts, and ß rays and γ rays;
5. protection against heavy particles, including neutrons and protons; and
6. disposal of radioactive wastes and handling of radioisotopes

There was no Committee on protection in medicine.

1958 – Publication 1 of the current series


RADIATION PROTECTION

Recommendations of the International Commission on Radiological Protection

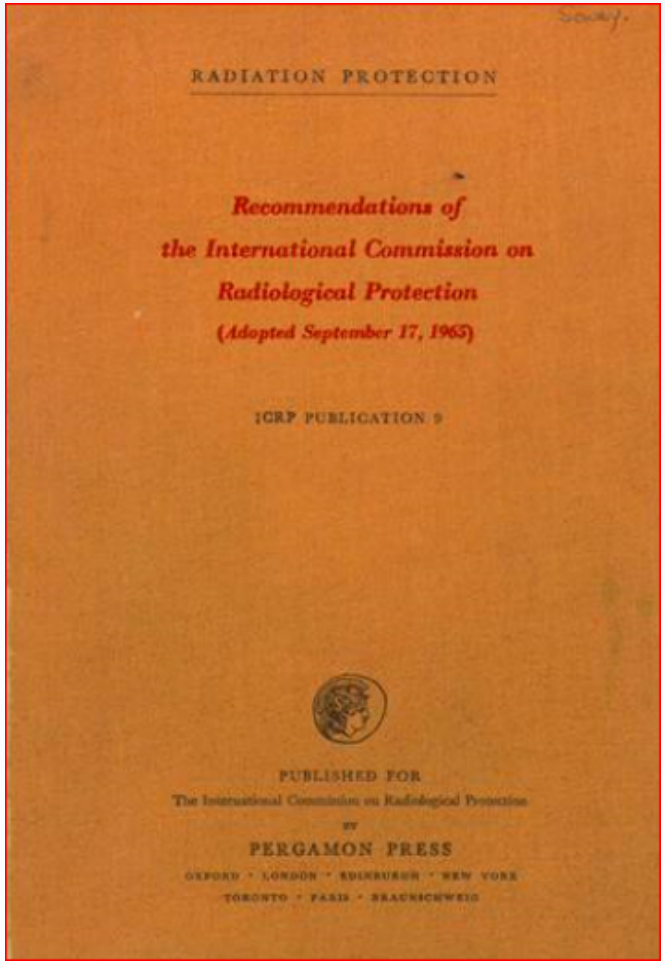
(Adopted September 9, 1958)

PUBLISHED FOR
The International Commission on Radiological Protection
BY
PERGAMON PRESS
NEW YORK · LONDON · PARIS · LOS ANGELES

- With "present maximum permissible exposure levels no special treatment of radiation workers with respect to working hours and length of vacation is needed"
- The report stated that "no recommendations are given with regard to the dose to the individual from medical exposure"

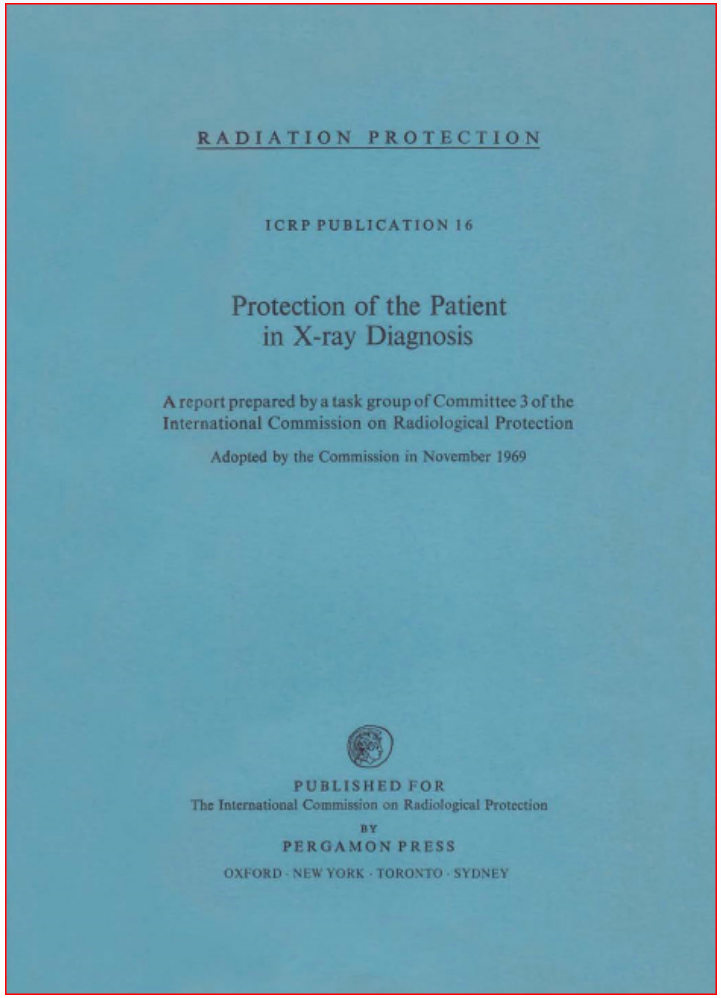
Beginning of patient protection (1966)

Patient protection remained excluded until Publication 9 (1966) in which…



- … citing the 1962 UNSCEAR report, recognized that medical exposure could be reduced without loss of medically important information.
- Soon after this statement in Publication 9, the first task group charged with patient protection in x-ray diagnosis was established,
- The task group prepared Publication 16 (ICRP, 1970).

First publication entirely devoted to patient protection


RADIATION PROTECTION

ICRP PUBLICATION 16

Protection of the Patient
in X-ray Diagnosis

A report prepared by a task group of Committee 3 of the
International Commission on Radiological Protection

Adopted by the Commission in November 1969

PUBLISHED FOR
The International Commission on Radiological Protection
BY
PERGAMON PRESS
OXFORD · NEW YORK · TORONTO · SYDNEY

- "the establishment of efficient measures for patient protection will in no way impede the continuing development of radiological diagnosis.

- It may be stated that, …, such measures contribute to the highest standards of clinical radiological practice."

Technical contents of Publication 16

- This publication addressed the following topics, with recommendations that are still applicable today:
  - properties of the radiation beam,
  - size and position of x-ray beam,
  - organ shielding,
  - antiscatter grids,
  - sensitivity of the recording system,
  - processing control and recording of radiation exposure, and
  - reduction in number of retakes.

