Minimizing radiation exposure during endovascular aortic procedures

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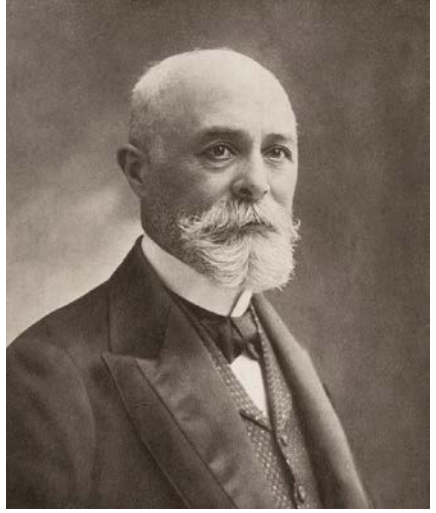
Who was the first person to use protective lead shields routinely?

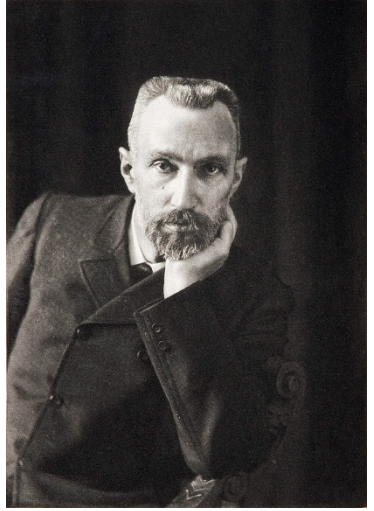
Wilhelm Conrad Röntgen

Wilhelm Conrad Röntgen
November 8, 1895
Discovered the X-Rays
He was one of the few pioneers in the field who used protective lead shields routinely!



Antoine Henri Becquerel
February 1896
Discover spontaneous radioactivity

SI unit for radioactivity
becquerel (Bq)



Pierre Curie
Piezoelectricity
Magnetism
-Torsion Balance
-Curie's constant
Radioactivity
Curie unit

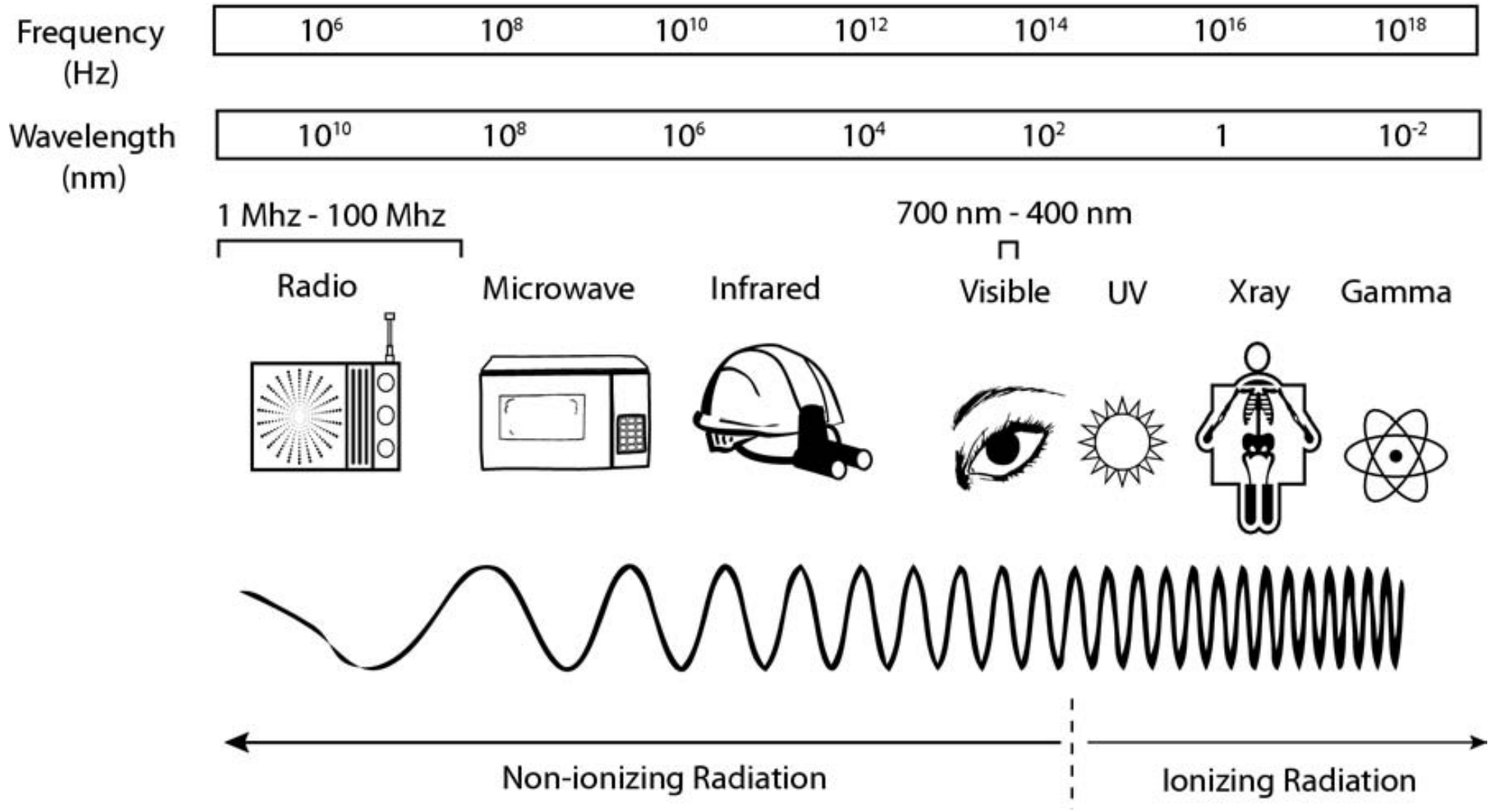
Marie Skłodowska-Curie
Theory of radioactivity
Polonium and Radium
First military field of radiological centers

