Radiation Protection in Diagnostic Radiology

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ASP SEMINAR SERIES

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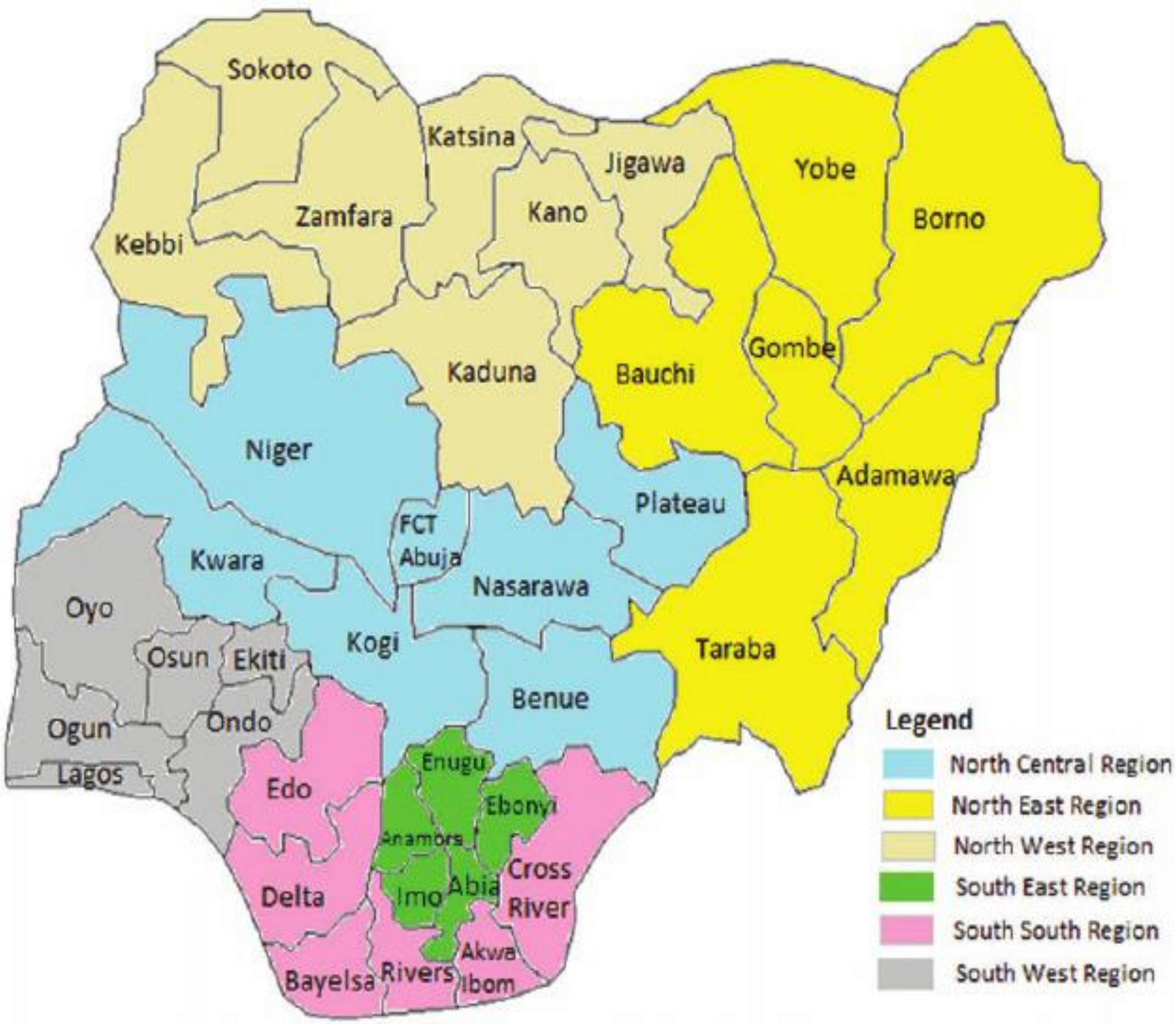
African School of Fundamental Physics and Applications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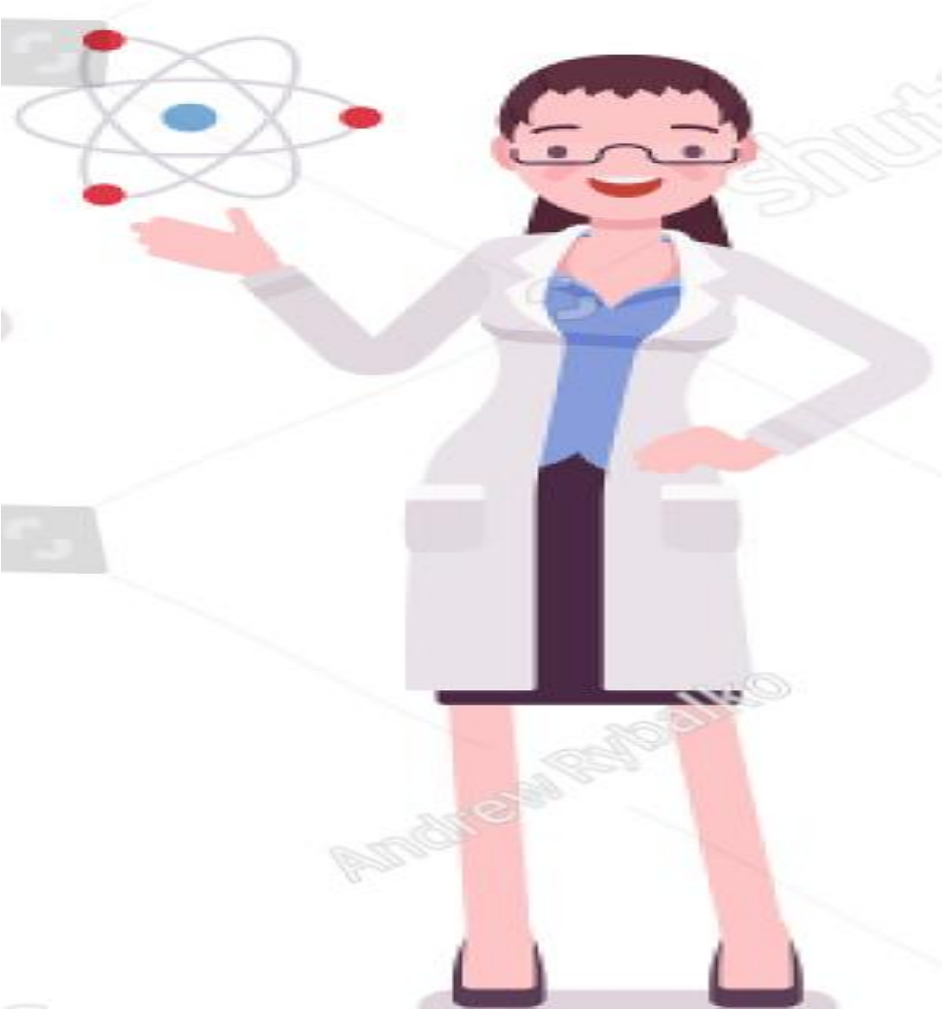
A dream of Medical Doctor to Proud Physicist