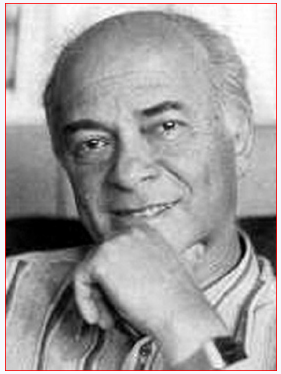
1977 Renaming and refocusing Committee 3

Radiological protection in medicine

"Matters requiring particular attention include the protection of the patient…"

Chairpersons of Committee 3 on Radiation protection in medicine since 1977

1977–1985
Charles B. Meinhold, USA,



1985–1993
Julian Liniecki, Poland

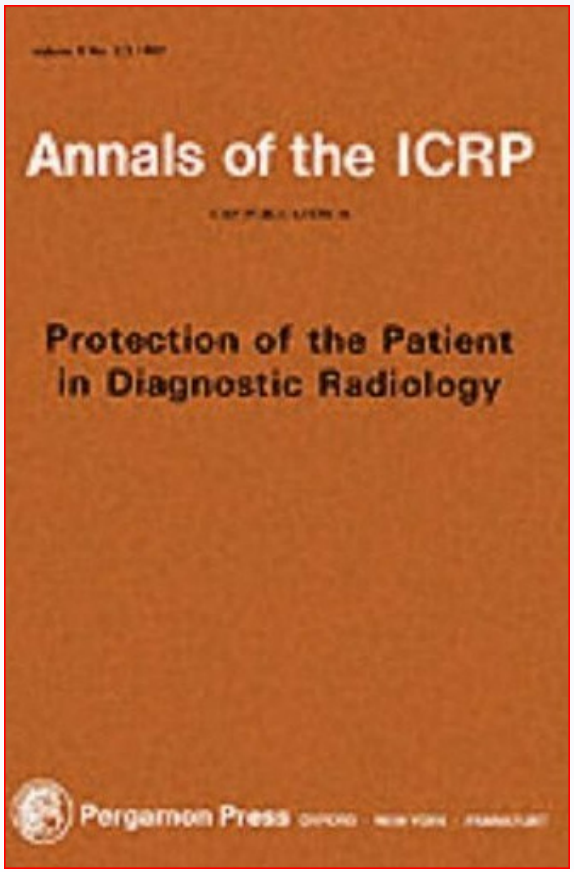
1993–1997
Henri Jammet, France

1997–2005
Fred J. Mettler, USA

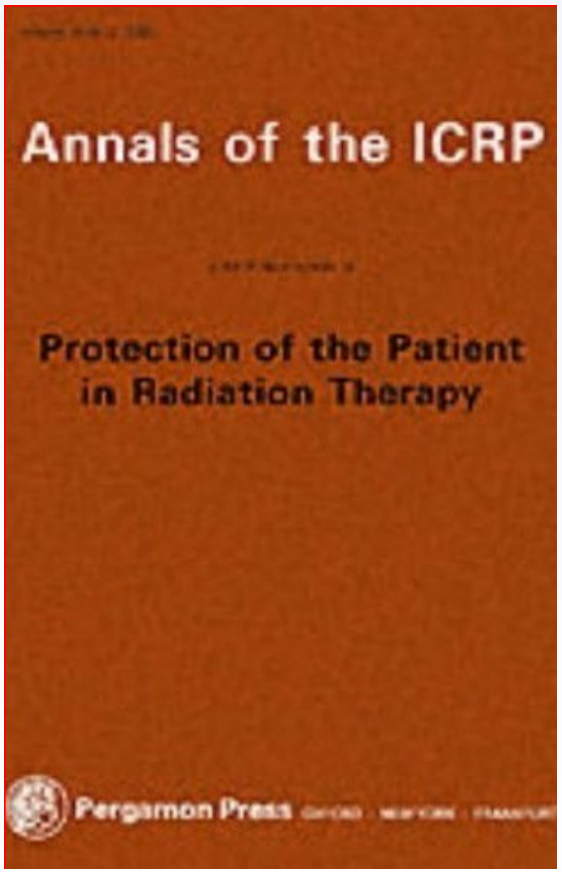
2005–2009
Claire Cousins, UK

2009 to date,
Eliseo Vañó, Spain

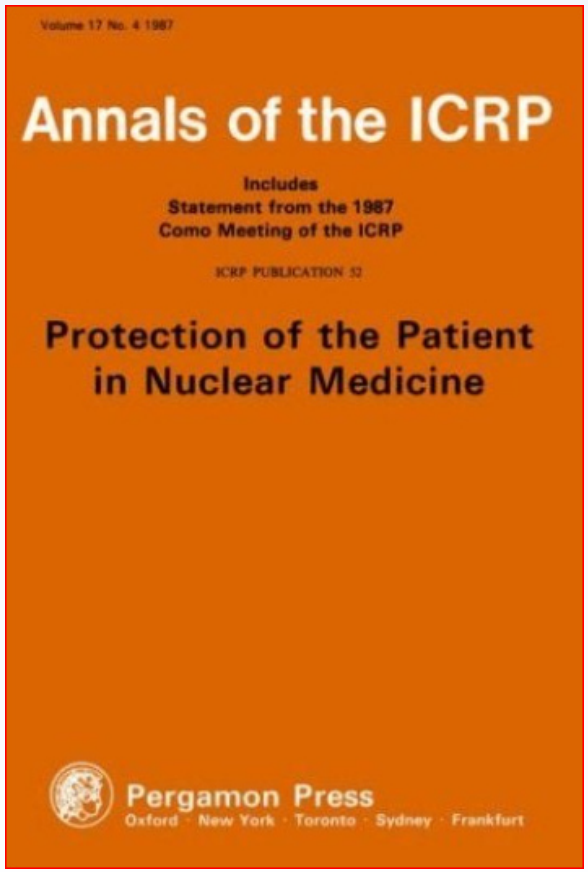
Series of comprehensive reports on the protection of patients were published in the 80´s



1982



1985



1987

ICRP 34: patient protection in diagnostic radiology

APPENDIX 1

Determination of Organ Doses from Diagnostic X-ray Examinations*

There are several methods for estimating the dose to specific organs of a patient from diagnostic x-ray examinations (A-1).† One method is to refer to tables of organ dose for a reference patient. An example of such data is presented in Table A1, which gives the calculated

Table A2. Average absorbed dose (1 mGy) in the thyroid for selected x-ray projections.[1] 1 Gy entrance kerma (air kerma in air without backscatter)

Projection	View	SID (cm)[2]	Image receptor size (cm)[3]	Beam quality (HVL, mm Al) 1.5	2.0	2.5	3.0	3.5	4.0
Skull	AP	102	25.4 × 30.5	216	273	316	351	378	399
	PA	102	25.4 × 30.5	9	15	23	31	41	52
	LAT	102	30.5 × 25.4	87	110	137	160	180	198
Abdominal[4]	AP	102	35.6 × 43.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	PA	102	35.6 × 43.2	0.02	0.07	0.1	0.2	0.5	0.6
	LAT	102	35.6 × 43.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lumbar spine	AP	102	35.6 × 43.2	0.06	0.2	0.3	0.6	0.9	1.3
	LAT	102	35.6 × 43.2	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Scapula (one side only)	AP	102	25.4 × 30.5	13	17	25	32	39	45
Full spine	AP	183	35.6 × 91.4	643	808	936	1040	1110	1170

- Parameters influending exposure
- Methods for optimization
- Education and training
- Appendices on organ dose calculation from entrance doses

