AIST Satellite Meeting, Tokyo, Japan, 13 November 2023

The Dosimetry System of ICRP. Present and future perspectives

María Antonia López
CIEMAT, Spain
Member of ICRP
Committee 2

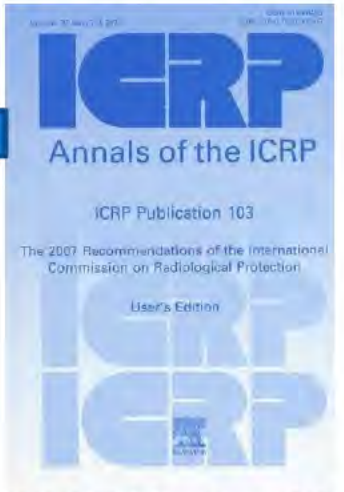
ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Doses from Radiation Exposure

- Dosimetric quantities were developed for the assessment of doses from radiation exposures
  - This is necessary to describe dose-response relationships for radiation effects which provide the basis for risk estimation in radiological protection
  - **Absorbed Dose D (gray Gy)** is the fundamental physical quantity for radiological protection, used for all types of ionizing radiation and any irradiation geometry

- **Equivalent Dose and Effective Dose** are defined by ICRP as protection quantities in ICRP Publication 103
  - For whole body and partial body exposures
  - From external radiations and intakes of radionuclides

- Equivalent Dose and Effective Dose cannot be measured directly in the body:
  - *Operational quantities* (that can be measured) are defined, from which the equivalent dose and the effective dose can be assessed



ICRP Publication 103

Doses from Radiation Exposure

➢ Health Effects

- **Stochastic Effects** - radiological protection in the low dose range is mainly concerned with protection against **radiation-induced cancer and heritable diseases**.
  - Probabilistic effects, with no threshold and increase in frequency in proportion with the dose
  - **Effective dose (Sv) is the proper quantity to assess**

- **Deterministic Effects** causing **tissue reactions** at high doses (e.g. emergency situations).
  - Damage occurs above threshold doses.
  - **Absorbed dose (Gy) is the proper quantity to assess**
  - When high-LET radiations (e.g. neutrons, alpha particles) are involved: an **absorbed dose, weighted with an appropriate RBE** (Relative Biological Effectiveness), should be used

Dose Quantities

➢ Absorbed dose *D*:

The energy absorbed per unit mass: $D = \frac{d\bar{\varepsilon}}{dm}$ gray (Gy); 1 Gy = 1 J kg^{-1}

Where $d\varepsilon$ is the mean energy imparted by ionising radiation to the matter in a volume element of mass dm
dm is the mass of the matter in this volume element.

- **The absorbed dose D** in general is averaged over a target region r_T (organ or tissue) being the ***organ absorbed dose*** D_T.

- It is assumed that **the mean value of the absorbed dose** in an organ/tissue **is correlated with radiation detriment from stochastic effects**

Doses from Radiation Exposure

➢ **Effective Dose**: most relevant quantity for dose assessment in radiological protection

- To relate radiation dose to radiation risk (detriment), taking into account variations in
  - the biological effectiveness of radiations of different quality
    - ✓ **w_R**: radiation weighting factors - differences in the effect of radiations in causing stochastic effects
  - the sensitivity of organs and tissues to ionizing radiations
    - ✓ **w_T:** tissue weighting factors - variations in radiation sensitivity of different organs/tissues to the induction of stochastic effects

- **Calculation of Effective Dose**:
  - To average absorbed dose over specified organs and tissues, applying proper w_R weighting factors to give **equivalent dose.**
  - Values of equivalent doses to organs and tissues weighted for the radiosensitivity of these organs and tissues (using w_T) are then summed to give the **effective dose**

Dose Quantities

- **Equivalent dose H_T**: A weighted sum of *absorbed doses* in an organ or tissue "T", determined by taking the sum of the products of the absorbed doses $D_{R,T}$ due to different radiation types "R" and the appropriate *radiation weighting factors* (w_R):

$$H_T = \sum_R w_R \cdot D_{R,T}$$

The SI unit for equivalent dose to an organ or tissue is the **sievert (Sv);** 1 Sv = J kg^{-1}.

ICRP 103.

w_R averaged over both sexes and all ages.

Only refers to stochastic effects.

Based on experimental RBE data

Radiation Type	Radiation Weighting Factor w_R
Photons	1
Electrons and muons	1
Protons and chargend pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	Continuous function of neutron energy

All values relate to the radiation incident on the body or for internal radiation sources emitted from the incorporated radionuclides

Dose Quantities

- **Effective dose *E***: risk-related quantity for assessment of detriment from radiation-induced stochastic effects. It is a weighted mean value of the equivalent doses to a selected number of target tissues for which explicit tissue weighting factors w_T are recommended.

Sex-averaged organ equivalent doses are used for its calculation:

$$E = \sum_T w_T \cdot \frac{(H_T^M + H_T^F)}{2}$$

The SI unit for effective dose is the **sievert (Sv)**.

- Sum over all organs and tissues considered to be sensitive to the induction of stochastic effects
- Remainder tissues: $H_{\text{rmd}} = \frac{1}{13}\sum_{1}^{13} H_T$
- **w_T averaged over both sexes and all ages**

Tissue	w_T	Σw_T
Bone marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salicary glands, Skin	0.01	0.04
	Total	1.00

Dose Quantities

Internal Exposures

Radiation sources (where incorporated radionuclides have accumulated) are inside the body and irradiation continues as long as the radionuclides remain inside the body, at a rate that changes with time.

The dose rate to the target region r_T delivered by each source region r_S is integrated over a given time period τ after intake:

$$H_T(\tau) = \int_0^\tau \dot{H}_T(t)dt = \sum_{r_S} \int_0^\tau A(r_S, t)\, S_w(r_T \leftarrow r_S, t)dt$$

where

$\dot{H}_T(t)$ equivalent dose rate in the **target organ or tissue r_T** at time *t;*

$A(r_S,t)$ activity (in Bq) in the **source region** r_S at time *t;*

$S_w(r_T \leftarrow r_S,t)$ mean equivalent dose rate to target region r_T at time *t* per unit activity present in source region r_S,

Time-integrated quantity $H_T(\tau)$ Sv is the *committed equivalent dose* = dose to the target organ due to the initial intake and received over a time period τ = 50 years (adults) and to the age of 70 years (children).