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Ref. PC/6 **Date:** July 20, 2017

Dear **Ms. Justina A. Achuka,**

SMALL GRANTS FOR THESES AND DISSERTATIONS: 2016/2017 ACADEMIC YEAR

I am pleased to inform you that your application for a grant to enable you complete your **PhD Thesis** titled **"Assessment of dose reference levels for common radio-diagnostic procedures in Southwestern Nigeria"** has been approved by the Association of African Universities (AAU). The Small Grants Scheme is intended to facilitate the early completion of research Dissertations and Theses by graduate students in African universities, and also to improve the quality of research conducted by these graduate students.

You have therefore been awarded a grant of **Three Thousand and Five Hundred Dollars ($3,500)** on the basis of your work plan and the institutional support promised by your

Why Radiation (Radiological) Protection?

- It is the protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this (IAEA, 2016).

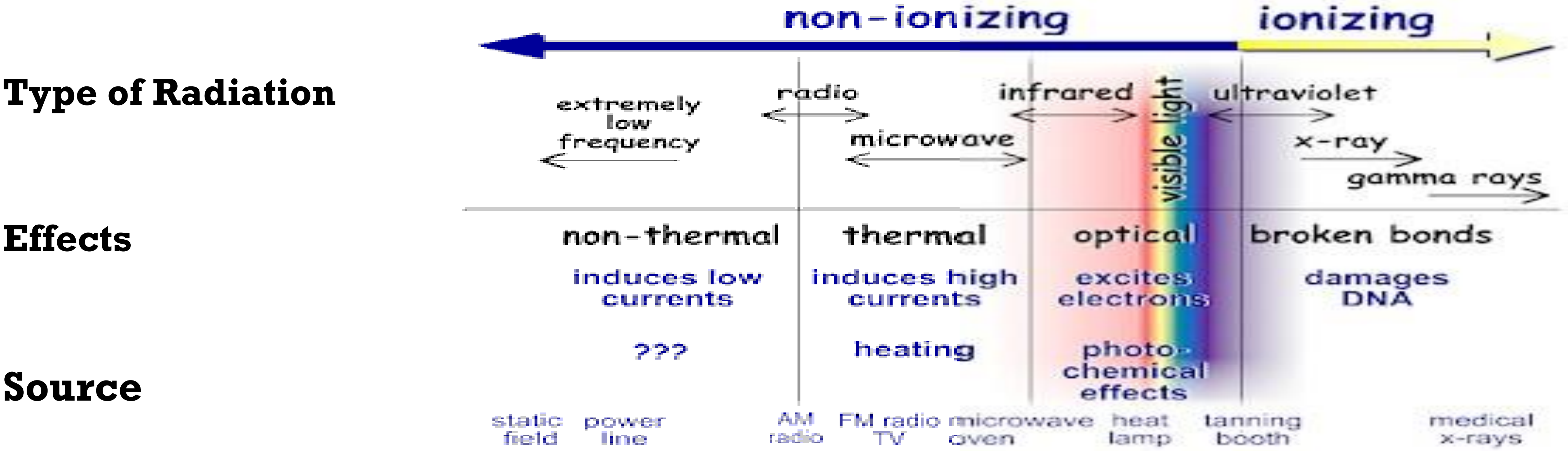


Fig. 2: Types of radiation in the electromagnetic spectrum (U.S. NRC, 2013)