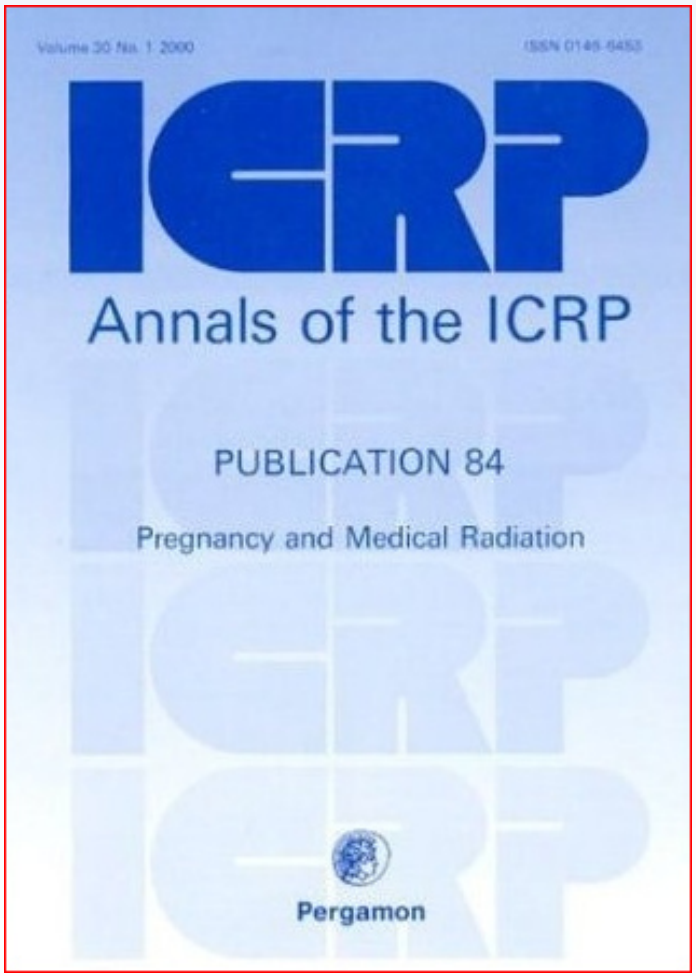
In 1997 Committee 3 recognized that

- Comprehensive ICRP reports were used by radiation protection specialists in hospitals,
- But not by the medical community
- The impact was, therefore, limited

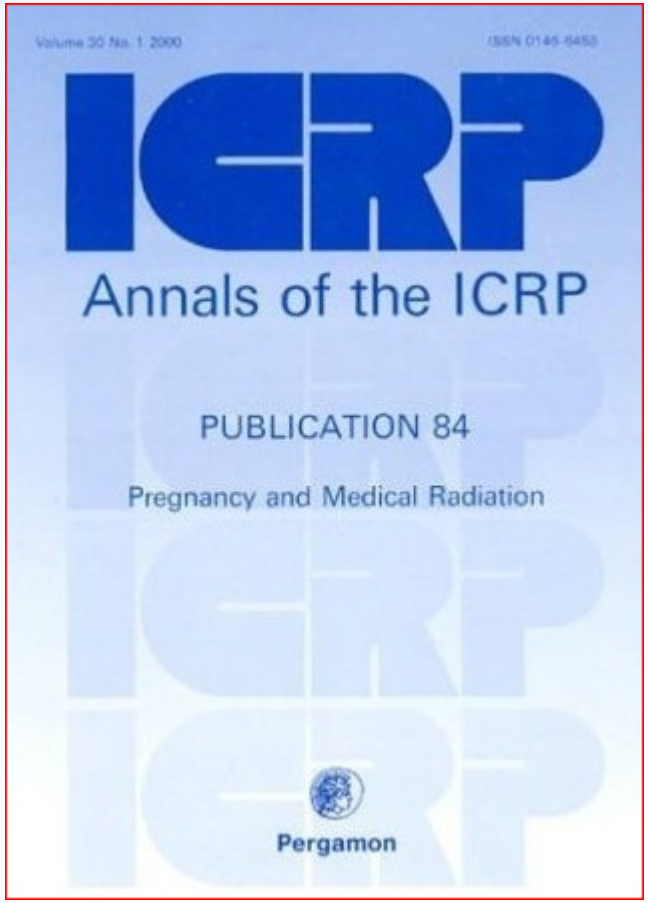
A decision was made to

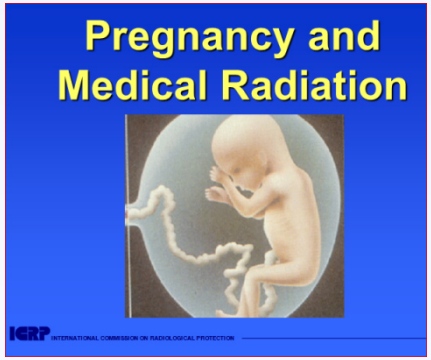
- Identify specific demands by specific audiences within the medical community,
- address them in short concise reports, worded in plain language understandable to these audiences
- but still in a scientific manner and consistent with all the ICRP recommendations
- accept high-quality translation by professional societies to local languages
- accompany them with a set of slides to be used or adapted by professionals in lectures