The *committed effective dose* -

$$E(\tau) = \sum_T w_T \left[\frac{H_T^{Male}(\tau) + HTFemale(\tau)}{2}\right]$$

Sex-averaged organ committed equivalent doses

Dose Quantities

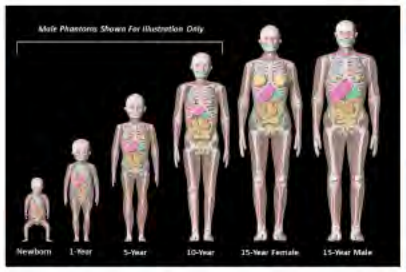
Reference voxel adult phantoms. ICRP Publication 110

Reference Computational Phantoms

- **Adult** Reference Male and Female (**ICRP Publication 110**)
- **Children** of different ages: newborn, 1, 5, 10 and 15-years old (**ICRP Publication 143**)

- Phantoms are based on tomographic images. Voxels have been adjusted to approximate organ masses according to ICRP Publication 89

- **Dose Conversion Factors (external exposures)** and **dose coefficients (internal exposures)** are calculated using computational phantoms



Family of reference voxel pediatric phantoms for members of the public Figure 3.3 ICRP Publication 143

Figure 2. Sex averaging to obtain the Effective Dose. ICRP Publication 103

Dose Quantities

- **Effective dose E** for protection purposes is estimated for the **Reference Person,** according to ICRP Publication 89

  - E takes account of the given exposure conditions but not of the characteristics of a specific individual and cannot be used for the assessment of individual risk

  - E is used for regulatory purposes for occupational and public exposures
    - Prospective dose assessment: planning and optimization of protection
    - Retrospective dose assessment: demostrating compliance with dose limits or to compare with dose constraints or reference levels

- **Physical radiation field quantities and Operational Dose Quantities**
  - The protection quantities H_T and E are not measurable and are assessed using their relationship to physical **radiation field quantities** (e.g. air kerma free in air K_a for photons, or fluence ϕ for electrons and neutrons) linked with the **operational dose quantities** (external exposures).
  - The aim is to provide a conservative approach of the protection quantities related to exposures of persons under most irradiation conditions

Dose Quantities

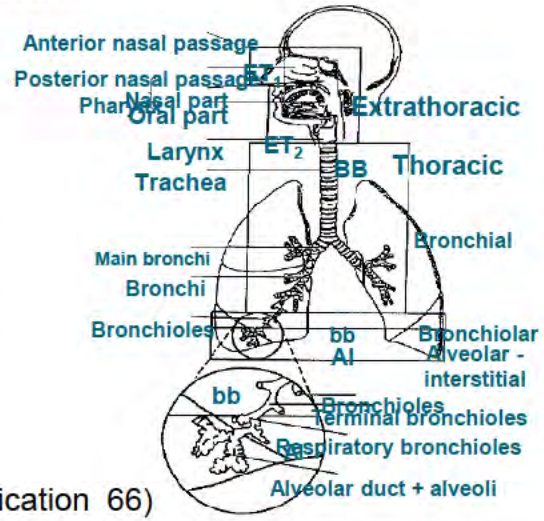
EXTERNAL EXPOSURES - OPERATIONAL QUANTITIES

- **Area monitoring**:
  - **Ambient Dose Equivalent H*(10)** – good measure of Effective Dose (survey instruments)
  - **Directional dose equivalent H'(d,0.07)** – good measure of Equivalent Dose (survey instruments)

- **Individual monitoring**: **Personal Dose Equivalent $H_p(d)$** as the dose equivalent in ICRU (soft) tissue at a depth *d* below an specific point of the human body (e.g. where the individual dosimeter is worn).
  - Assessment of Effective Dose: $H_p(10)$ with d= 10 mm
  - Assessment of dose to the skin or the hands and feet: $H_p(0.07)$ with d= 0.07 mm
  - Assessment of dose to the lens of the eye: $H_p(3)$ with d= 3 mm

INTERNAL EXPOSURES

- Biokinetic models are used for the interpretation of measurement data of activity in the body or in excreta of incorporated radionuclides, to assess the Intake I(Bq). Then the committed doses are obtained using dose coefficients ($SvBq^{-1}$) provided by ICRP, calculated from dosimetric models.



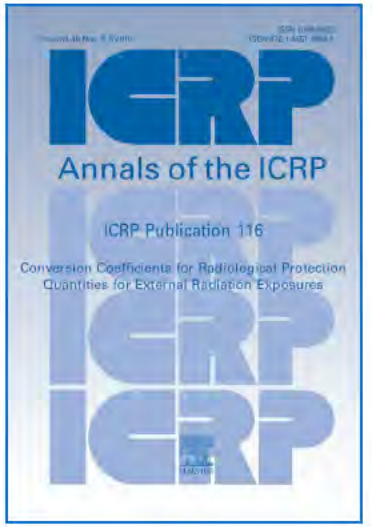
Human Respiratory Tract Model (ICRP Publication 66)

Dose Quantities

EXTERNAL EXPOSURES

- **ICRP Publication 116 – Conversion Coefficients for Radiological Protection Quantitities for External Radiation Exposures**

- **ICRU Report 95 – New Operational Quantities in Radiological Protection**
  - Wider radiation type and energy coverage
  - Improvement of representativeness in the diagnostic/interventional photon energy range
  - Dose conversión factor calculated using ICRP voxel reference computational phantoms
  - Area monitoring:
    - **Ambient Dose H***
    - **Directional Absorbed dose D'(Ω)**
  - Individual monitoring:
    - **Personal Dose H_p**
    - **Personal Absorbed Dose D_p**
  - **Impact of the new ICRU Operational quantities: see EURADOS Report 2022-02** (eurados.sckcen.be/sites/eurados/files/uploads/Report-Publications/Reports/2022/)



Dose Quantities

INTERNAL EXPOSURES OF WORKERS

OIR Series – "Dose Coefficients for Occupational Intakes of Radionuclides" – Parts 1-5

- **Publication 130** – OIR Part 1 (2015): Methodology, general principles consistent with ICRP Publication103; Update of ICRP66 Respiratory tract Model, ICRP100 Alimentary Tract Model, more realistic systemic models
- **Publication 134** – OIR Part 2 (2017): H, C, P, S, Ca, Fe, Co, Zn, Sr, Y, Zr, Nb, Mo, Tc
- **Publication 137** – OIR Part 3 (2017): Ru, Sb, Te, I, Cs, Ba, Ir, Pb, Bi, Po, Ra, Th, U, Rn
- **Publication 141** – OIR Part 4 (2019): La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ac, Pa, Np, Pu, Am, Cm, …
- **Publication 151** – OIR Part 5 (2022): Be, F, Na, Mg, Al, Si, Cl, K, Sc, Ti, V, Cr, Mn, Ni, Cu, Ga, Ge, … and noble gases Ne, Ar, Kr, Xe