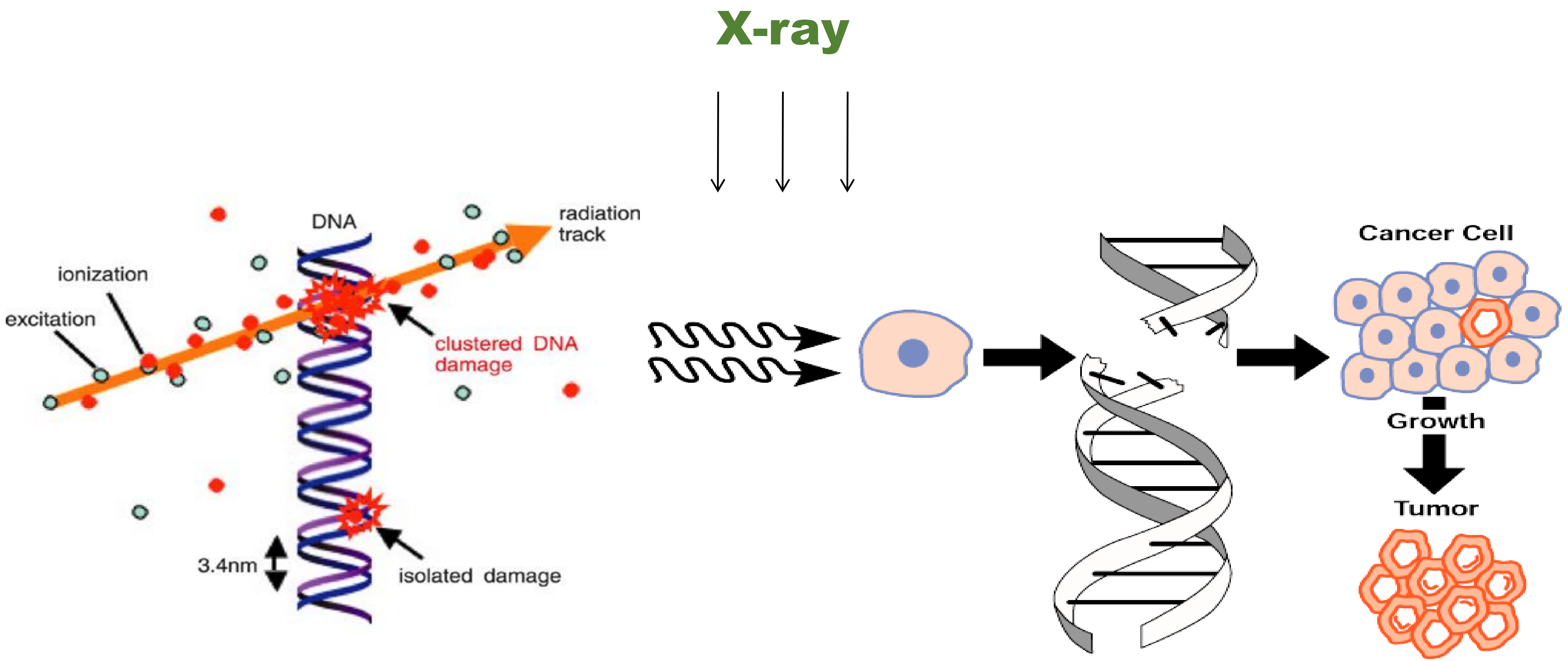
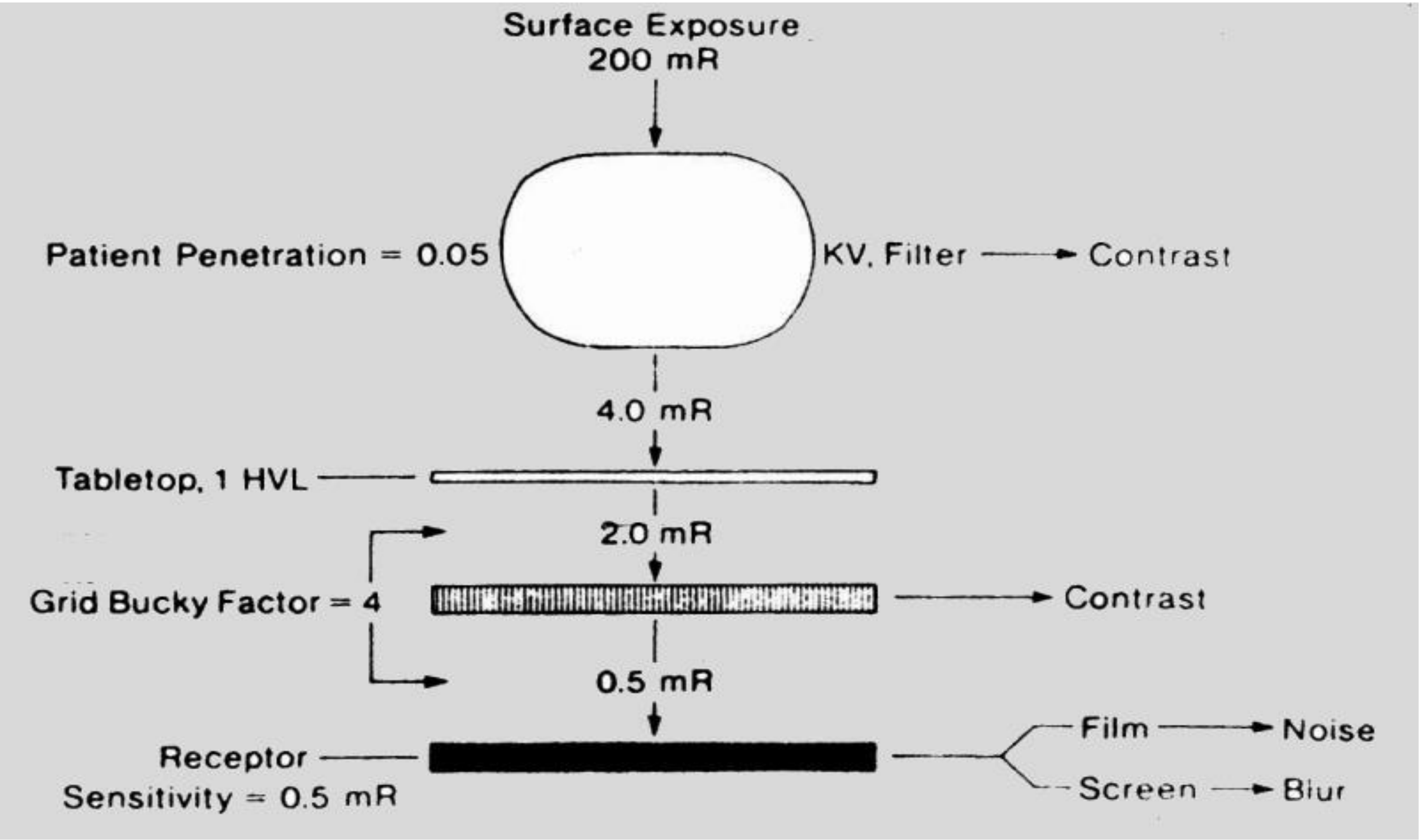