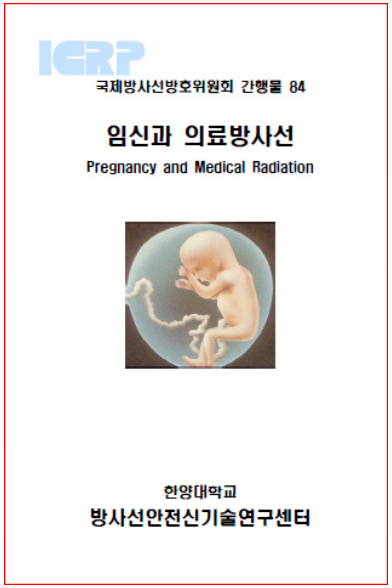
ICRP 84
Pregnancy and medical radiation



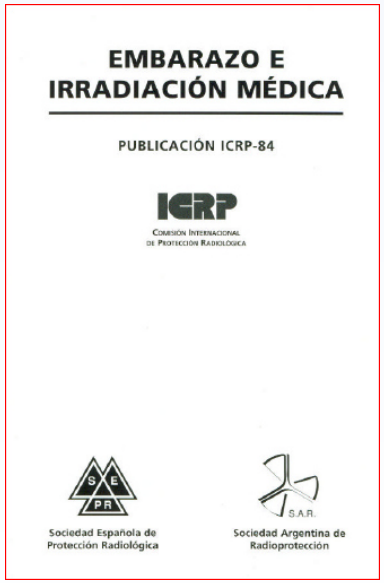
Pregnancy and medical radiation





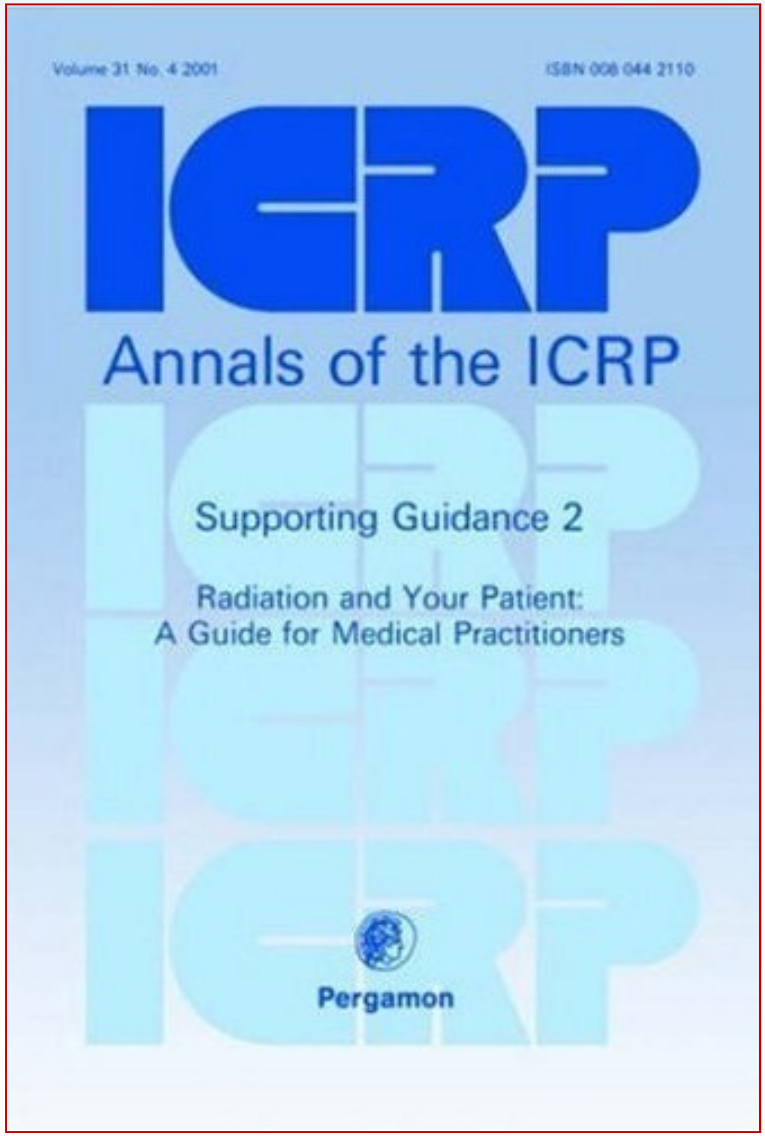


In Korean

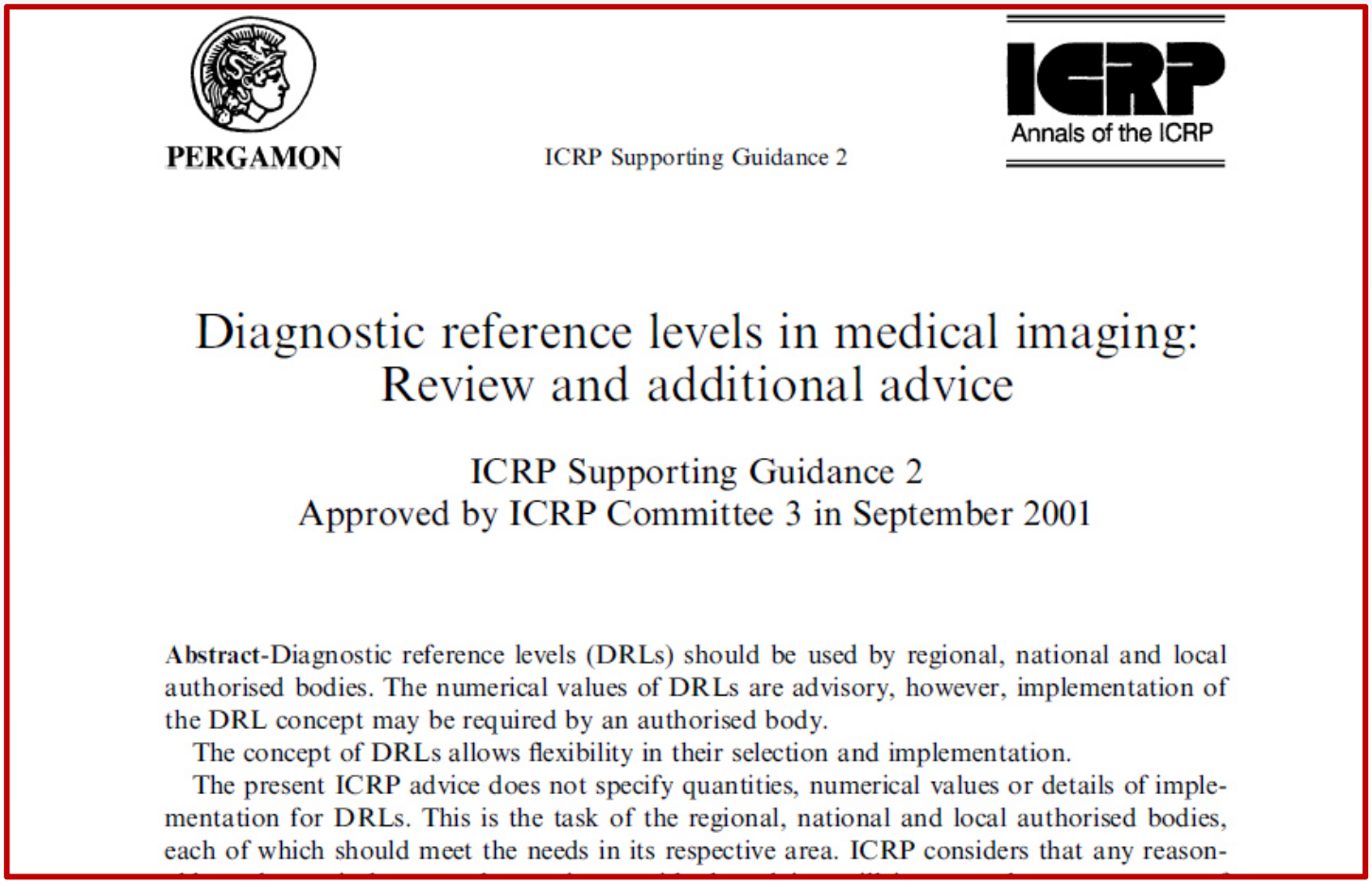


In Spanish

Guidance for physicians: Radiation and your patient



An overview of existing approaches for diagnostic reference levels



PERGAMON

ICRP Supporting Guidance 2

Annals of the ICRP

Diagnostic reference levels in medical imaging: Review and additional advice

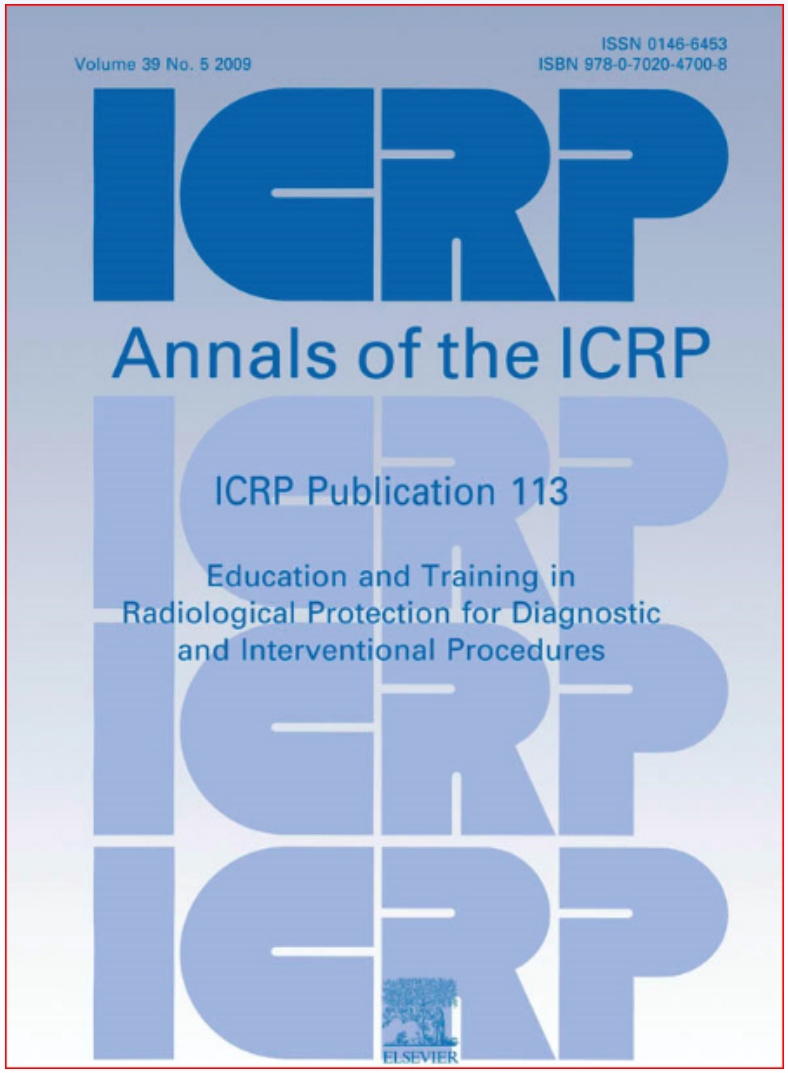
ICRP Supporting Guidance 2
Approved by ICRP Committee 3 in September 2001