Z(t) "dose per content function" – NEW -

$$z(t) = \frac{e(50)}{m(t)}\ SvBq^{-1}$$

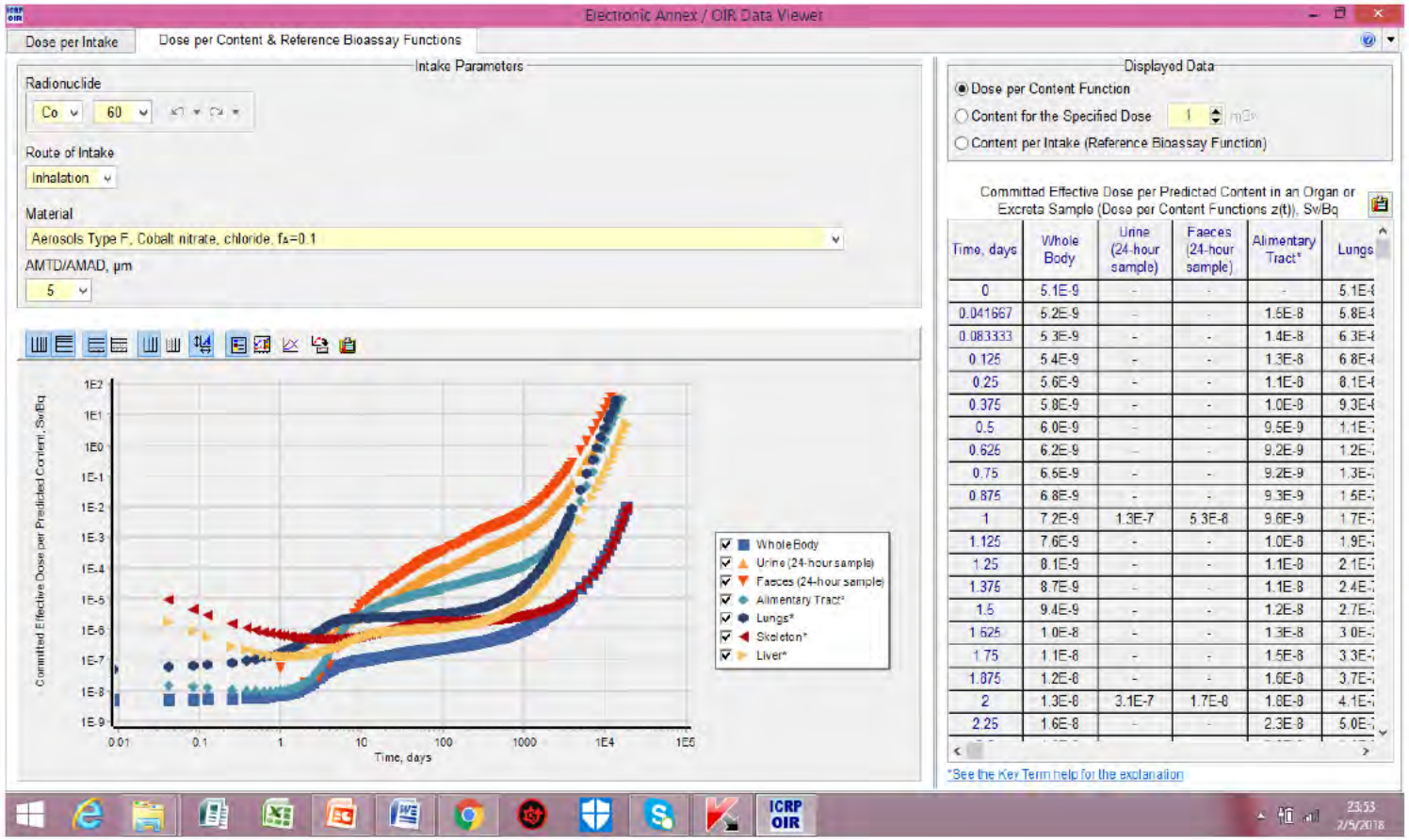
Direct assessment of committed effective dose, using in vivo M(Bq) or in vitro M(Bqd^{-1}, BqL^{-1}) monitoring data

$$E(50)\ \text{Sv} = M\ (\text{Bq}) \times Z(t)\ \text{Sv Bq}^{-1}$$

e(50): dose coefficient Sv Bq^{-1}
m(t): reference bioassay retention/excretion function
t: time (days) after intake

Dose Quantities

OIR Data Viewer, Electronic Annex of ICRP Publication 151



OIR Data Viewer can show:

- ✓Classification of incorporated materials according to chemical form (inhalation: Type F, M, S, F/M, M/S; ingestion: f_A)
- ✓Reference bioassay retention/excretion functions m(t)
- ✓Dose coefficients e(50) $SvBq^{-1}$ for inhalation, ingestion, injection

"Z(t) Dose per content" functions

Dose Quantities

➢ Occupational Exposures:

Total Effective dose, considering external and internal exposures of WORKERS:

E= $H_p(10)$ + E(50) Sv to demonstrate compliance with dose limits and constraints

$$E_t = H_P(10) + \sum_j I_{j,ing} e(g)_{j,ing} + \sum_j I_{j,inh} e(g)_{j,inh}$$

$H_P(10)$ Sv: personal dose equivalent for External Exposures (uniform whole body exposure)

E(50) Sv: committed effective dose for Internal Exposures

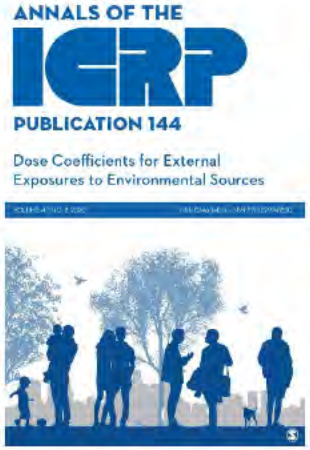
- **I ing**: Intake (Bq) for ingestion
- **e(g) ing** : committed effective dose coefficient $SvBq^{-1}$ – ingestion
- **I inh**: Intake (Bq) for inhalation
- **e(g) inh**: committed effective dose coefficient $SvBq^{-1}$ – inhalation
- **g:** integration period= 50 years

$$e(50) = \sum_T w_T \left[\frac{h_T^{Male}(50) + hTFemale\ (50)}{2}\right]$$

Dose Quantities

Public Exposures

- From **natural radiation sources** and from **technical installations**



- **External exposures**: radionuclides released, which are present in the air, soil or water.
- **ICRP Publication 144:** Dose Coefficients for External Exposures to Environmental Sources