Figure 3: Development of cancer from mutation produced by ionizing radiation

Brief History of X-rays

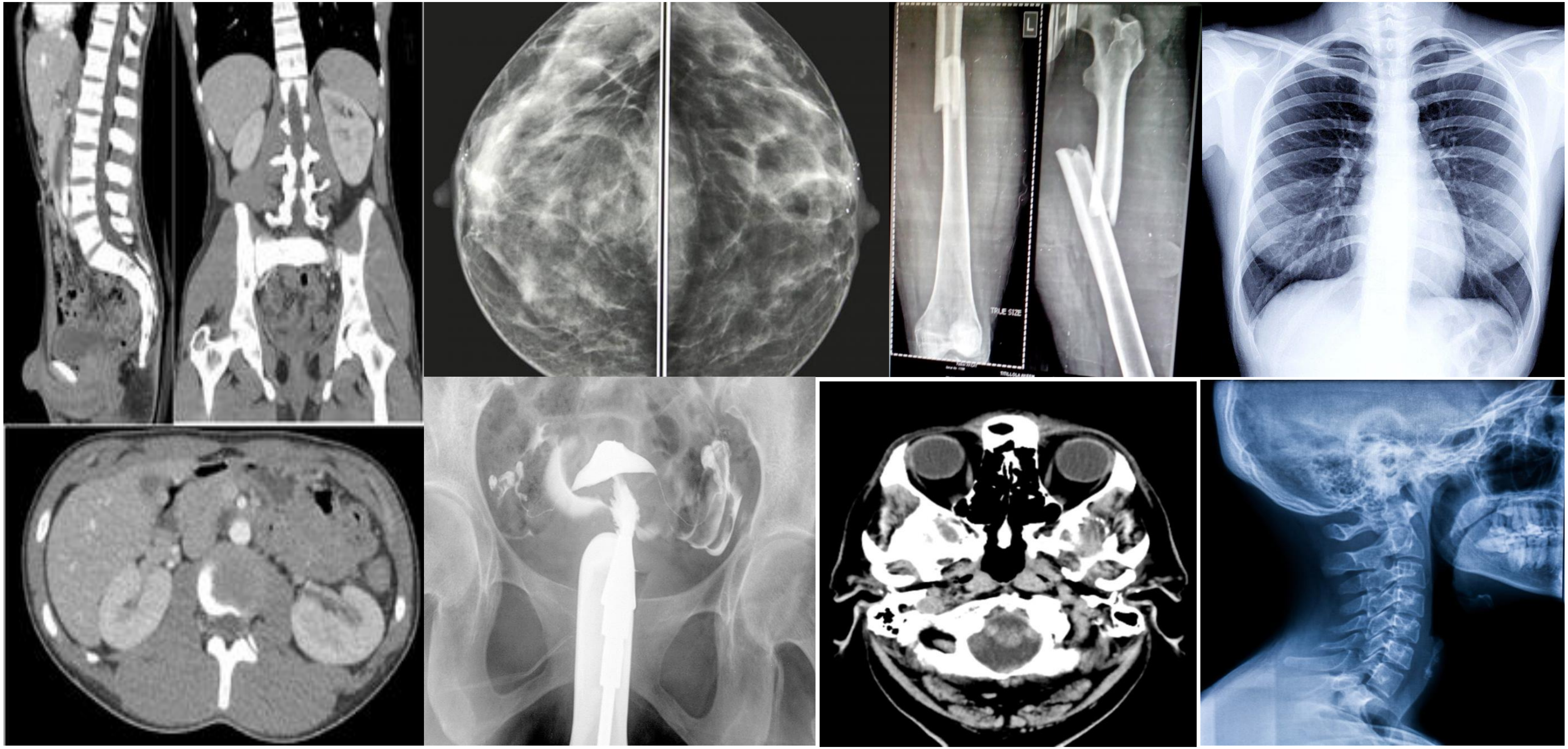
- X-ray was discovered in 1895 by **Wilhelm Conrad Röntgen.**
- It has a very short wavelength and high frequency.
- Wavelength: $1.0 \times 10^{-11} – 1.0 \times 10^{-8}$ m,
- Frequency: $3 \times 10^{16} – 3 \times 10^{19}$ Hz
- Energy: 100 eV – 100 keV.