Abstract-Diagnostic reference levels (DRLs) should be used by regional, national and local authorised bodies. The numerical values of DRLs are advisory, however, implementation of the DRL concept may be required by an authorised body.

The concept of DRLs allows flexibility in their selection and implementation.

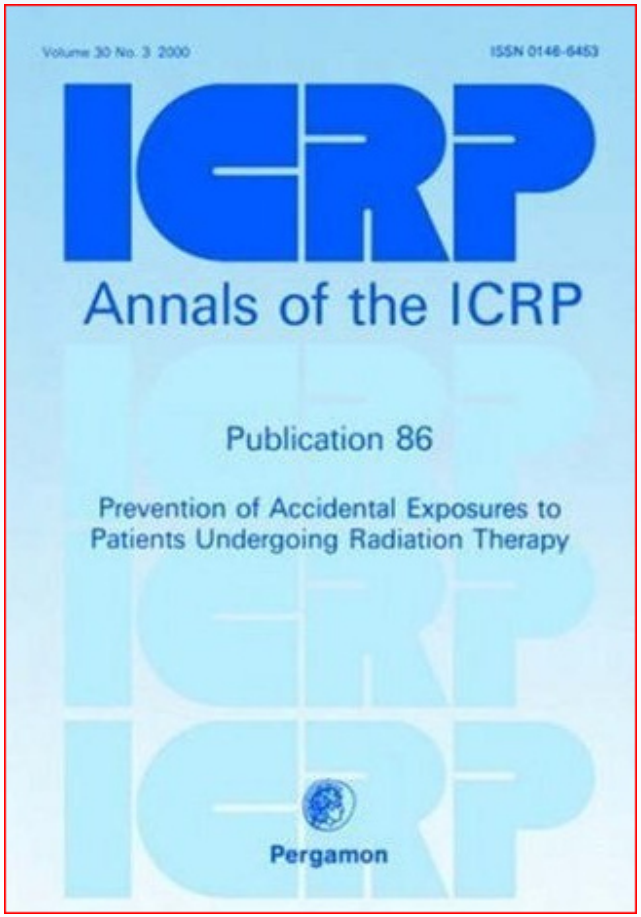
The present ICRP advice does not specify quantities, numerical values or details of implementation for DRLs. This is the task of the regional, national and local authorised bodies, each of which should meet the needs in its respective area. ICRP considers that any reason-

Education and training

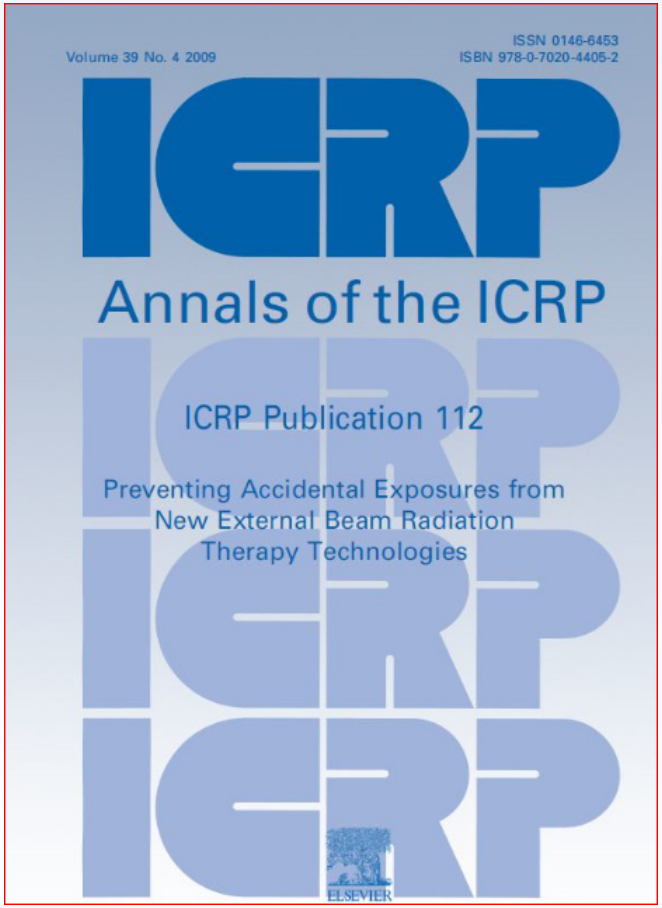


Radiation therapy

Radiation Safety in Radiation Therapy
Emphasis on Prevention of Accidental Exposures