Nobel Prize 1901

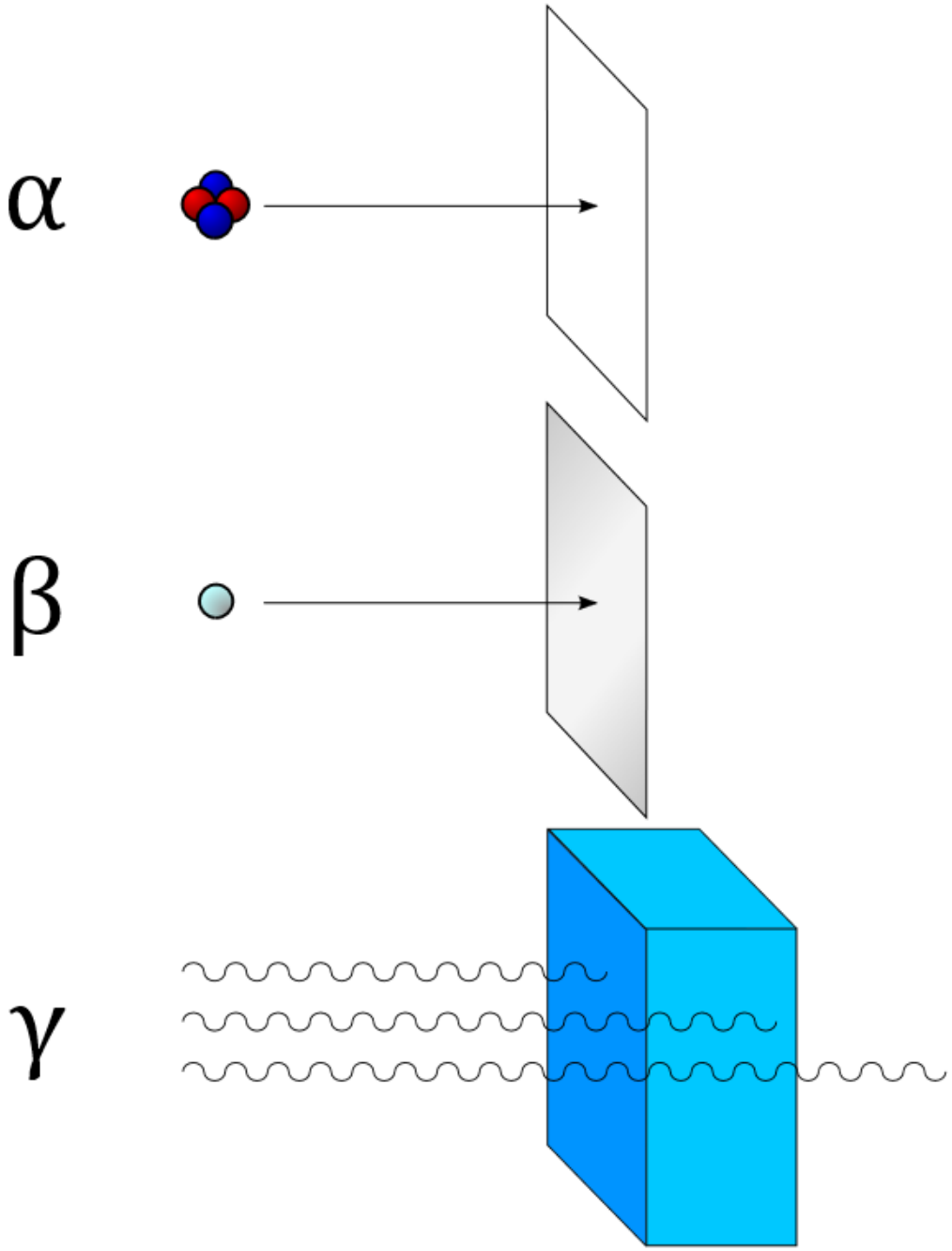
All three shared the Nobel Prize in 1903

Second Nobel Prize 1911
Curie Family won
Five Nobel Prizes

Electromagnetic spectrum



Higher-frequency radiation, such as x-rays, carry more energy than lower frequencies and can penetrate tissue.



Alpha particles may be completely stopped by a sheet of paper

Beta particles by aluminum shielding

X-rays and Gamma rays can only be reduced by much more substantial mass, such as a very thick layer of lead.

Dr. H.D. Hawks reported of suffering severe hand and chest burns in an x-ray demonstration, and it was the first of many other reports in Electrical Review.

Elihu Thomson at Thomas Edison's lab, William J. Morton, and Nikola Tesla also reported burns.

Elihu Thomson deliberately exposed a finger to an x-ray tube over a period of time and suffered pain, swelling, and blistering.

Marie Curie died in 1934 from aplastic anemia due to radiation exposure. She carried test tubes of radium in her pockets during research. She also offered service in mobile X-ray units created by her during WWI.

Endovascular aortic procedures expose patients and staff to significant doses of ionizing radiation.

Medical imaging studies now represent the greatest man-made source of ionizing radiation to the general population and patients undergoing EVAR are a prime example.

Virtually all patients undergoing EVAR have a

- pre-op CT scan
- intraoperative fluoroscopic imaging
- lifelong surveillance imaging

Knowledge basics about radiation has not been developed and incorporated into training.

Appropriate behavior in the interventional suite is very often ignored, leading to unnecessary radiation exposure.

Minor radiation exposure

More radiation exposure

The gray - quantity "D"

1 Gy = 1 joule/kilogram - a physical quantity

1 Gy is the deposit of a joule of radiation energy in a kg of tissue

The sievert - quantity "H"

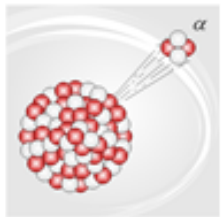
1 Sv = 1 joule/Kg - a biological effect.

The sievert represents the equivalent biological effect of depositing 1 joule/Kg

The equivalence to absorbed dose is denoted by Q.

Radioactivity and Ionizing Radiation

Radioactive decay

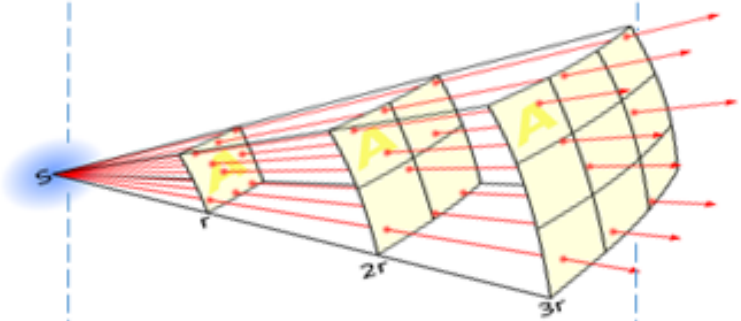


Measurement quantity

- becquerel (Bq)

The becquerel is the SI unit of activity.
1 becquerel = 1 decay per second

Ionizing radiation



Transmission factors

- Distance (Inverse square law)
- Scattering
- Absorption

Ionizing radiation strength from a point source decreases with the square of distance it travels.
The intervening medium can also absorb and scatter radiation.

Detection

Measurement quantities

Dose

- gray (Gy)
- sievert (Sv)

Particle counts

- per second (cps)
- per minute (cpm)

Both dose and counts are used: depending on the application and the radiation type.
Physical dose is measured in grays, and biological dose in sieverts.

Dose quantities in SI units for external radiological protection

Sources of external radiation

- Monitored quantities
- Instrument responses

Measured in practice by Radiological Protection Instruments

Related by instrument calibration.

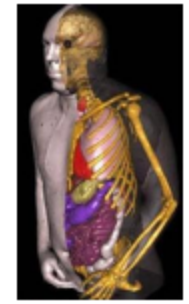
Physical quantities

- Fluence, Φ
- Kerma, K *(gray)*
- Absorbed dose, D *(gray)*

Dose equivalents calculated using absorbed dose and Q (L), and simple phantoms (sphere or slab). Validated by measurements and calculations.

A "phantom" is a device used to model and calculate the absorbed dose for an irradiated entity.

Calculated using anthropomorphic phantom for organ absorbed dose, then factors W_R and W_T for biological effect.



Operational quantities

- Ambient dose equivalent, $H^*(d)$
- Directional dose equivalent, $H'(d,\Omega)$
- Personal dose equivalent, $H_p(d)$

Unit = sievert

These quantities are measurable, and used for practical evaluation of dose for regulation and assessment.