Distribution of x-ray dose from the tube through the patient to the detector



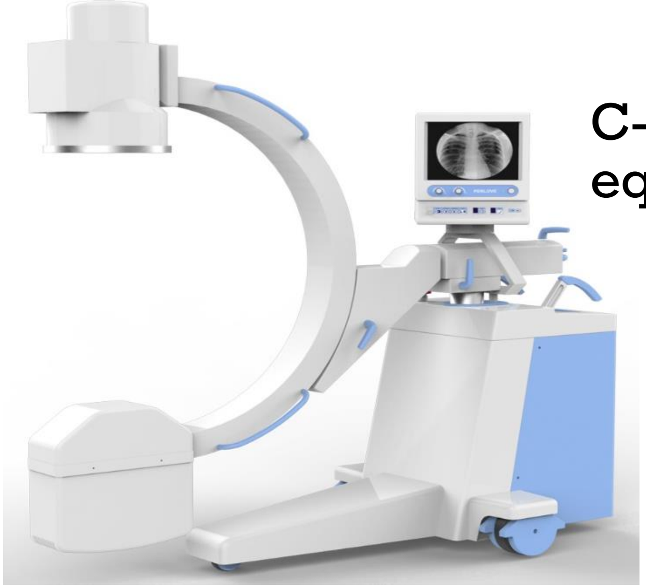
Adapted: Tabakov, 2018

Images from x-ray scan



X-ray Imaging Equipment

Computed
Tomography
scanner

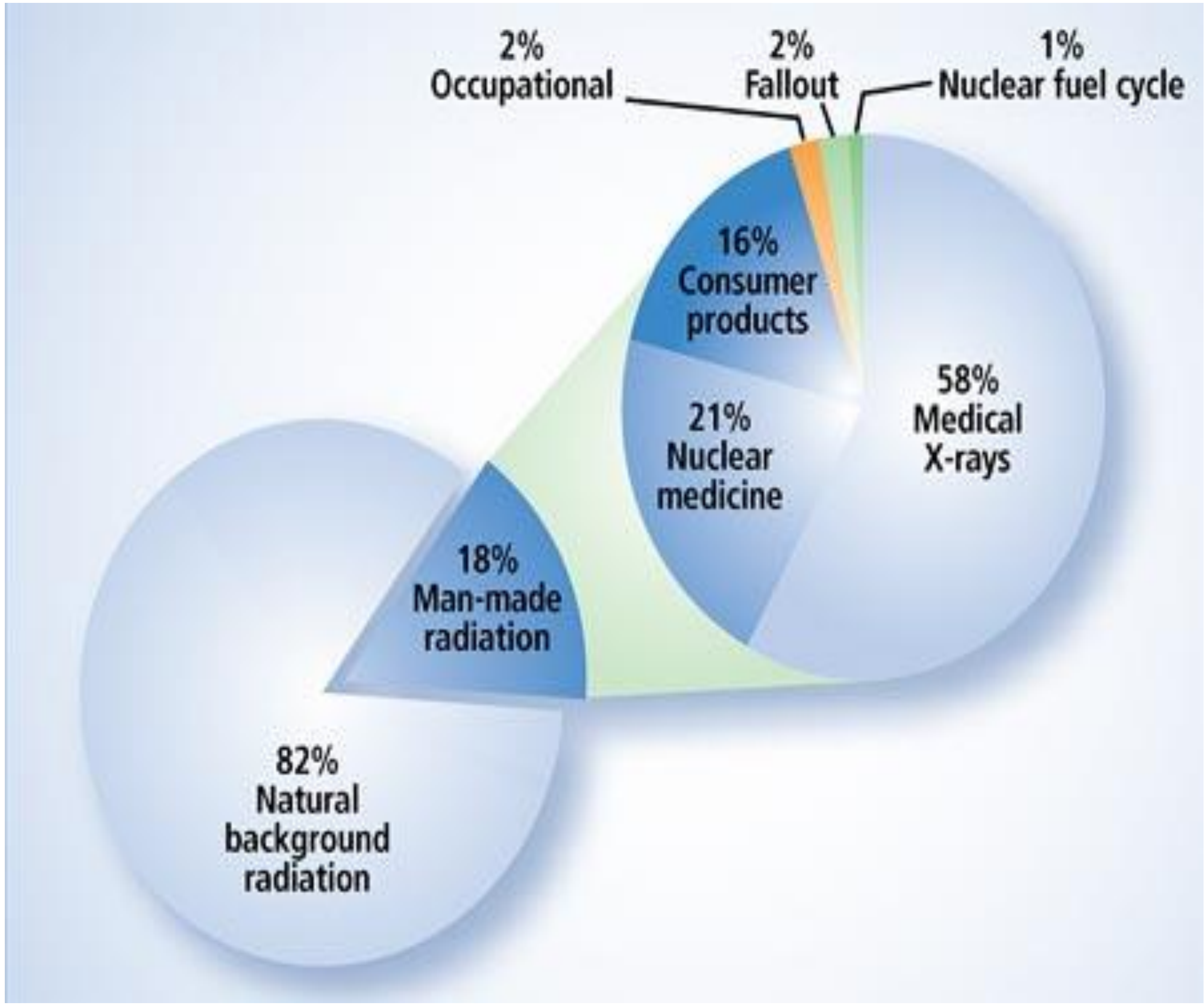


C-Arm
equipment

Radiography
machine

Mammography
scanner

Radiation Exposure from X-rays



http://www.lef.org/magazine/mag2005/oct2005_awsi_03.htm

3.6 billion diagnostic radiologic examinations per annum

(UNSCEAR, 2012; WHO, 2016)

Selected Exposure Estimates

Table 4. Typical effective doses for diagnostic imaging examinations and their equivalence in terms of number of chest X-rays and duration of exposure to natural background radiation[a]

Diagnostic procedure	Equivalent number of chest X-rays	Equivalent period of exposure to natural radiation[b]	Typical effective dose (mSv)
Chest X-ray (single PA film)			
Adult	1	3 days	0.02[c]
5-year-old	1	3 days	0.02[c]
CT head			
Adult	100	10 months	2[c]
Newborne	200	2.5 years	6
1-year-old	185	1.5 years	3.7
5-year-old	100	10 months	2[d]
10-year-old	110	11 months	2.2
Paediatric head CT angiography[f]	250	2 years	5
CT chest			
Adult	350	3 years	7[c]
Newborng	85	8.6 months	1.7
1-year-old	90	9 months	1.8
5-year-old	150	1.2 years	3[d]
10-year-old	175	1.4 years	3.5

Adapted: Mettler et al., 2008; UNSCEAR, 2010

Brief History of Radiation Protection

- A dose limit of about 100 mGy per day was first recommended in 1902 (Khare et al., 2014)
- International Commission on Radiological Protection (ICRP)
- National Council on Radiation Protection and Measurements (NCRP) in 1928 (FRC, 1960).
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).
- NEXT (US)
- HPE (UK)

Principles of Radiation Protection

- Justification of examination
- Optimization of procedures
- Dose limitation
- ALARA (As Low As Readily Achievable) Principle

X-ray examinations are considered justified when the benefits of examination supersede the risks. Diagnostic X-ray procedure is optimized when dose delivered to patient is as low as reasonably achievable.