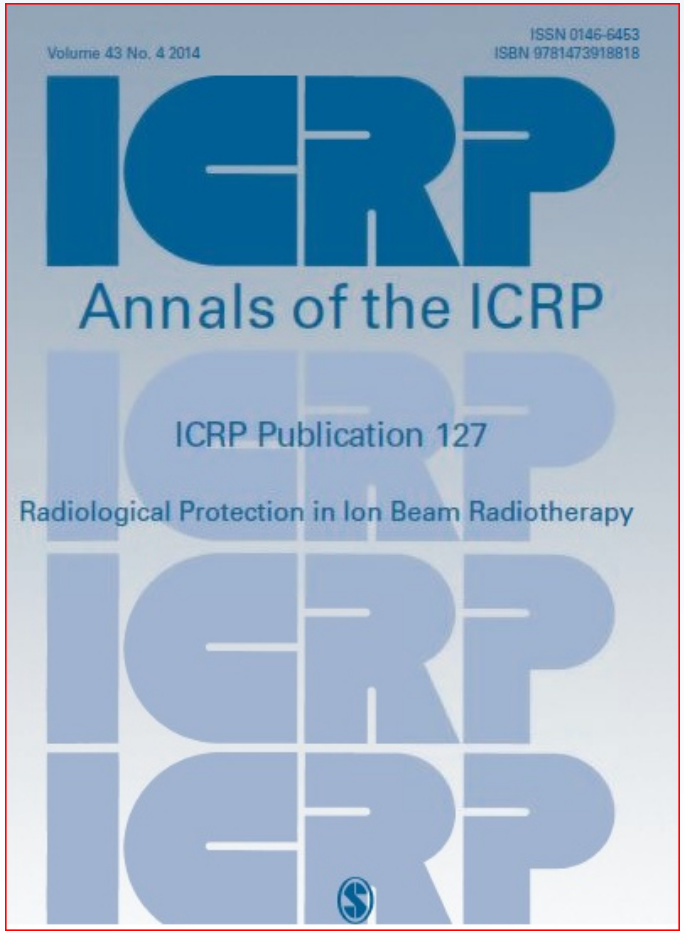


Conventional Radiotherapy

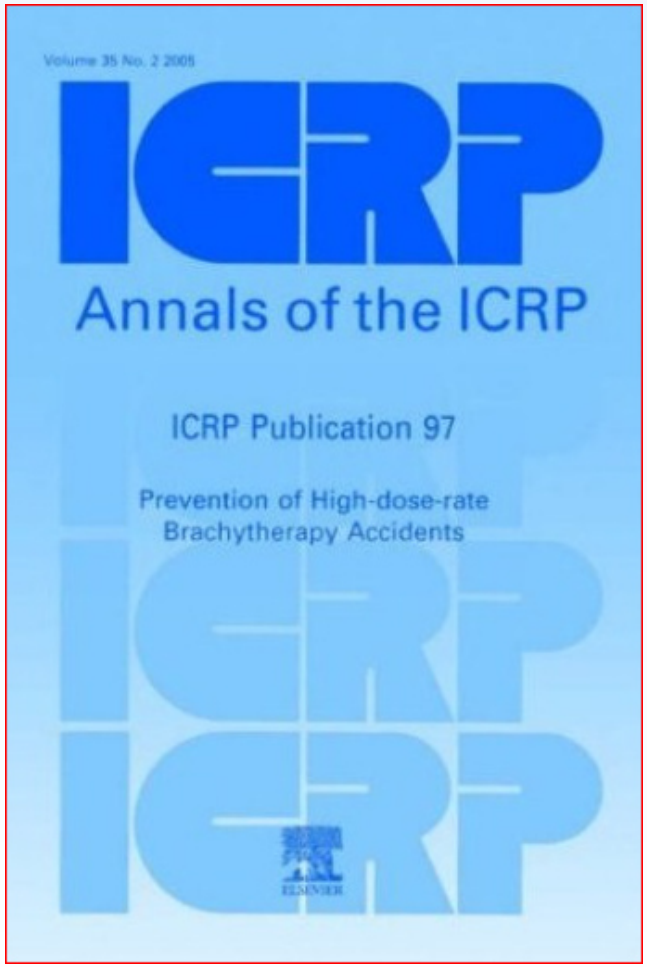


New technologies external beam

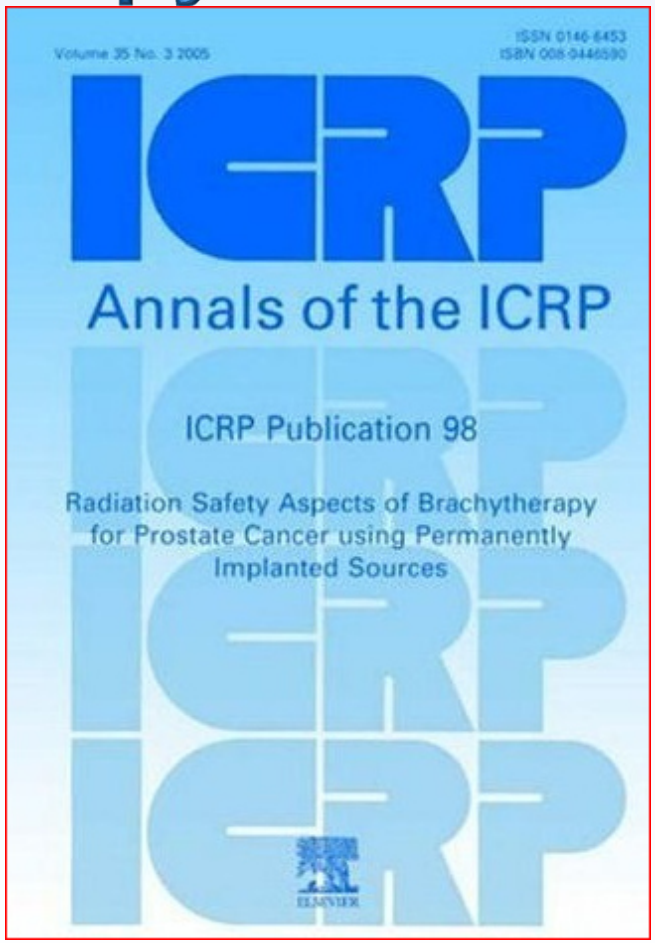
Radiation safety in ion beam radiotherapy