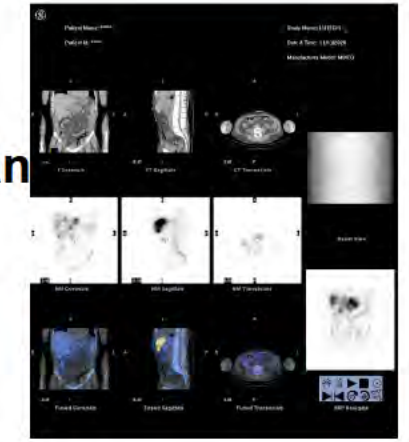
- **Internal exposures**: inhalation of airborne radionuclides from a cloud, inhalation of resuspended radionuclides and by ingestion of contaminated food or water
- **Effective Dose** may be obtained by environmental measurements, habit data and modelling. Information on concentrations of radionuclides in effluents and the environment are used together with radioecological modelling (pathway analysis of environmental transport, trough air, water, soil, sediments, plants and animals to humans).

Dose Quantities

➢ Medical Exposures to patients

- The use and interpretation of **effective dose for medical exposures** is **problematic** **an** **has limitations**, especially in case of partial and very heterogeneous exposures.

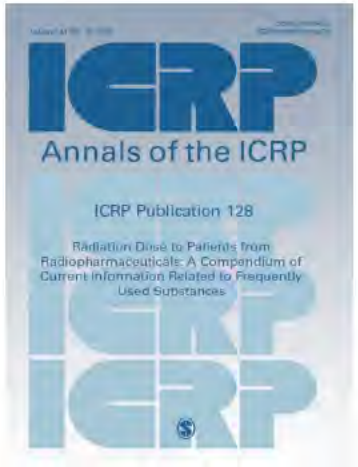
  Effective Dose calculated for the reference person can be used in medicine:
  - to compare doses from different medical procedures
  - to inform judgements and decisions on justification of patient medical procedures
  - planning research studies involving radiation exposure



SPECT-CT image courtesy of Eva Corredoira (Hospital La Paz, Spain)

- Relevant quantities for planning the medical exposures of patients and risk-benefit assessments are the **equivalent dose** or preferably the **absorbed dose** to irradiated tissues

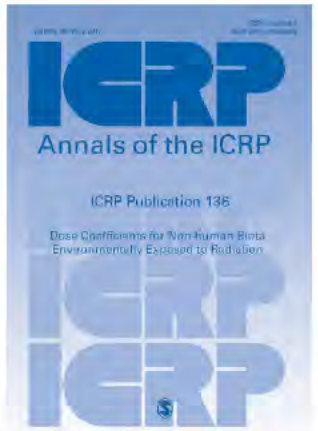
- **ICRP Publication 128:** Radiation Dose to Patients from Radiopharmaceuticals. A Compendium of Current Information Related to Frequently Used Substances
- **ICRP Publication 140:** Radiological Protection in Therapy with Radiopharmaceuticals. Absorbed Dose calculations



Dose Quantities

Other Exposures

- **ICRP Publication 136** - Dose Coefficients for **Non-Human Biota** Environmentally Exposed to Radiations
  - **ICRP Publication 148 -** Radiation Weighting for Reference Animals and Plants



- **ICRU Report 84** – Reference Data for the Validation of Doses from **Cosmic Radiation Exposure of Aircraft Crew**

- **ICRP Publication 123** – Assessment of Radiation exposure of **Astronauts in Space**

Dose Limits recommended by ICRP

Type of Dose Limit	Dose Limit - Occupational Exposure	Dose Limit - Public Exposure
Effective Dose	20 mSv per year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv *After a worker declares a pregnancy, the dose to the embryo/fetus should not exceed about 1 mSv during the remainder of the pregnancy*	1 mSv in a year *In special circumstances, a higher value could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year*
Equivalent Dose to the Lens of the Eye	20 mSv per year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv	15 mSv in a year
Equivalent Dose to the Skin *Averaged over 1 cm^2 of skin regardless of the area exposed*	500 mSv in a year	50 mSv in a year
Equivalent Dose to the Hands and feet	500 mSv in a year	-

Dose Limits recommended by ICRP

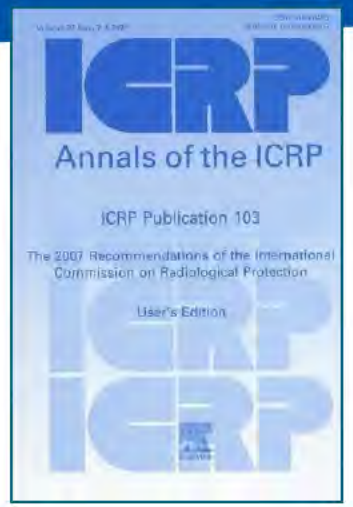
- Dose limits function in combination with the RP principles of justification and optimisation.

- Dose limits apply to doses received **above the local natural background radiation**

- **Limits on effective dose**, combined with optimisation of protection, are designed **to avoid a risk of stochastic effects** that would be considered **intolerable** in a planned exposure situation.
- **Limits on equivalent dose to an organ**, combined with optimisation of protection, are designed **to prevent the occurrence of deterministic effects.**

- Dose limits apply only in **planned exposure situation**.
- In other situations, **restrictions on individual dose** and **reference levels are defined,** providing the additional flexibility needed **in emergency and existing exposure situations** to make sure protection is optimised.
- **Dose limits do not apply to medical exposures of patients**. The focus here is on justification of medical procedures and optimisation of protection.

Effective Dose

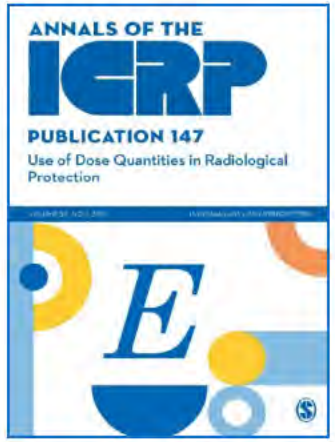


➢ The application of the effective dose

- In the frame of radiological protection of exposed workers and members of the public the main use of effective dose is **to provide a means of demonstrating compliance with dose limits or for comparing with dose constraints and reference levels**
- Effective dose provides the **dose of the Reference Person under a given exposure situation.**
- In case of doses to individuals that may substancially **exceed dose limits**, effective dose can provide a **first approach of the overall detriment,** and further specific estimates of **organ/tissues doses are needed**, for the evaluation of organ-specific risks for the specific individual.
- **Effective Dose is not recommended for epidemiological studies** nor for detailed specific retrospective investigations of individual exposure and risk. **Absorbed dose** should be used instead.