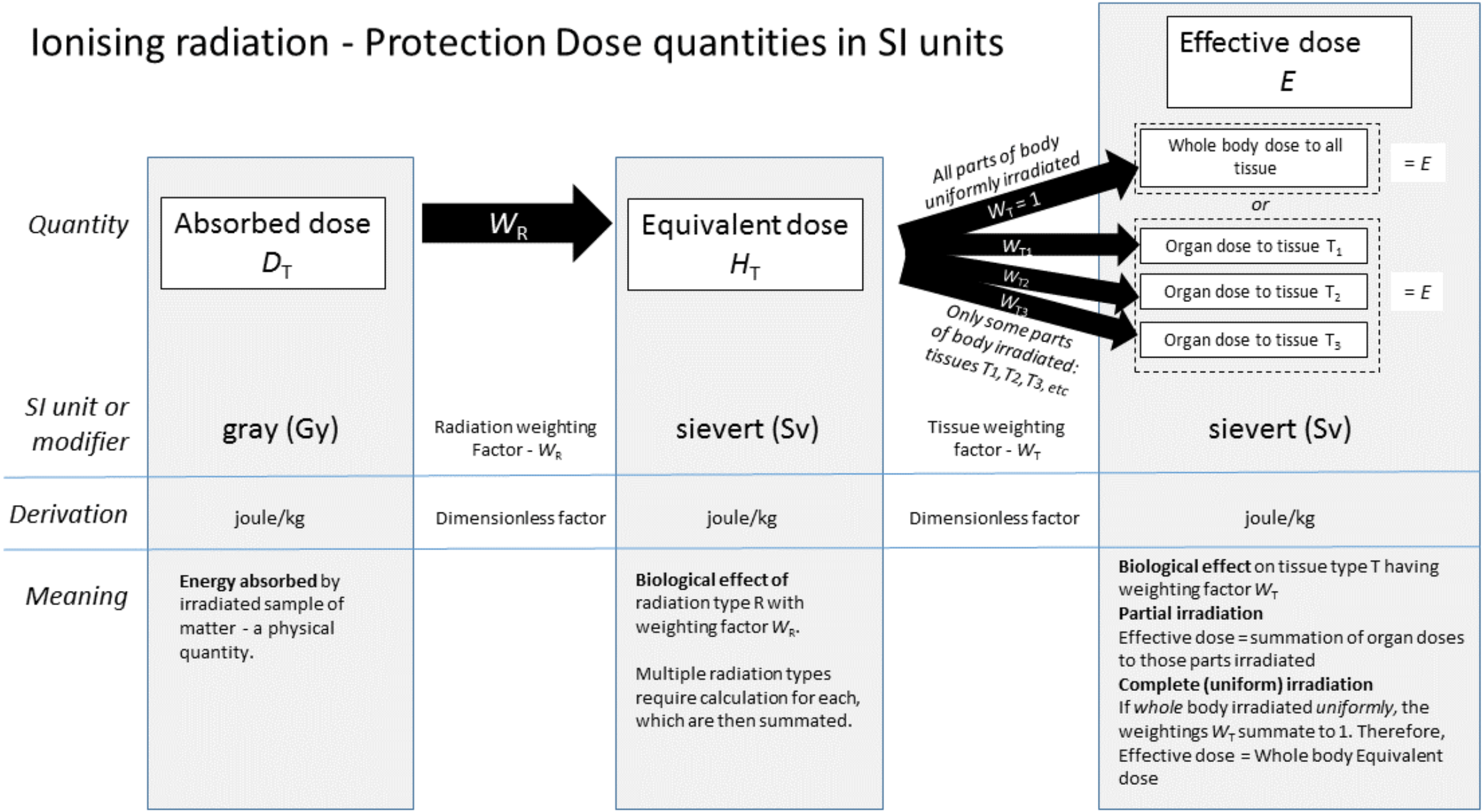
Comparison using the measured and calculated values to establish relationship

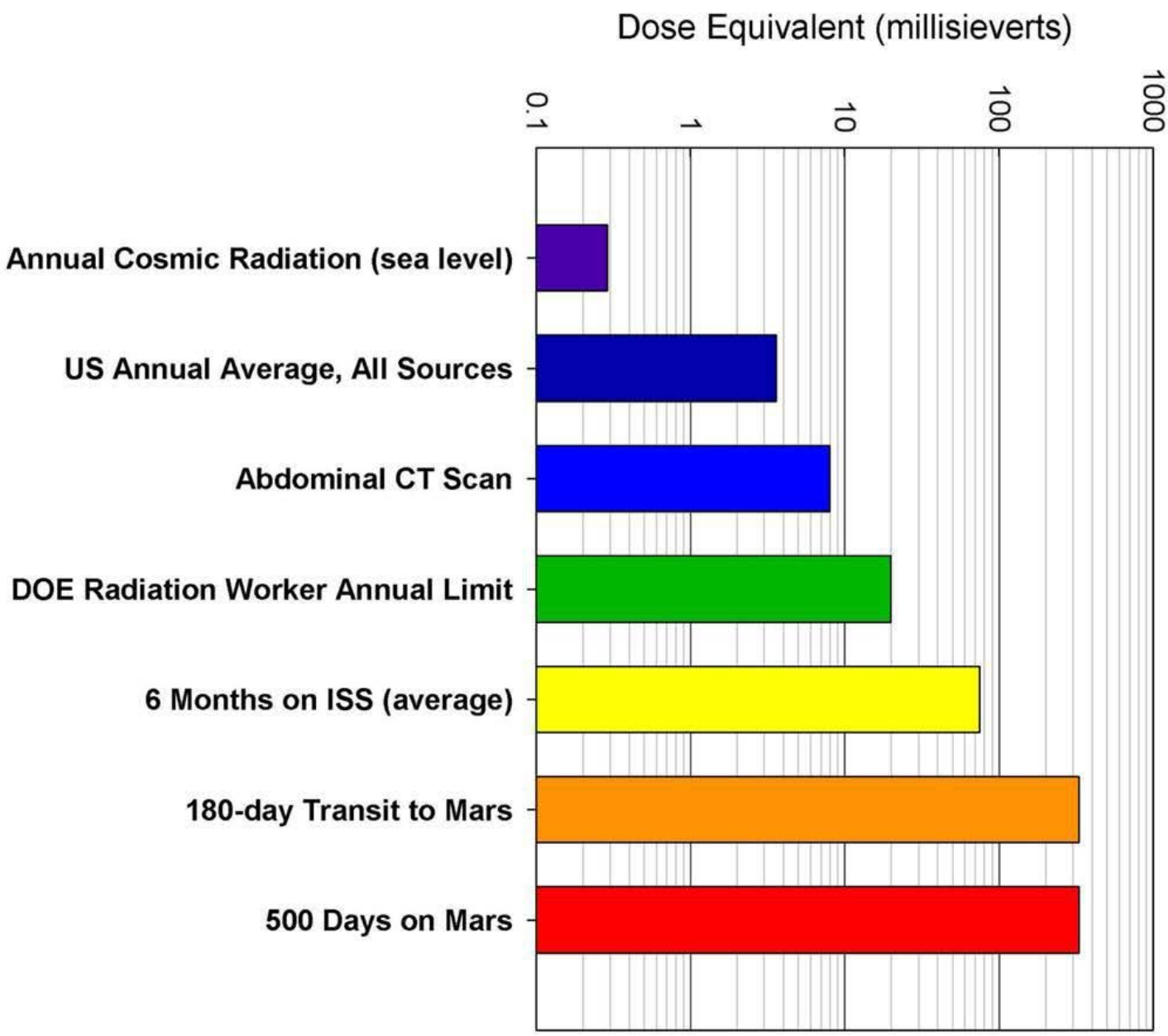
Protection quantities

- Organ absorbed dose, D_T *(gray)*
- Organ equivalent dose, H_T *(sievert)*
- Effective dose, E *(sievert)*

These quantities are not measurable; they are calculated quantities used to compare against observed health effects, and to set limits for exposure.