Specific issues in radiation safety in brachytherapy



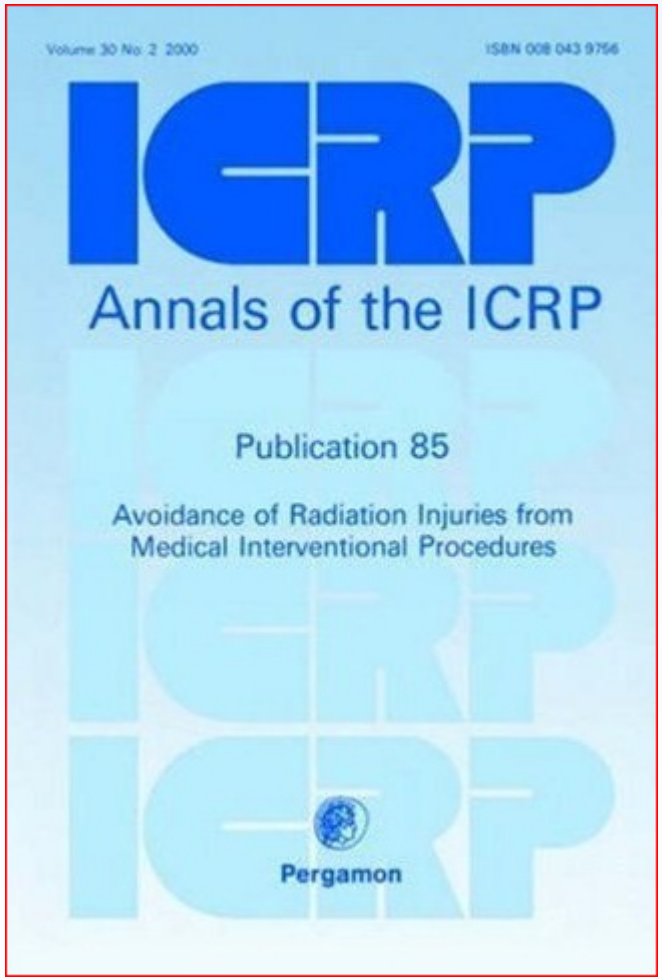
HDR brachytherapy



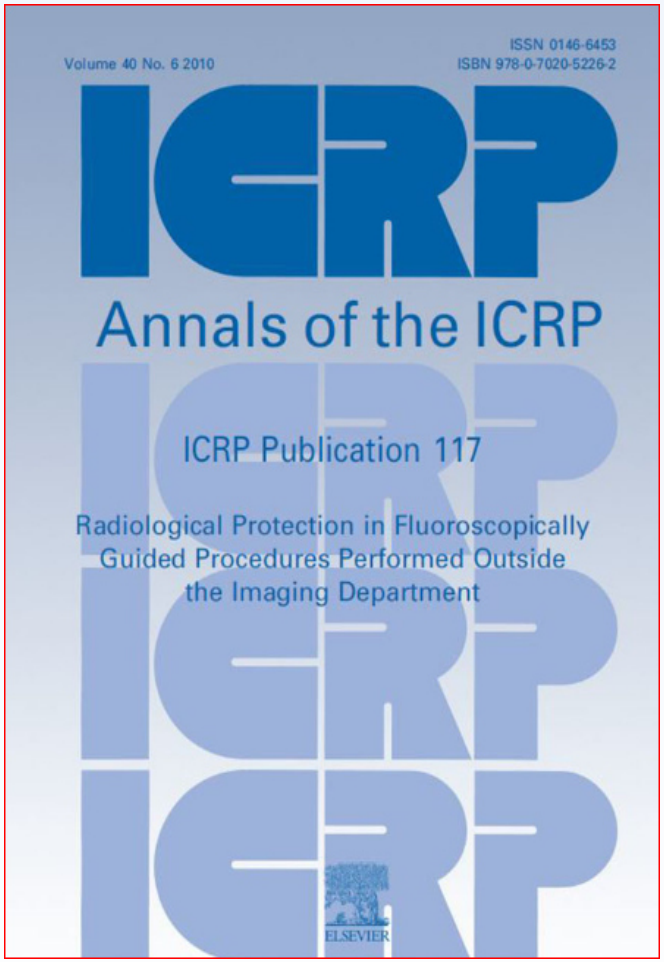
Prostate treatment with permanent implants

Fluoroscopy and interventional

Fluoroscopy and interventional

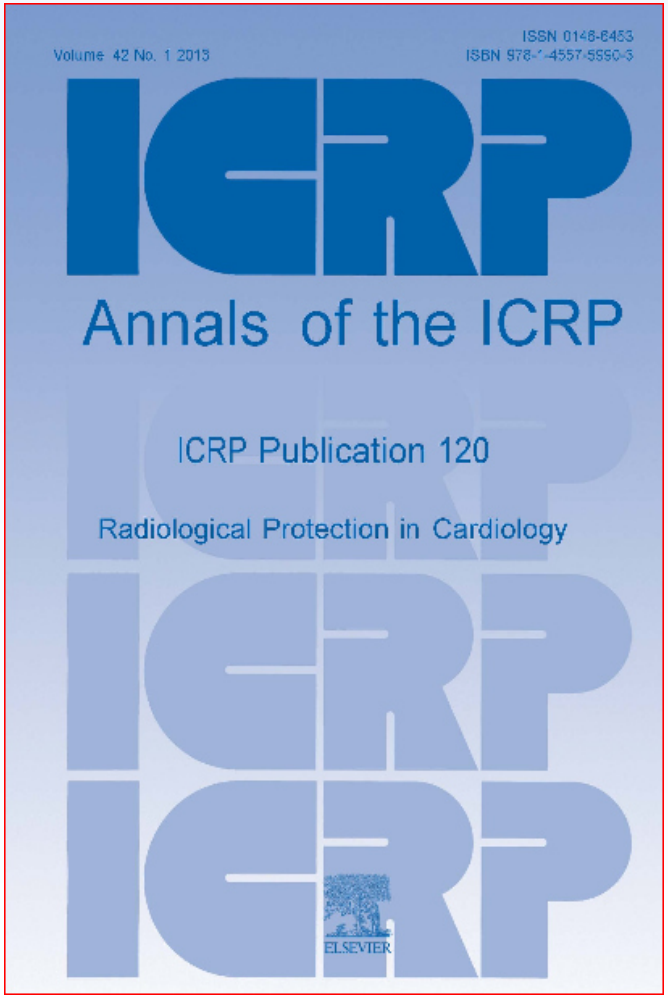


Avoiding radiation injuries



Interventions outside the imaging department

Cardiology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Radiological Protection in Cardiology
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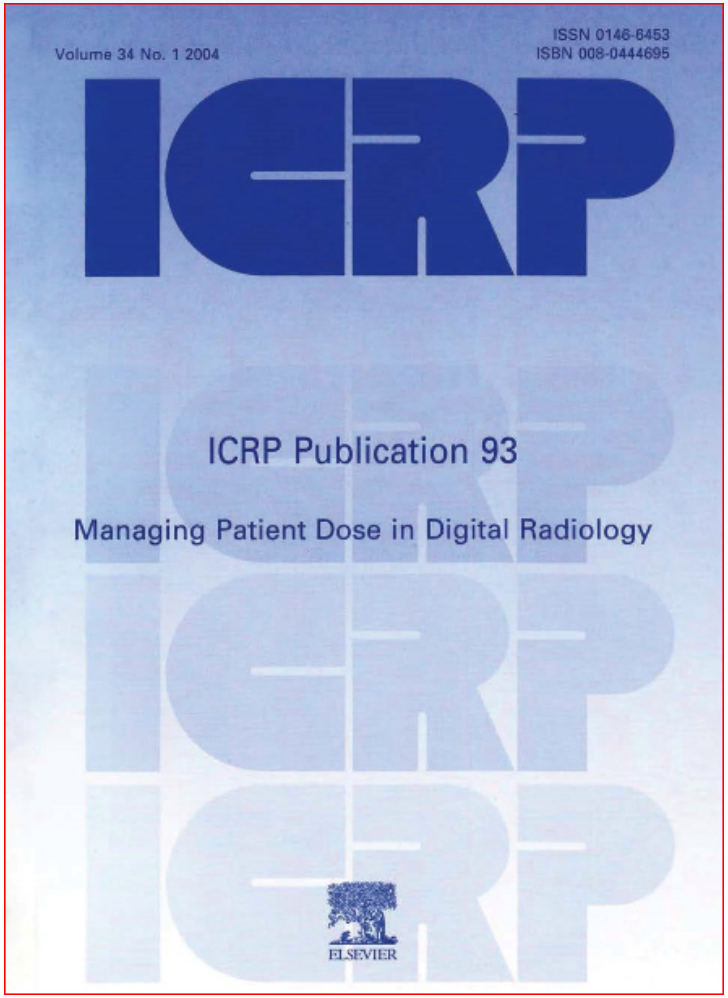
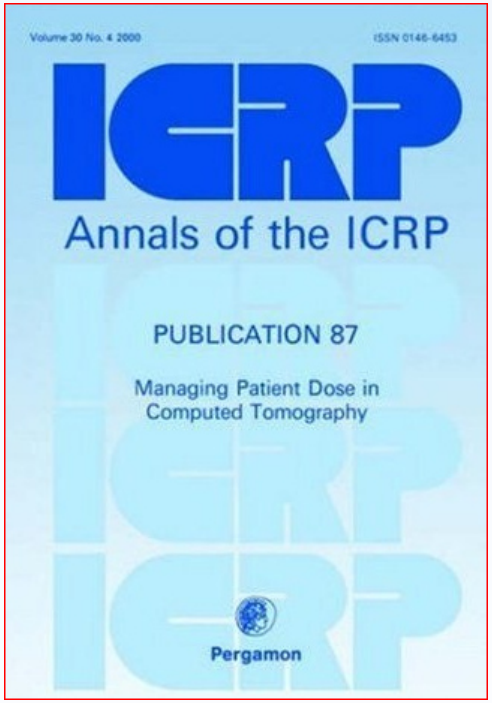
Digital radiography