Dose Quantities

➢ ICRP Publication 147 – Use of dose quantities in Radiological Protection



- Effective dose is a risk-adjusted dosimetric quantity for the management of protection against stochastic effects (cancer and heritable effects). Its use is relying on the assumption of a Linear Non-Threshold (LNT) dose response relationship

- Effective Dose ***E*** and Collective Effective Dose ***S*** (integral over effective doses received by a group of exposed individuals) are valuable tools for use in the **optimization** of protection against stochastic effects for occupational and public exposures

- **Equivalent dose is not required as a protection quantity. It will be more appropriate that limits for tissue reactions for the skin, hands and feet, and lens of the eye are set in terms of absorbed dose** rather than equivalent dose.

- Effective dose will generally be used at doses <100 mSv, but its use at acute doses in the range up to 1 Sv (e.g. in emergency situations) is reasonable, noting the possibility of occurrence of tissue reactions particularly from non-uniform distribution of dose

Future perspectives of the ICRP dosimetry system

The work of ICRP Committee 2

Doses from Radiation Exposure

ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

ICRP Committee 2 - *Doses from Radiation Exposure*

- François Bochud (Chair), IRA CHUV, Switzerland
- Francois Paquet (Vice-Chair), French Institute for Radiological Protection and Nuclear Safety (IRSN), France
- Maria Antonia Lopez (Secretary), CIEMAT, Spain
- Martin Andersson (Member), Gothenburg University , Sweden
- Volodymyr Berkovskyy (Member), Ukrainian Radiation Protection Institute (RPI) and National Research Center for Radiation Medicine (NRCRM), Ukraine
- Denison de Souza Santos (Member), Instituto de Radioproteção e Dosimetria, Brazil
- Augusto Giussani (Member), Federal Office for Radiation Protection (BfS), Germany
- Derek Jokisch (Member), Francis Marion University, USA
- Chan Hyeong Kim (Member), Hanyang University, Korea
- Mukund Shrinivas Kulkarni (Member), BHABHA ATOMIC RESEARCH CENTRE, India
- Stephanie Lamart (Member), French Institute for Radiological Protection and Nuclear Safety (IRSN), France
- Choonsik Lee (Member), National Cancer Institute, USA
- Junli Li (Member), Tsinghua University, China
- Nina Petoussi-Henss (Member), Federal Office for Radiation Protection (BfS), Germany
- Tatsuhiko Sato (Member), Japan Atomic Energy Agency (JAEA), Japan
- Tracy Smith (Member), UKHSA, UK Health Security Agency, United Kingdom
- Alexander Ulanowski (Member), International Atomic Energy Agency, Austria
- Yeon Soo Yeom (Member), Yonsei University, South Korea - NEW
- Keith Eckerman (Member emeritus), Oak Ridge National Laboratory (ORNL), USA
- Jizeng Ma (Representative), International Atomic Energy Agency (IAEA), Austria
- Thomas Otto (Representative), International Commission on Radiation Units & Measurements (ICRU), Switzerland
- Rick Tanner (Representative) European Radiation Dosimetry Group (EURADOS)
- Annette Röttger (Representative) European Association of National Metrology Insititutes (EURAMET)

- **Chair: François Bochud, Switzerland**
- Vice-chair: François Paquet, France
- Secretary: María Antonia López, Spain

- **18 members** 2021 – 2025
- 1 **emeritus** member (K. Eckerman, EEUU)
- Representatives of **IAEA, ICRU and EURADOS**

- **13 countries** (Europe, America and Asia)
  - Germany
  - Brazil
  - China
  - Korea
  - Spain
  - United States
  - France
  - India
  - Japan
  - United Kingdom
  - Sweden
  - Switzerland
  - Ukraine

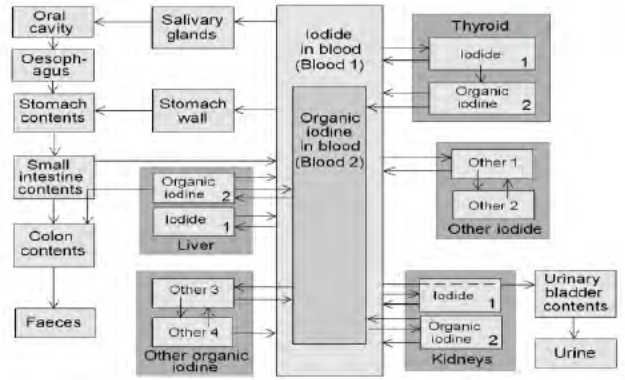
ICRP Committee 2 - *Doses from Radiation Exposure*

➢ The objectives of ICRP Committee 2 are:

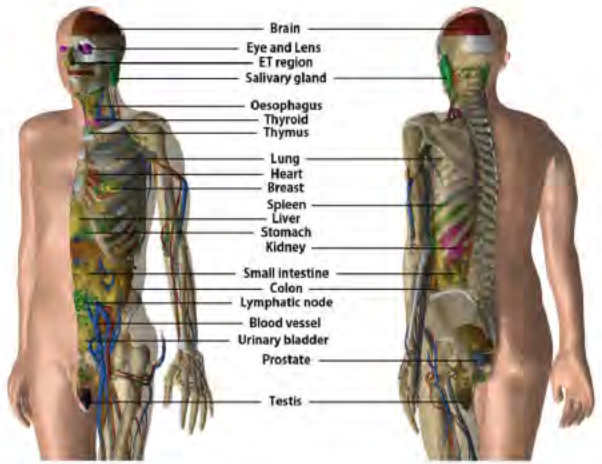
- Development of dose coefficients for the assessment of occupational, public and medical exposures,
- Dealing with internal and external exposures,
- Development and update of biokinetic and dosimetric models,
- To provide reference dosimetric data for workers and members of the public.