Ionising radiation - Protection Dose quantities in SI units

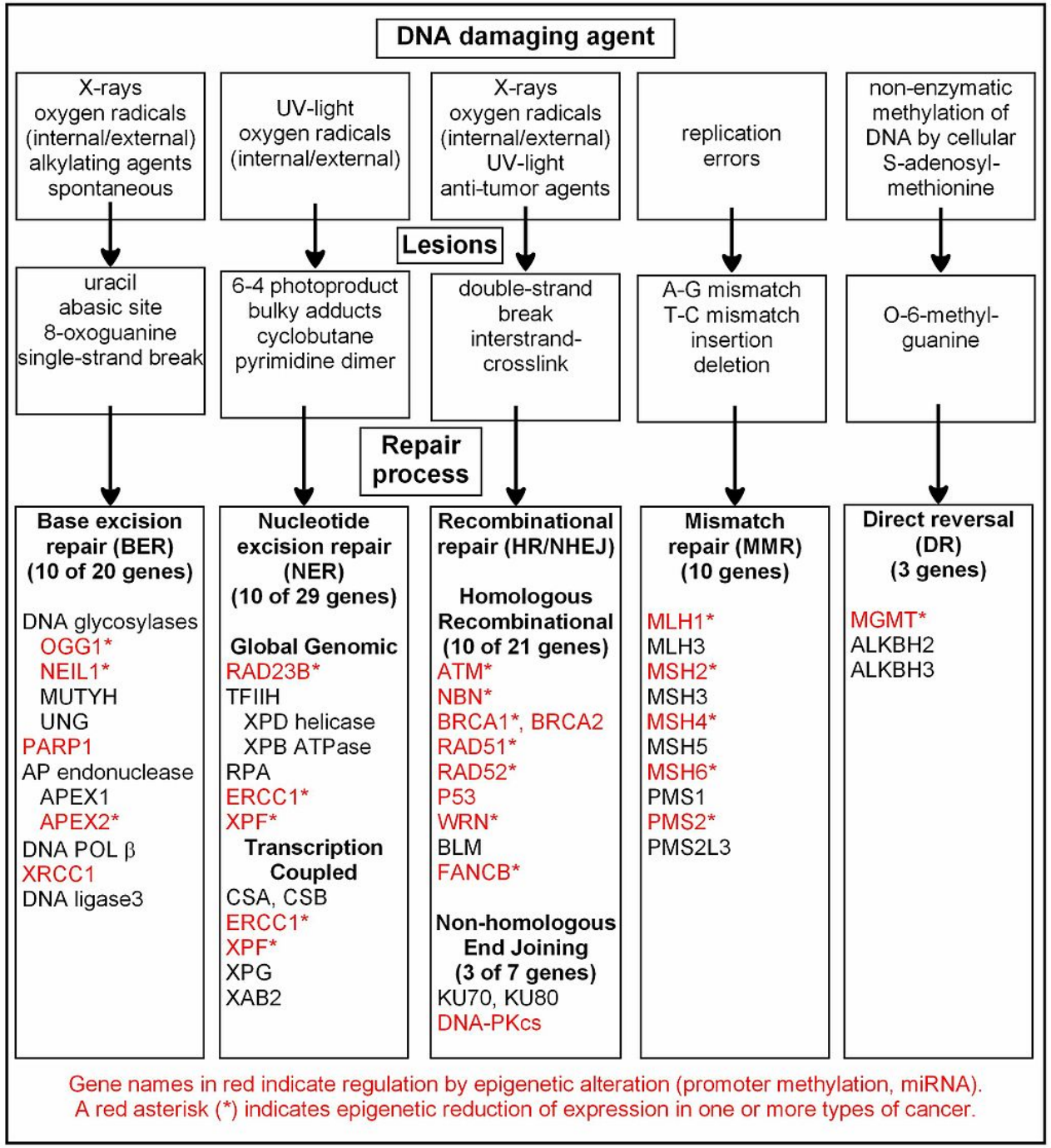



Dose Equivalent (millisieverts)
0.1
1
10
100
1000
Annual Cosmic Radiation (sea level)
US Annual Average, All Sources
Abdominal CT Scan
DOE Radiation Worker Annual Limit
6 Months on ISS (average)
180-day Transit to Mars
500 Days on Mars

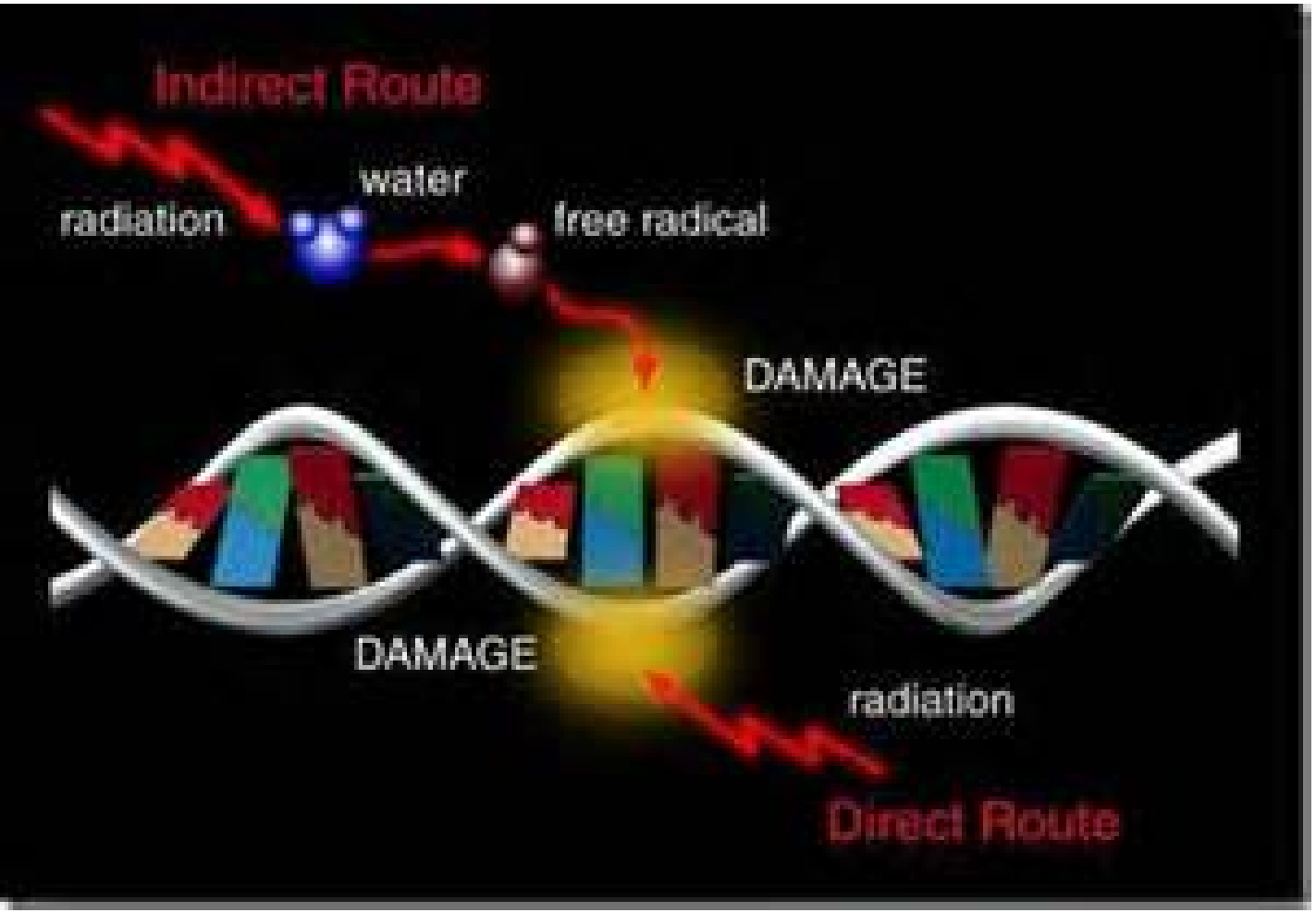
Interactions between x-rays and DNA

Direct interaction: an x-ray interacts with the DNA molecule itself (Rare).