Transition from conventional to digital radiology

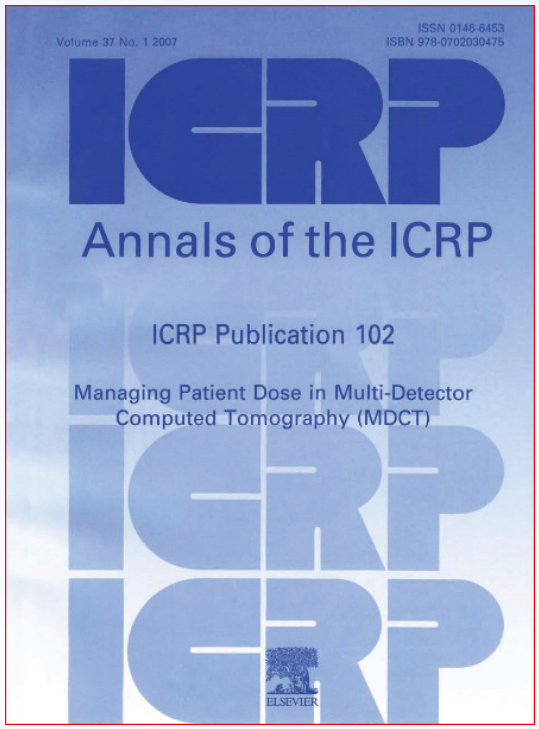


Computed tomography

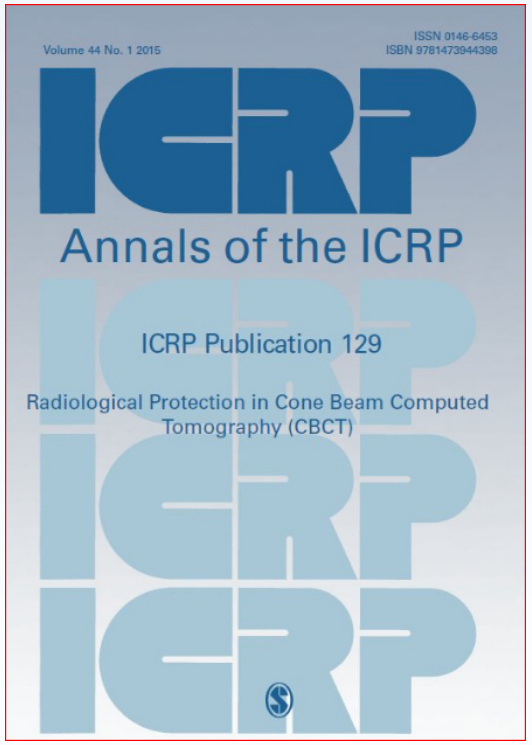
Radiation protection in computed tomography



Single slice CT



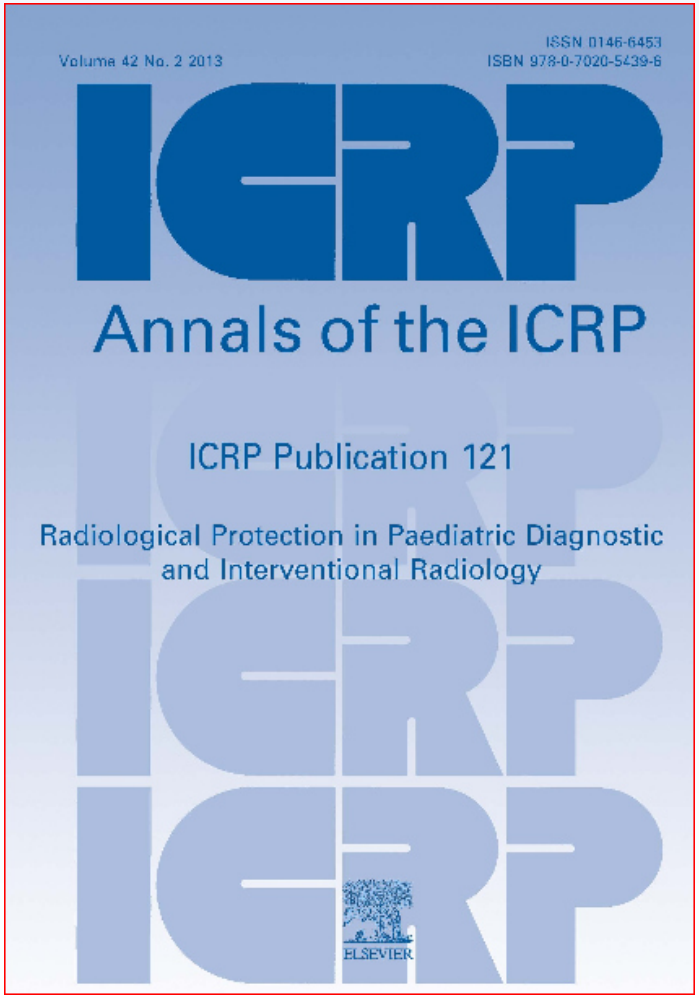
Multi slice CT



Cone beam CT

Special groups: paediatry

Paediatric imaging



In summary, 20 concise publications from 2000 to date

Committee 3 current work

- Occupational radiological protection in brachytherapy,
- Occupational radiation protection issues in radiation imaging guided interventions,
- Justification: framework for justification in medical uses of ionizing radiation,
- Diagnostic reference levels for diagnostic and interventional imaging
- Radiological protection in therapy with radiopharmaceuticals,
- Radiological protection in medicine related to individual radiosusceptibility

Conclusions

Conclusions

- Since its birth in 1928, the ICRP has been intimately related to protection in medicine. It was born at the International Congress of Radiology, in response to growing concerns about the effects of ionizing radiation observed in the medical community.
- During the first 30 years its recommendations were devoted to protection of the radiological professionals.
- In the 50´s the ICRP widened its scope to embrace other areas of protection

Conclusions

- In 1977 undertook a significant re-orientation of priorities assigning Committee 3 radiation protection in medicine, including the patients.
- In the 80´s, comprehensive publications were devoted to patient protection in radiology, nuclear medicine and radiotherapy and
- From year 2000 about 20 concise publications have been published, addressing specific concerns from specific audiences within the medical community

Thank you for your attention

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