The group is also working on the development and use of a new generation of computational phantoms.

https://www.icrp.org/icrp_group.asp?id=8



OIR Biokinetic Systemic Model (occupational exposure) for the Iodine (Leggett, 2010)
Figure 5.2, Publication 137 of ICRP



Mesh reference phantom of adult man.
Figure 6.1, Publication 145 of ICRP

ICRP Committee 2 - *Doses from Radiation Exposure*

6 Task Groups

- **TG 36 - Radiation Dose to Patients in Diagnostic Nuclear Medicine** (C2, C3) - A. Giussani (C2)
- **TG 95 - Internal Dose Coefficients (IDC) –** F. Paquet
- **TG 96 - Computational Phantoms and Radiation Transport –** D. Jokish – END -
- **TG 103 - Mesh-type Reference Computational Phantoms (MRCP)-** C. H. Kim
- **TG 112 - Emergency Dosimetry –** V.Berkovskyy
- **TG 113 - Reference Organ and Effective Dose Coefficients for Common Diagnostic x-ray Imaging Examinations** (C2, C3)- N. Petoussi-Henss (C2), D. Sutton (C3)

ICRP Committee 2 - *Doses from Radiation Exposure*

TG 96 – Computational Phantoms and Radiation Transport – *Derek Jokish* - END -

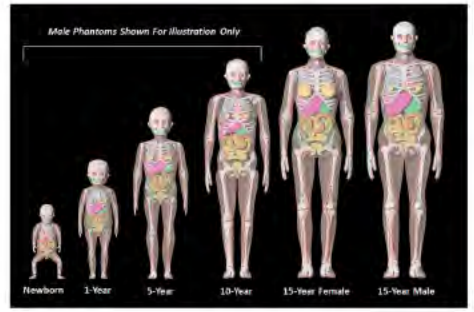
- **Publication 133:** The ICRP Computational Framework for Internal Dose Assessment for Reference Adults: Specific Absorbed Fractions
- **New Publication:** Specific Absorbed Fractions for Reference Paediatric Individuals in 2023

- **SAF (Specific Absorption Fraction)** values have been generated for male and female ICRP reference individuals for the 6 age groups (newborn, children aged 1, 5, 10, 15 years and adults) for photons, electrons, alpha particles and neutrons.

- The SAF values for adults are those used in the dose coefficients of the OIR series of publications and for Nuclear Medicine

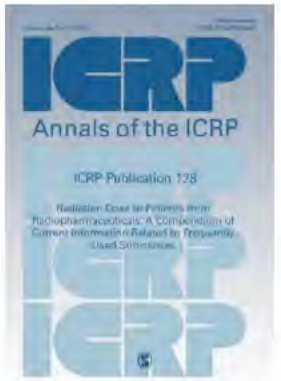
- Simulations of radiation transport with ICRP143 Voxel-type paediatric phantoms and other stylized models are used for EIR series and Nuclear Medicine

- Energy-dependent SAFs for electrons and alpha particles represent a significant improvement over ICRP 30 SAF values



Family of reference voxel pediatric phantoms for members of the public Figure 3.3 ICRP Publication 143

ICRP Committee 2 - *Doses from Radiation Exposure*

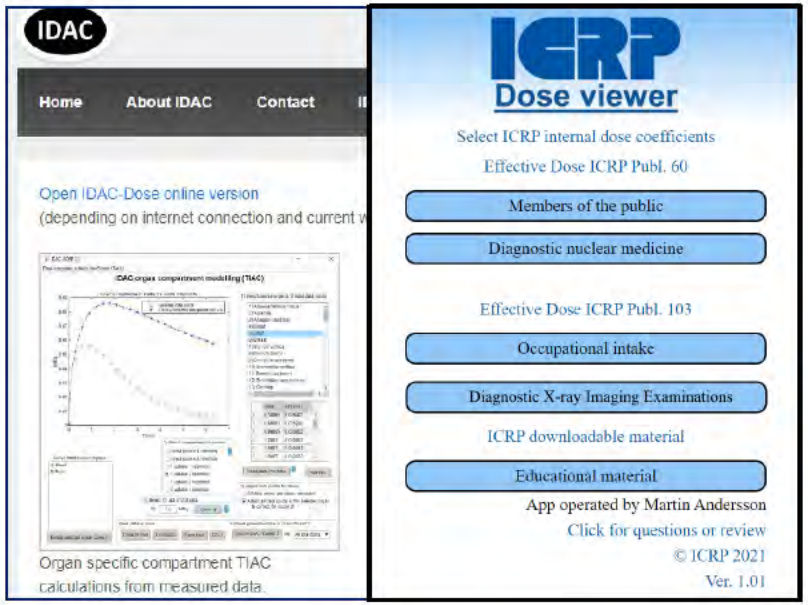


TG 36 – Radiopharmaceutical Dosimetry – *A. Giussani y M. Andersson*

Update of ICRP Publication 128 *"Radiation Dose to Patients from Radiopharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances"*

- **Update of biokinetic models for radiopharmaceuticals (DIAGNOSIS)**
  - ✓ Development of new compartmental models for new substances and improvement/updating of currently available models
  - ✓ Dynamic model for the bladder for adults and children (full and empty bladder, forced hydration).
  - ✓ On-going studies:
    - ^{18}F[FDG] for PET/CT; [^{18}F]-choline for prostate cancer patients;
    - [^{99m}Tc] pertecnetate (oral e i.v).; [^{99m}Tc] pertechnegas; [^{99m}Tc] Tc-difosfonates
    - ^{123}I, ^{124}I, ^{125}I and ^{131}I
    - Iodine Model for patients with no thyroid or thyroid blockage
    - PSMA for prostate cancer patients

TG 36 – Radiopharmaceutical Dosimetry – *(cont.)*



- **Assessment of dose coefficients**
  - ✓ Age-dependent, for both sexes
  - ✓ Implementation of new biokinetic and dosimetric models
  - ✓ SAF values of Voxel-type reference phantoms
  - ✓ Absorbed Organ Dose (mGy/MBq) and Effective Dose (mSv/MBq)

- **Quality Control**
  - ✓ Development and QA with software IDAC (Univ. Gothenburg), DOSAGE (BfS), DCAL (ORNL).
  - ✓ Validation of models with real patient data.
  - ✓ IDAC-Dose 2.1 - free software for diagnostic nuclear medicine. It allows calculation of effective dose and absorbed dose in patients treated with radiopharmaceuticals.
  - ✓ Update to "ICRP Dose Viewer App/ Diagnostic nuclear medicine" (Android, Apple)

TG 95 – Internal Dose Coefficients

- **INTERNAL EXPOSURES OF MEMBERS OF THE PUBLIC**

EIR Series – "Dose Coefficients for Intakes of Radionuclides by members of the PUBLIC"
Biokinetic models and age-dependent dosimetric data. Age groups according to ICRP Publication 89: newborn, 1 year, 5 years, 10 years, 15 years, adult