ALARA (As Low As Readily Achievable) Principle

ALARA principle

a) *‘No practice shall be adopted unless its introduction produces a net benefit;*

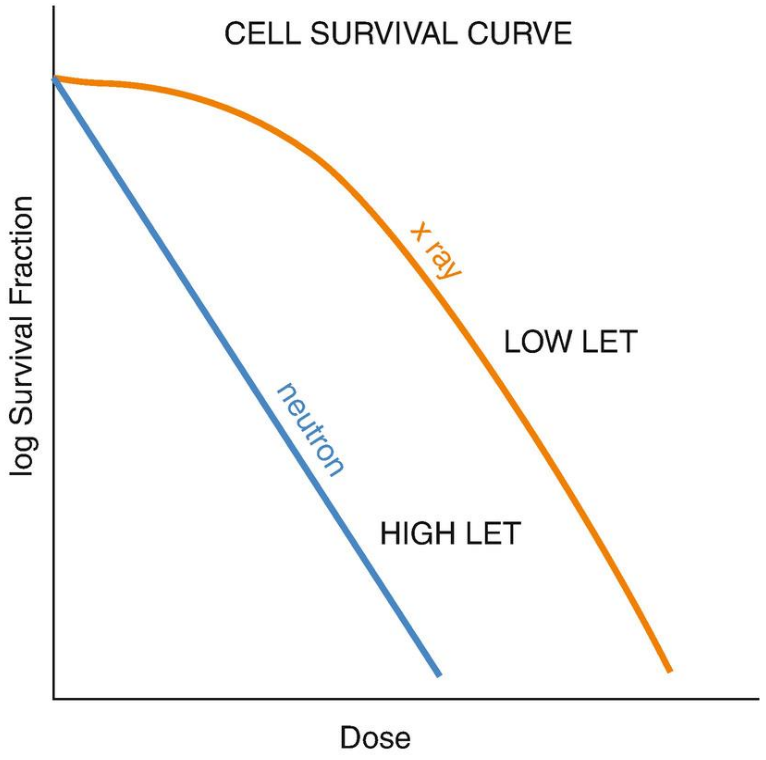
b) ***All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account;***

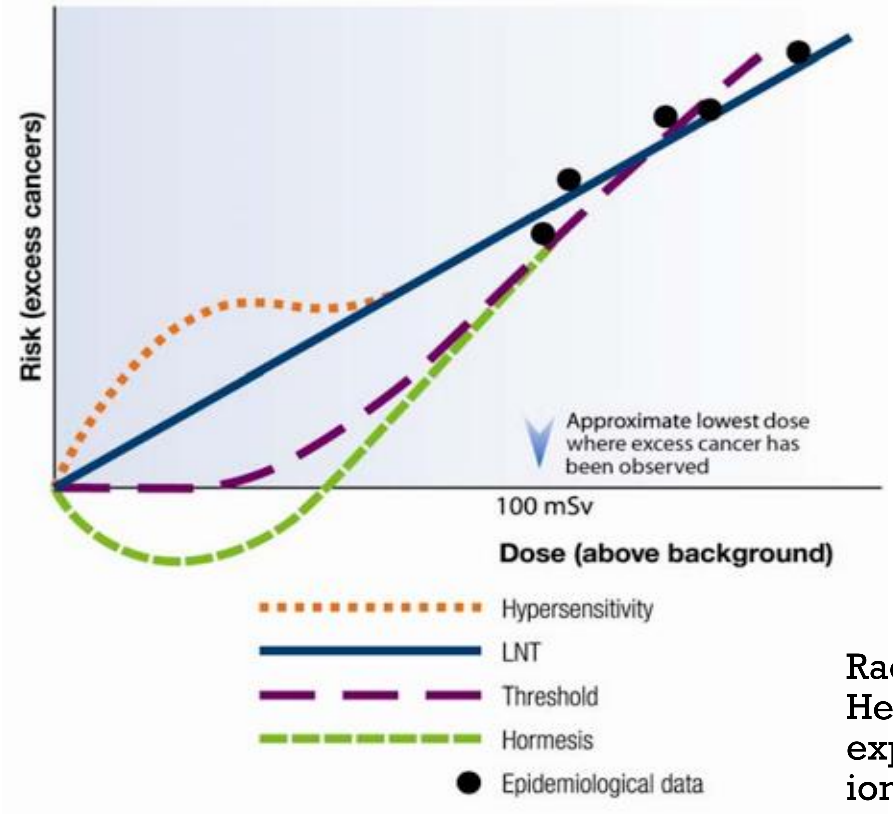
c) *The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission.’*

- Quality control (QC) in diagnostic radiology is periodic evaluation of procedures.
- Quality assurance (QA) in diagnostic radiology is defined as an organized effort by the staff operating a facility to ensure that the diagnostic images produced by the facility are of sufficiently high quality that they consistently provide adequate diagnostic information at the lowest possible cost and with the least possible exposure of the patient to radiation (IAEA, 2012).

Biological Effects of X-ray Exposure

- X-rays has low linear energy transfer (LET)
- Relative Biologic Effectiveness (RBE) ~ 1 keV/µm
- Oxygen Enhancement Ratio (OER) is between 2 and 3 (Huda, 2010).