Indirect interaction: x-rays ionize water, and the reactive species that are created interact secondarily with DNA, causing damage and DNA strand breakage.



Fluoroscopy may cause burns if performed repeatedly or for too long



National Research Council. Health risks from exposure to low levels of ionizing radiation: BEIR VII phase 2.
Washington, DC: National Academies Press, 2006.

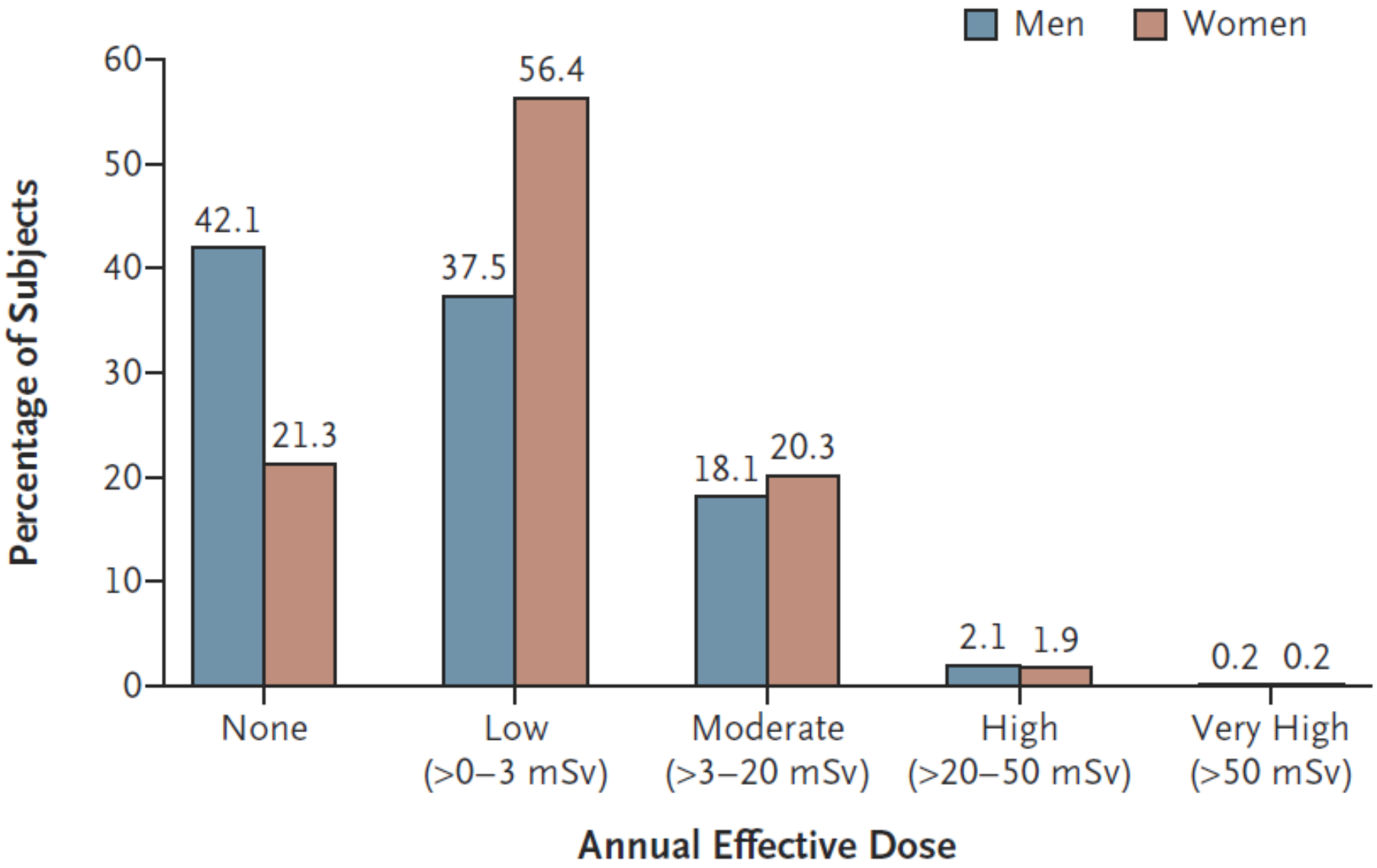
Experimental and epidemiologic evidence has linked exposure to low-dose, ionizing radiation with the development of solid cancers and leukemia.

People at risk for repeated radiation exposure (workers in health care and the nuclear industry), are typically monitored and restricted to effective doses of 100 mSv every 5 years with a maximum of 50 mSv allowed in any given year.

Radiation exposure in patients who undergo medical imaging procedures is not typically monitored. Patient data on longitudinal radiation exposure from these procedures are scant, even though in clinical practice these types of procedures are frequently performed multiple times in the same patient.

Exposure to Low-Dose Ionizing Radiation from Medical Imaging Procedures

Fazel R, Krumholz HM, Wang Y, et al. N Engl J Med 2009;361:849-57.



Radiation exposure during endovascular aneurysm repair.

Weerakkody RA, et al.British Journal of Surgery 2008; 95: 699–702

Table 1 Screening time and median radiation dose during endovascular aneurysm repair based on an irradiated area of 243 cm^2

	Dose area product ($cGy\ cm^2$)	Screening time (min)	Entrance skin dose (Gy)	Effective dose (mSv)	% exceeding 2-Gy threshold for skin damage
All patients ($n = 96$)	150 (90–659)	21 (16–31)	0·85 (0·51–3·74)	27 (16–117)	29
Branched grafts excluded ($n = 5$)		21 (16–31)	0·55 (0·34–2·60)	26 (16–124)	28
Iliac disease excluded ($n = 23$)		20 (16–29)	0·52 (0·34–1·99)	25 (16–95)	25

Radiation doses administered during EVAR were higher than previously thought, with a potential risk of radiation-induced skin damage and later malignancy.

Radiation safety education in vascular surgery training.

Bordoli SJ, et al. J Vasc Surg 2014;59:860-4

The response rate was 14%

Trainees

45% had no formal radiation safety training

74% were unaware of the radiation safety polic

48% did not know their radiation safety o

43% were unaware of the yearly a exposure.