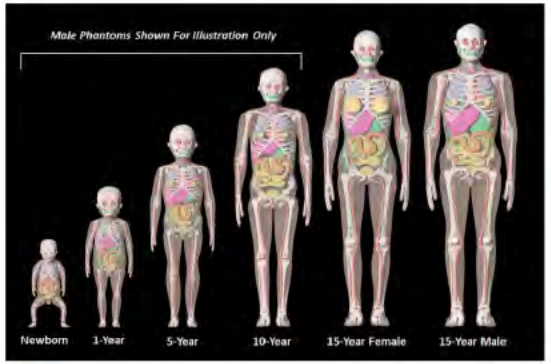
EIR Part 1: elements of OIR Parts 1-3 – *public consultation finished. Publication in 2023-2024*

EIR Part 2: elements of OIR Part 4 – *in progress*

EIR Part 3: elements of OIR Part 5

EIR Part 4: Transfer to milk and child
EIR Part 5: Transfer to the embryo and foetus

EIR Data Viewer: in progress
ICRP Webinar by the end of 2023



Family of reference voxel pediatric phantoms for members of the public
Figure 3.3 ICRP Publication 143

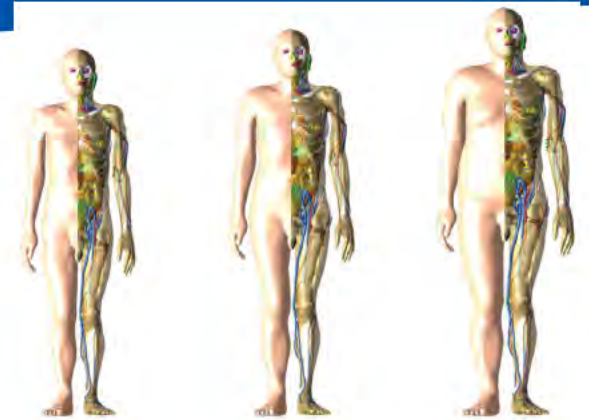
TG 103 – Mesh-type Reference Computational Phantoms – *C. H. Kim*

- **Publication 145: Adult** Mesh-type Reference Computational Phantoms
- **Draft Report: Paediatric Mesh-type** Reference Computational Phantoms (2023)

- Mesh phantoms improve the definition of internal structures of organs and tissues (relevant in skin, eye, respiratory/alimentary tract, bone)

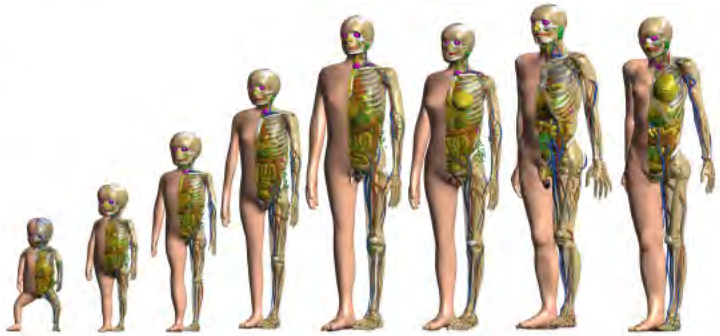
- Development of "Libraries" of Mesh phantoms:
  - ✓ **9 male phantoms, 9 female phantoms in Publication 145,** 10/50/90th percentiles, adult weight and height variation
  - ✓ **108 adult male and 104 female phantoms,** with weight and height variations, in standard standing position and arms up
  - ✓ **226 male and 201 female pediatric phantoms** according to weight, height and age

- Mesh phantoms in 5 positions: walking, sitting, bending, kneeling and squatting



Adult male reference Mesh phantom (center), 10th (left) and 90th (right) percentiles.
Figure 8.1 ICRP Publication 145

Mesh-type phantoms in 5 positions
Courtesy of C. H. Kim, Chair TG 103



Mesh type pediatric phantoms
Courtesy of C. Hyeong Kim, Chair TG 103

TG 103 – Mesh-type Reference Computational Phantoms *(cont.)*

- Mesh-type Computational Phantoms (MRCP) will replace Voxel-Type phantoms in upcoming ICRP radiation protection recommendations

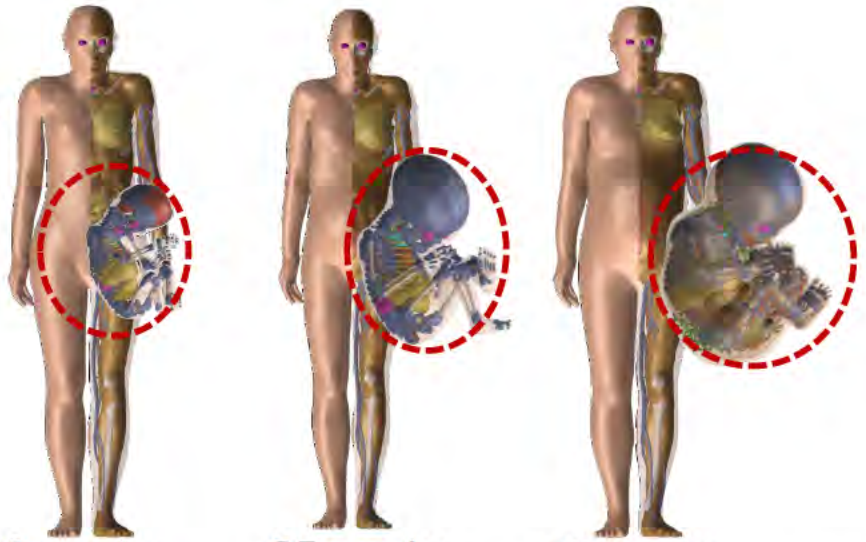
- New **Mesh developments**: phantoms of the **pregnant woman and fetus**, based on ICRP Publication 89

  ✓ Phantoms of the mother and fetus in **8 states of pregnancy**:
  Weeks 8, 10, 15, 20, 25, 30, 35 and 38

  ✓ Developments based on the series of phantoms of University of Florida and the Ferdowski University of Mashhad (FUM) University in Iran

  ✓ **Adjustment of the mother's anatomy:** lungs, ribs, abdomen,...

  ✓ **Combination of mother-fetus** phantoms completed



Courtesy of C. H. Kim, Chair TG 103

TG 112 – Emergency Dosimetry – *V. Berkovskyy*

- Development of methodologies and data (dose coefficients) for dosimetric estimation of internal and external exposure in radiological and nuclear emergency situations
- Scenarios with possible high dose of radiation. Stochastic and deterministic effects.
- **Dosimetric quantities of interest: absorbed dose in organs/tissues** (AD_T and $AD(\Delta)_T$ with Δ= 30 days), equivalent dose H_T and Effective dose E. RBE-weighted absorbed doses.