Radiation risk models: Health risks from exposure to low levels of ionizing radiation

Patient Dosimetry

- Measurement of patient dose enhances good understanding of exposure factors, working habits, use of technological utilities, sensitizing imaging professionals to the optimization of radiation protection and protection of effective quality assurance (Korir *et al*., 2010).
- Periodic evaluation of patient dose enhances diagnostic quality.
- It is a strategy for radiation protection.

Diagnostic Reference Levels (DRL)

- Introduced by ICRP in 1996.
- DRL are established using the 75th percentile values.
- It is a dose level for a typical x-ray examination of a group of patients with standard body sizes and for broadly defined types of equipment (WHO, 2008; Dellie and Rao, 2016).
- Harmonization of radiation dose.
- Using DRL as a reference and working within these levels will reduce variability, promote good practice and enhance radiation protection (WHO, 2008).

Summary of dose reference levels for model adult human subjects for radiography

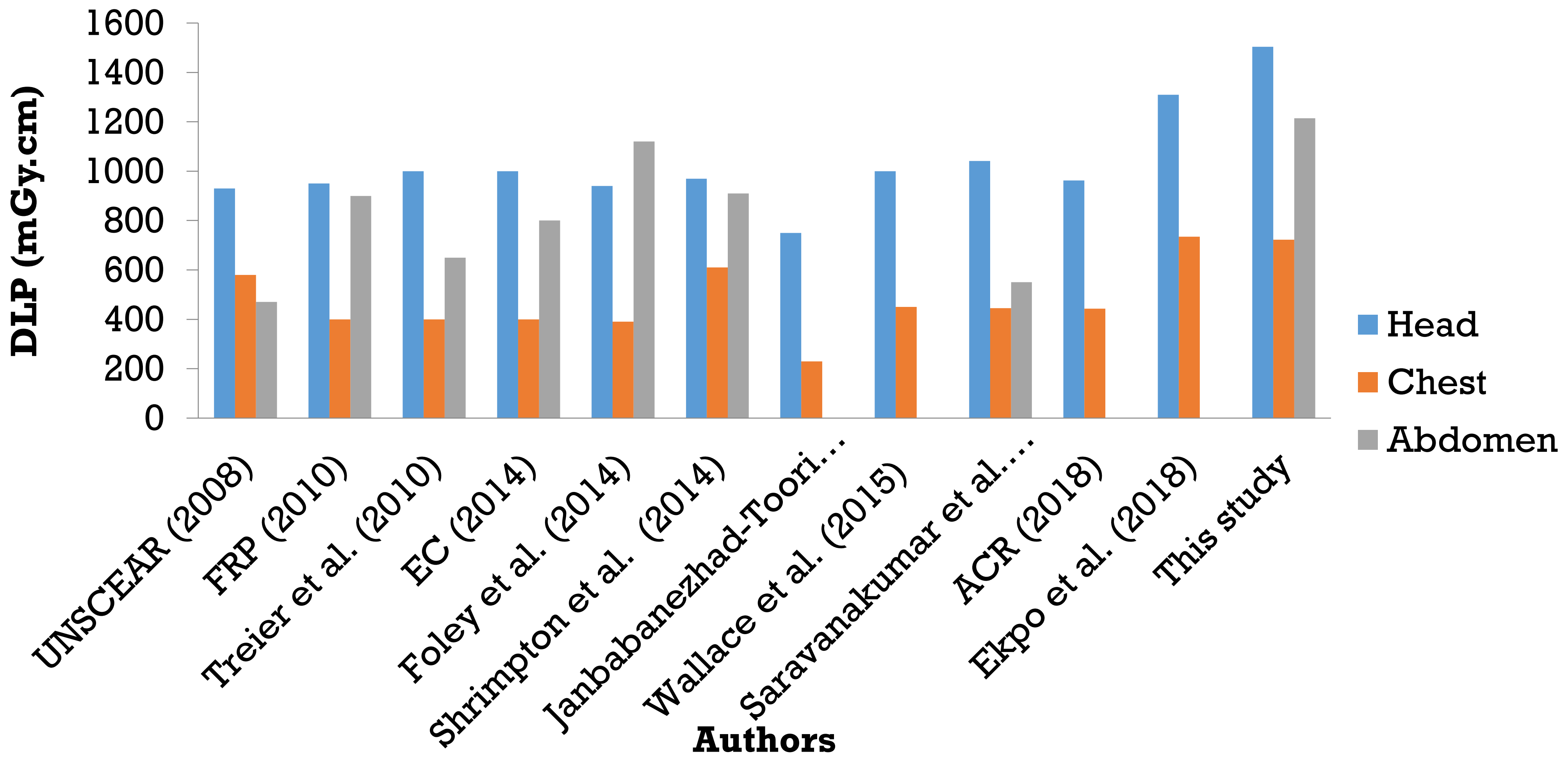
Examination	DRL (mGy)	Effective dose (mSv)
Chest PA	1.32	0.55
CS AP	1.94	0.29
CS LAT	2.16	0.64
LS AP	4.94	1.53
LS LAT	7.96	1.45
Upper Ext AP/LAT	1.27	0.005
Lower Ext AP/LAT	1.38	0.005

Selected organ dose for chest PA

ESD (mGy)	ED (mSv)	Heart (mGy)	Kidney (mGy)	Liver (mGy)	Lungs (mGy)
1.12	0.126	0.351	0.024	0.062	0.484
1.00	0.113	0.314	0.022	0.056	0.432
1.08	0.122	0.339	0.023	0.060	0.467
1.61	0.177	0.489	0.033	0.089	0.667
1.69	0.306	0.741	0.026	0.131	1.290
0.87	0.175	0.410	0.014	0.070	0.735
0.68	0.137	0.321	0.011	0.055	0.575
0.81	0.163	0.382	0.013	0.065	0.685