Trained residents

Knew more ba ion, and more likely wore their dosimeter badges (

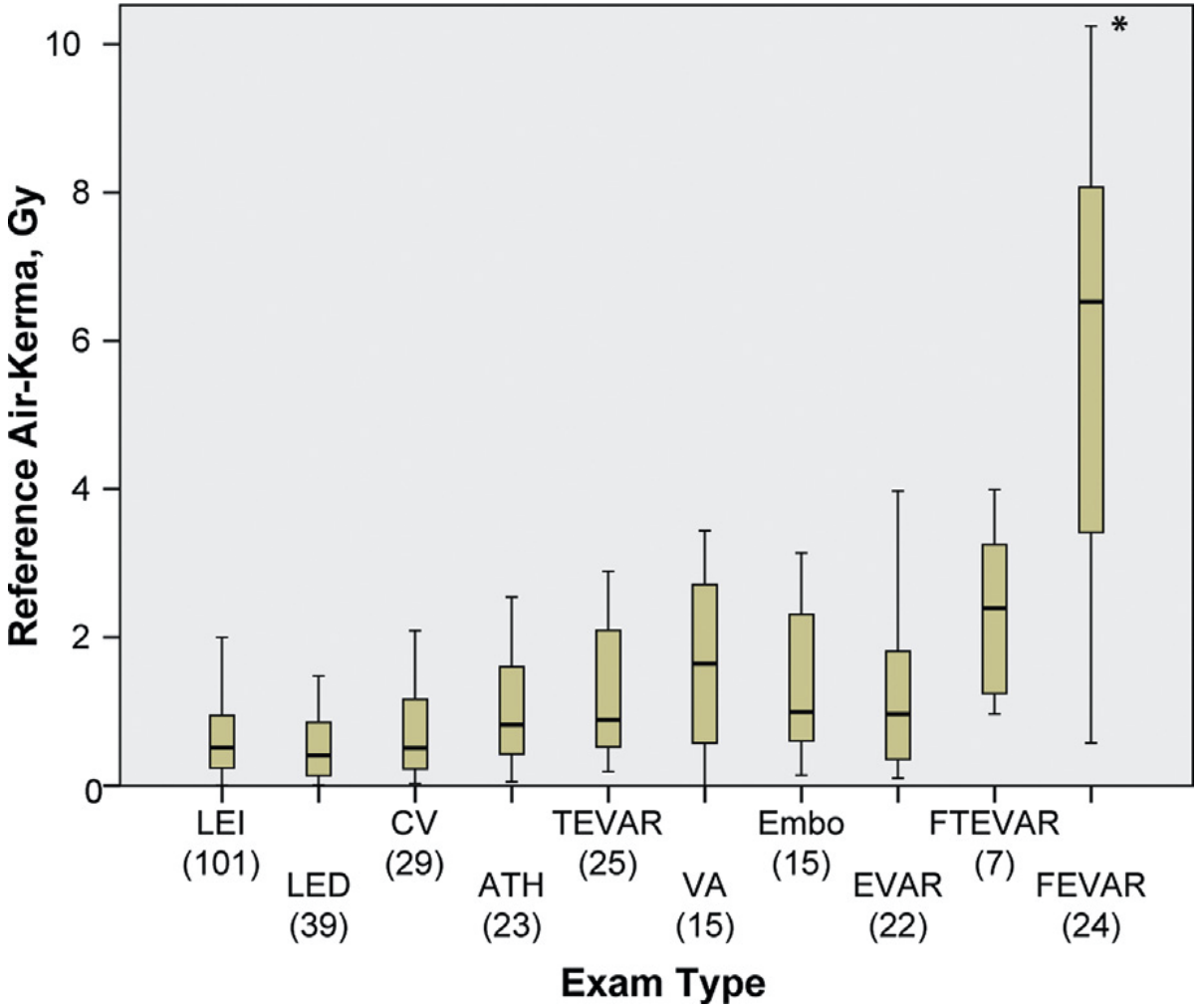
officer helpful in developing safety habits (P < .05)

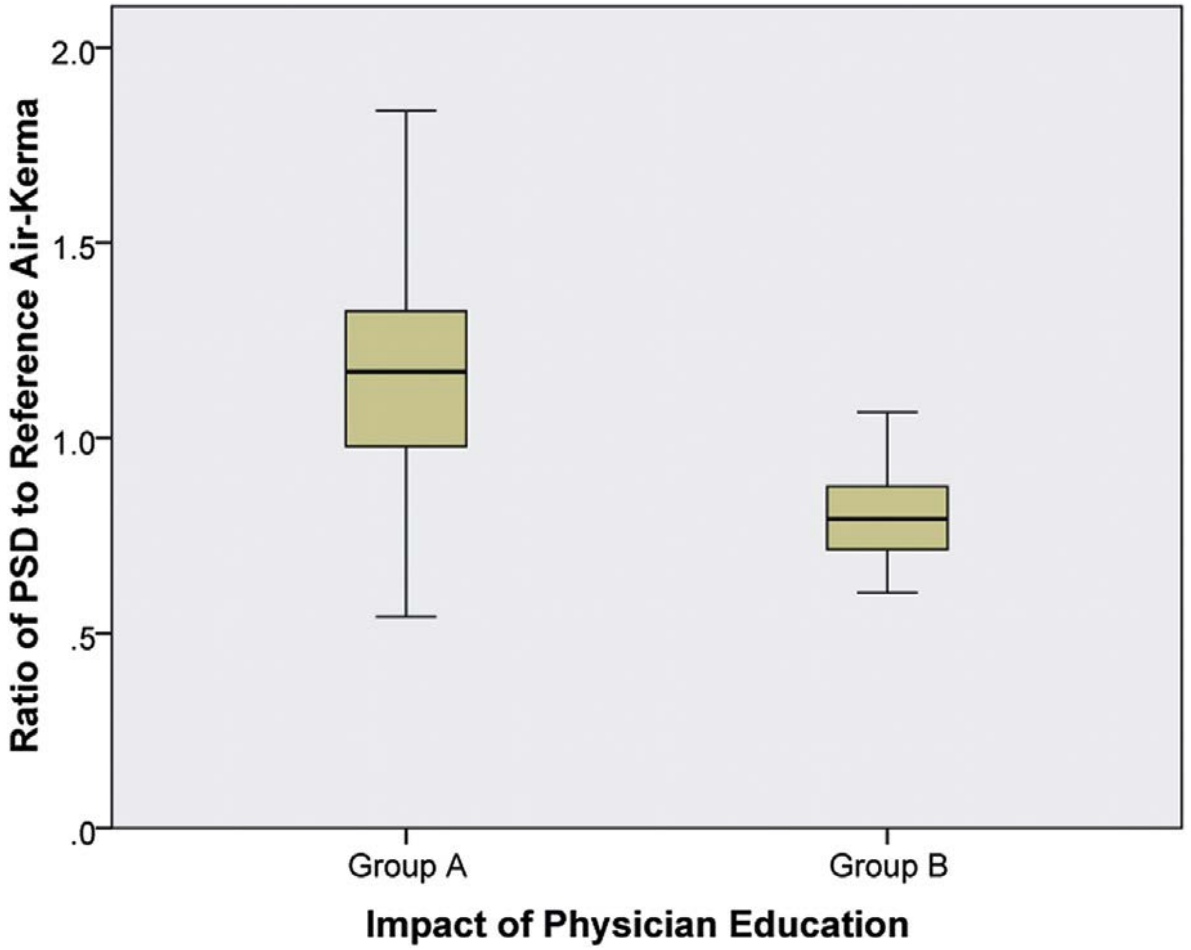
consistently practiced ALARA strategies were more likely to themselves (P < .05)