- 3 exposure levels and dose assessment based on experimental environmental and individual monitoring data:
  - **Level 0** – Screening monitoring. Rapid and conservative initial assessment in the initial phase
  - **Level 1 –** Detailed case-by-case assessment during the emergency
  - **Level 2 –** Advanced evaluation, high doses, medical and dosimetric follow-up

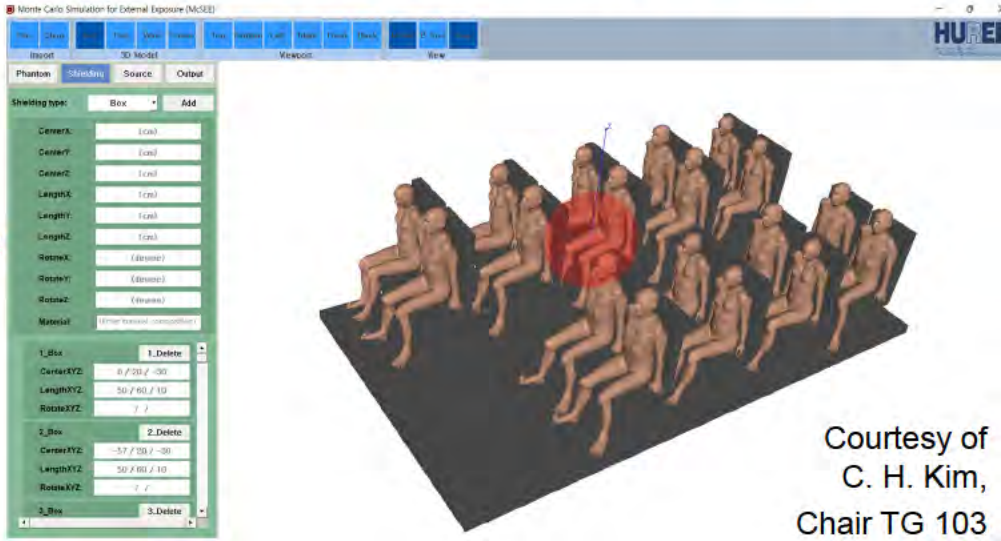
- **Internal exposure: the absorbed dose rate coefficient shall depend on:**
  - the route of incorporation: inhalation (according to particle size AMAD/AMATD), ingestion, wounds
  - Physicochemical properties of internal contaminants

TG 112 – Emergency Dosimetry *(cont.)*

- **Code McSEE**: Monte Carlo Simulation Program for External Exposure for Dosimetric Estimates in Emergency Situations, Hanyang University, Korea. It will be an electronic annex to Report TG112
  - **C++ ,** with MC simulation of radiation transport (Geant4)
  - **"Library" of mesh phantoms for the calculation of**
    - Organ/tissue dose and effective dose
    - Hp(10), Hp(3), Hp(0.07)
    - Distribution of the dose to the skin

- **Dose coefficients for specific scenarios**
- **Input panel:** phantom definition, shielding and radiation source
- **Output panel:** organ dose and effective dose, dose to skin

McSEE for Ir-192 Source Exposure in a bus.
Radiological accident in Cochabamba



Courtesy of
C. H. Kim,
Chair TG 103

ICRP Committee 2 - *Doses from Radiation Exposure*

TG 113 – Dose Coefficients for diagnostic x-ray imaging *C2: Nina Petoussi-Henss*

- Committee 2 (dosimetric calculation) + Committee 3 (selection of procedures)
- MC simulations for well-defined diagnostic imaging protocols
- Use of voxel computational adult and pediatric phantoms according to ICRP Publications 110/143.
- In the future: pregnant woman and non-standard individuals.
- Calculation of organ absorbed dose and effective dose reference coefficients
- **Radiography**
  - Procedures (children and adults): Thorax, pelvis, skull, abdominal, lumbar, cervical,...
  - Electronic tools in progress: ICRP Dose Viewer
- **Computed Tomography (CT)**
- A ICRP representative scanner, based on the characteristics of 13 CT scanners (and 102 different operating conditions) has been developed
- For the ICRP scanner, organ and effective dose coefficients were calculated for all male and female adult and paediatric phantoms. These can be made representative for every scanner by entering the selected CTDIvol, tube voltage and the relevant CTDI phantom

Courtesy of Nina Petoussi-Henss, Co-Chair TG 113

ICRP Committee 2 - *Doses from Radiation Exposure*

Contributions of C2 members to other working groups:

- TG 115 - Doses and risks for RP of astronauts (C1)

- TG 118 - Relative Biological Effectiveness (RBE), Quality Factor (Q), and Radiation Weighting Factor (wR) (C1)
- TG 119 - Cardiovascular diseases (C1)

- TG 120 - RP for Radiation Emergencies and Malicious Events (C4)

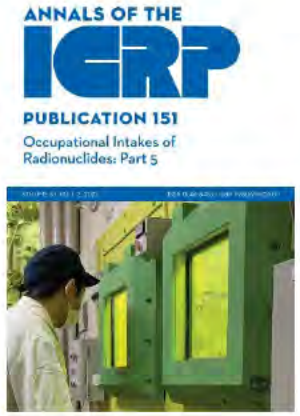
- TG 121 - Effects of Ionising Radiation Exposure in Offspring and Next Generations (C1)
- TG 128 – Individualization/Stratification in Radiological Protection (C1)

- IAEA Project - Improvements in dosimetry for biota in terrestrial environments
- ICRP/EURADOS Training Course on Biokinetic Modelling – how to calculate dose coefficients

ICRP Committee 2 - *Doses from Radiation Exposure*

Recent ICRP C2 Publications

- ICRP Publication 151 Occupational Intakes of Radionuclides: Part 5
- ICRP Publication 141 Occupational Intakes of Radionuclides: Part 4
- ICRP Publication 137 Occupational Intakes of Radionuclides: Part 3
- ICRP Publication 134 Occupational Intakes of Radionuclides: Part 2
- ICRP Publication 130 Occupational Intakes of Radionuclides: Part 1



- ICRP Publication 144 Dose Coefficients for External Exposures to Environmental Sources

- ICRP Publication 145 Adult Mesh-type Reference Computational Phantoms
- ICRP Publication 143 Paediatric Computational Reference Phantoms
- ICRP Publication 133 The ICRP Computational Framework for Internal Dose Assessment for Reference Adults: Specific Absorbed Fractions

- ICRP Publication 150 Cancer Risk from Exposure to Plutonium and Uranium

- ICRP Publication 147 Use of Dose Quantities in Radiological Protection
- ICRU Report 95 Operational Quantities for External Radiation Exposure - *Prepared jointly with ICRP*

Thanks for your attention