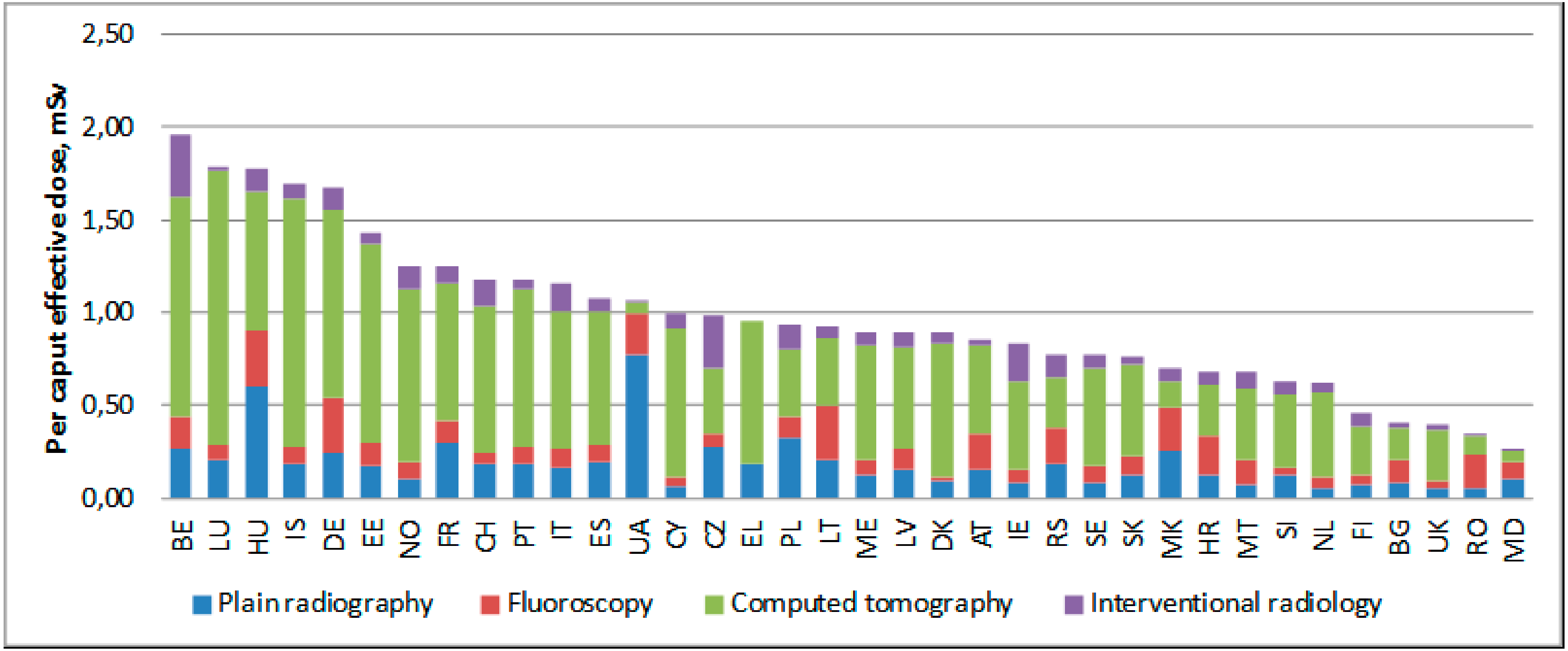
Summary of dose reference levels for computed tomography examinations

Examinations	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	SSDE (mGy)	ED (mSv)
Head CT without contrast	54.00	1504.38	52.38	3.01
Head CT with contrast	47.50	2030.80	46.08	4.06
Abdomen CT without contrast	20.15	1214.52	23.98	29.15
Abdomen CT with contrast	20.45	1188.43	24.34	28.52
Chest CT with/without contrast	13.45	723.43	17.75	19.53



Comparison of DLP in this study with other countries

Per caput effective doses for different countries in Europe (from DDM2 Report (2)).



Diagnostic Reference level in UK

Category	Rounded room third quartile values				
	Mid-1980s Survey	1995 review	2000 review	2005 review	2010 review
Radiographs	ESD per radiograph (mGy)				
Abdomen AP	10	7	6	4	4.4
Chest LAT	1.5	0.7	1	0.6	0.5
Chest PA	0.3	0.2	0.2	0.15	0.15
Lumbar spine AP	10	7	6	5	5.7
Lumbar spine LAT	30	20	14	11	10
Pelvis AP	10	5	4	4	3.9
Skull AP/PA	5	4	3	2	1.8
Skull LAT	3	2	1.6	1.3	1.1
Thoracic spine AP	7	5	3.5	4	3.5
Thoracic spine LAT	20	16	10	7	7
Radiographs	DAP per radiograph (Gy cm^2)				
Abdomen AP			3	2.6	2.5
Chest PA			0.12	0.11	0.1
Lumbar spine AP			1.6	1.6	1.5
Lumbar spine LAT			3	2.5	2.5
Pelvis AP			3	2.1	2.2
Diagnostic exams	DAP per examination or procedure (Gy cm^2)				
Barium enema	60	32	31	24	21
Barium follow through		15	14	12	8

Adapted: HPA 2012

Diagnostic Reference Levels and achievable dose in the United States

Procedure	Diagnostic Reference Level (mGy)	Achievable dose (mGy)
AP Abdomen	3.4	2.4
AP Lumbar	4.2	2.8
PA Chest	0.15	0.11
Upper GI fluoroscopy without contrast	54	40
Upper GI fluoroscopy with contrast	80	72
CT dose Index ($CTDI_{vol}$)		
Head	75	57
Abdomen-Pelvis	25	17
chest	21	14

Adapted: NCDHHS, 2013


THANK YOU