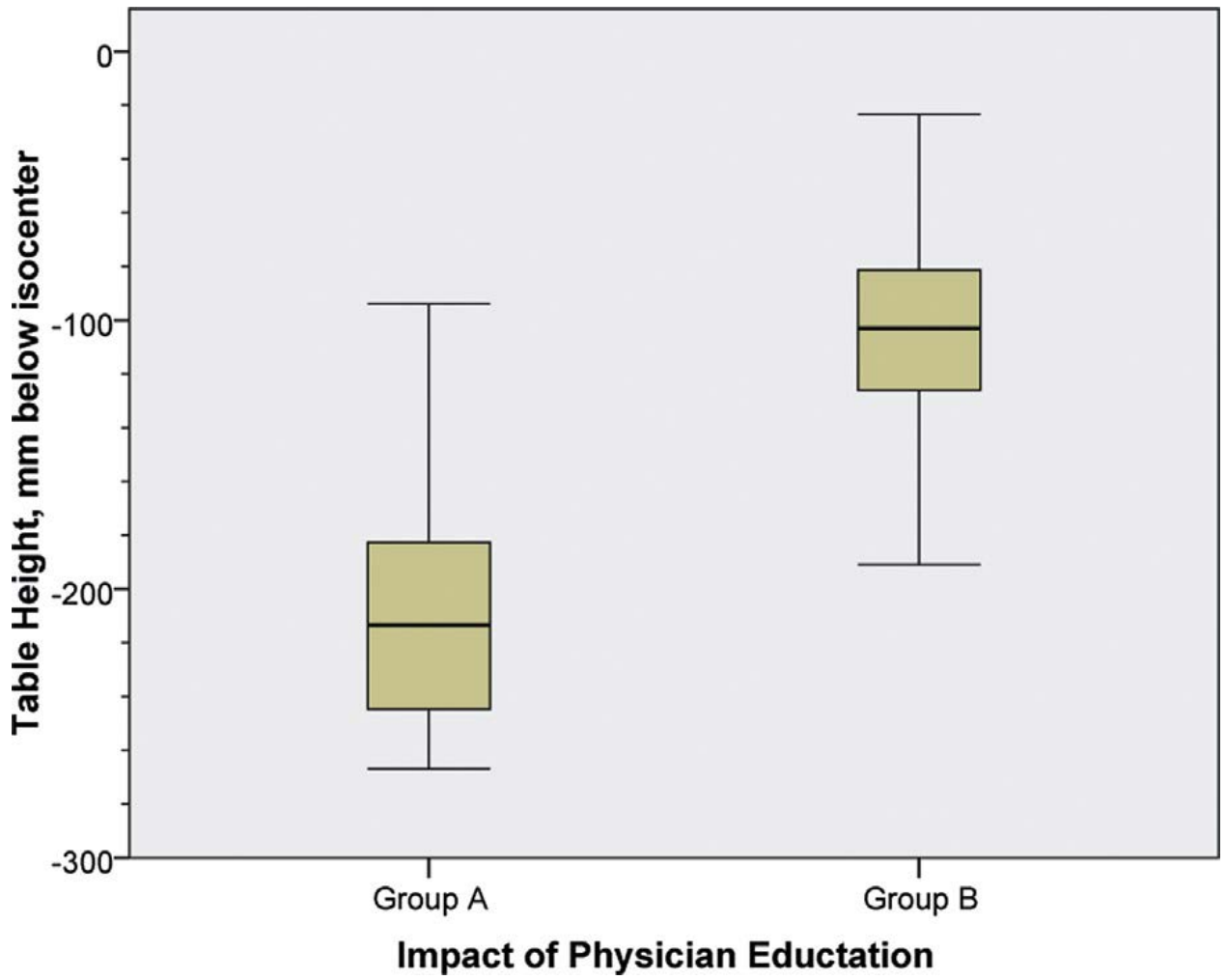
The current state of radiation safety training in U.S. vascular surgery fellowships may be inadequate, contributing to trainees' lack of basic safety knowledge and utilization of protective equipment.

Surgeon education decreases radiation dose in complex endovascular procedures and improves patient safety.

Kirkwood ML, et al. J Vasc Surg 2013;58:715-21



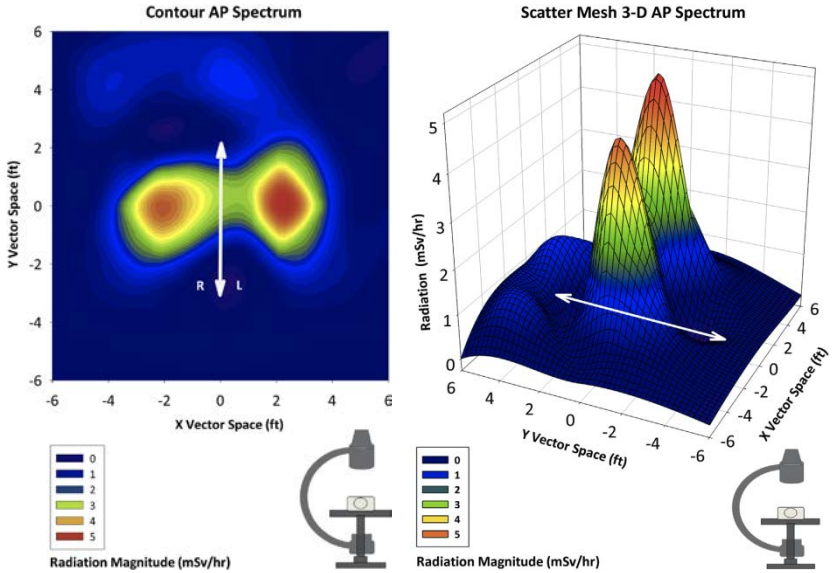




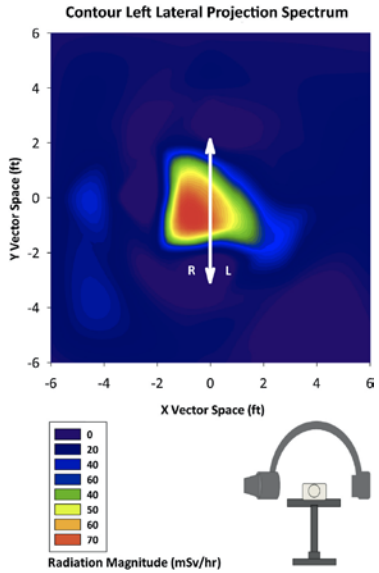
Education on the appropriate use of technical factors improved operating practice, reduced patient radiation dose, and decreased the number of non-FEVAR cases >6 Gy. It is essential that vascular surgeons be educated in best operating practices to lower PSD; FEVAR remains a high-dose procedure.

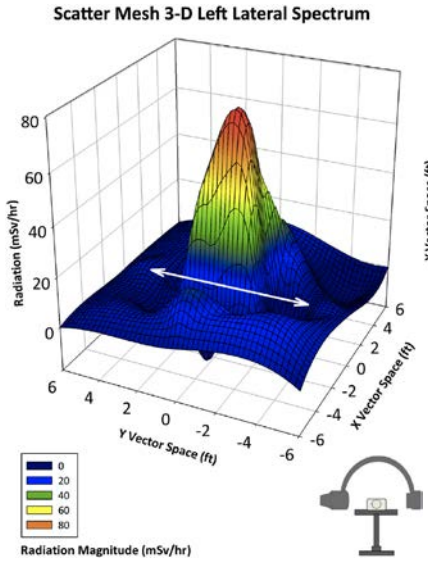
Defining the radiation "scatter cloud" in the interventional suite.

Haqqani OP, et al. J Vasc Surg 2013;58:1339-45

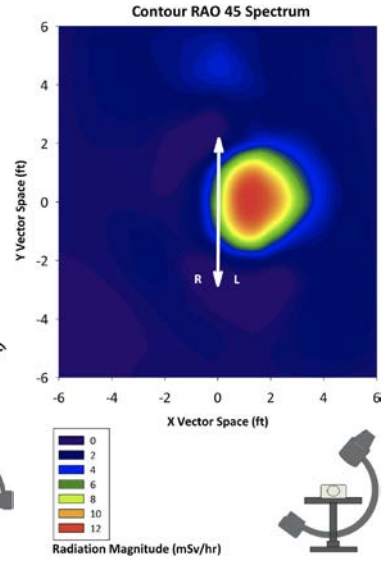


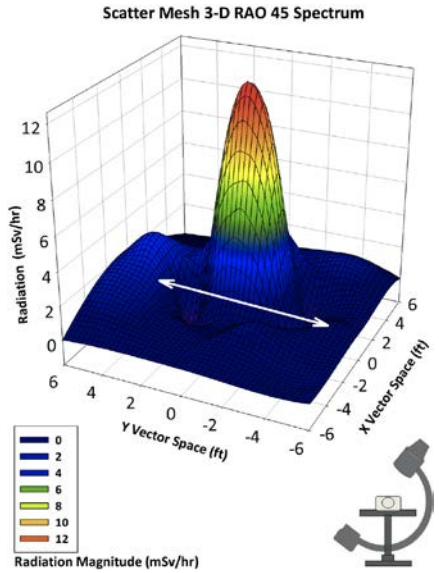
AP: 4.99mSv





90º: 69mSv/h



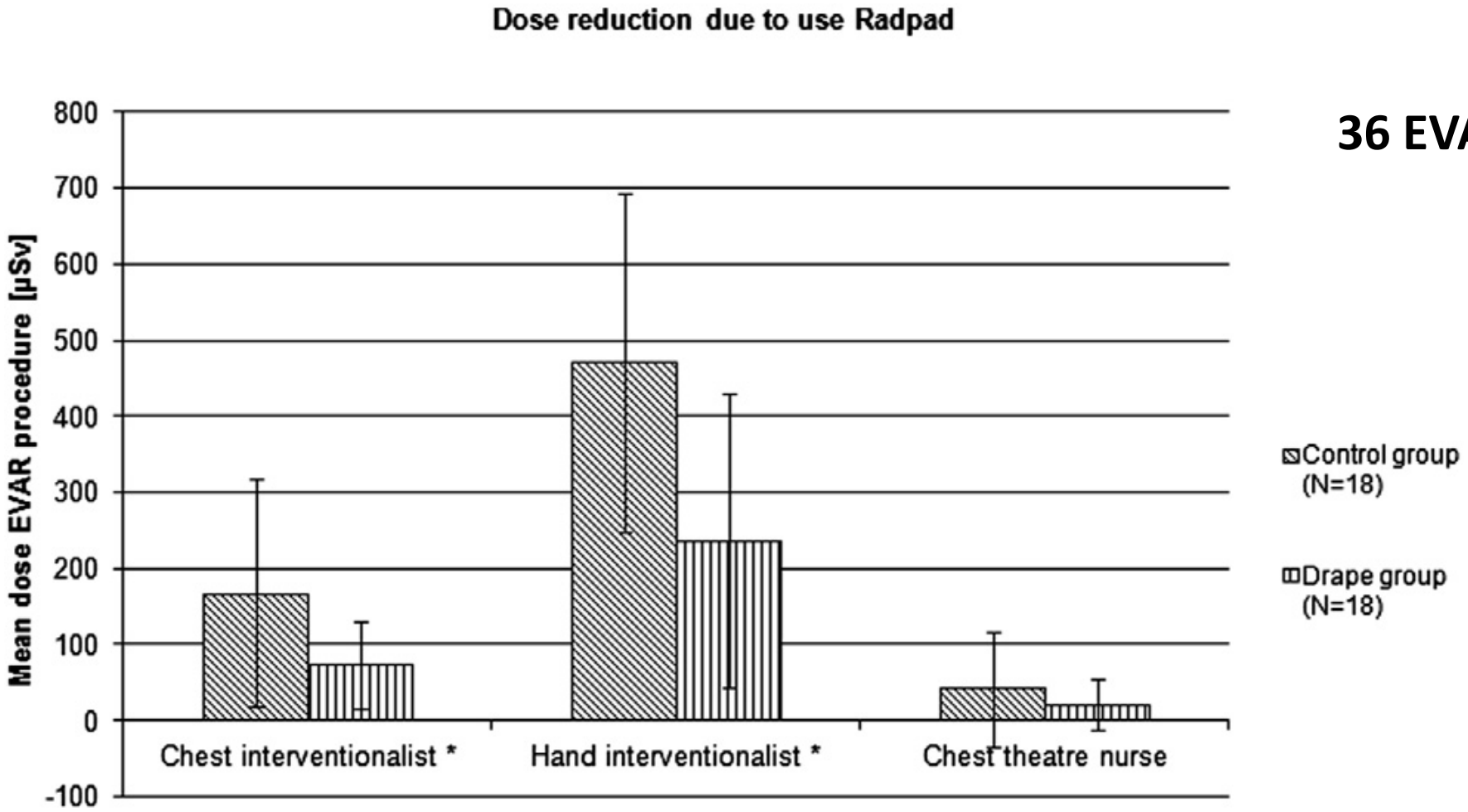


45º: 10.9 mSv/h

At most positions around the angiographic table, radiation exposure decreased as the distance from the source emitter increased. The intensity of the exposure varied dramatically around the axis of imaging. Minimal exposure is experienced along the axis of the table, decreasing with distance from the source (<0.77 mSv/h).

Use of Disposable Radiation-absorbing Surgical Drapes Results in Significant Dose Reduction During EVAR Procedures.

Kloeze C, et al. EJVES 2014;47:268e272



36 EVAR procedures

Non Lead drapes -Few millimeters thick containing bismuth and barium.

For centers that have no non-dedicated endosuite. Additional cost €75 per drape.

Impact of Hybrid Rooms with Image Fusion on Radiation Exposure during Endovascular Aortic Repair.

Hertault A, et al. EJVES. 2014 Jul 17. pii: S1078-5884(14)00310-4. doi: 10.1016/j.ejvs.2014.05.026. [Epub ahead of print]

The exposure of patients and operators to radiation is significantly reduced by routine use of image fusion during standard and complex EVAR.

Image fusion can facilitate endovascular navigation, and allow table and C-arm positioning without fluoroscopy. Routine use of image fusion during EVAR significantly reduces both radiation exposure and contrast volumes during complex EVAR

Philips Receives FDA Clearance for AlluraClarity Interventional X-ray System

It consists of a multitude of software and hardware improvements that combine high quality imaging with low X-ray dose. According to Philips, radiation dose is decreased up to 73% in neuroradiology compared to older systems.

- Wear lead and cover all pertinent areas in the body
- Lead garments, lead gloves, thyroid shields, leaded eyeglasses, lead drapes, and clear leaded glass barriers between the patient and the operator all reduce exposure to medical personnel from scattered radiation.
- Throughout the procedure, the equipment should be operated at the lowest fluoroscopic dose rate that yields adequate images.
- Pulsed fluoroscopy should be used, at the lowest pulse rate that yields adequate image quality.
- Care should be taken to use the least amount of fluoroscopic time and acquire the least number of fluorographic images consistent with achieving the clinical goals of the procedure.
- Appropriate collimation should be used. The source-to-image receptor distance should be maximized and the object-to-image receptor distance should be minimized (Reduce radiation dispersion).
- Image magnification (zoom) should be used only when essential clinically.

- C-arm angles should be varied from time to time in order to minimize skin dose. C-arm angulation is of increased importance once the operator receives the first dose notification.

- Take the best possible distance from the emitter and the patient.
  -Increasing distance reduces dose due to the inverse square law

- May use new surgical drapes in centers without an endosuite

- New imaging equipment that reduces significantly radiation dose

The best defense against radiation injury to both the patient and staff:

- minimize the total fluoroscopy time
- keep the image intensifier close to the patient
- collimate to the region of interest
- maximize the operator distance from the patient
- use appropriate radiation shielding and radiation monitoring

More importantly take part on more pleasant activities and use special fluids as often as possible!