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Trigger Levels in Interventional radiology.

The role of the medical physicist

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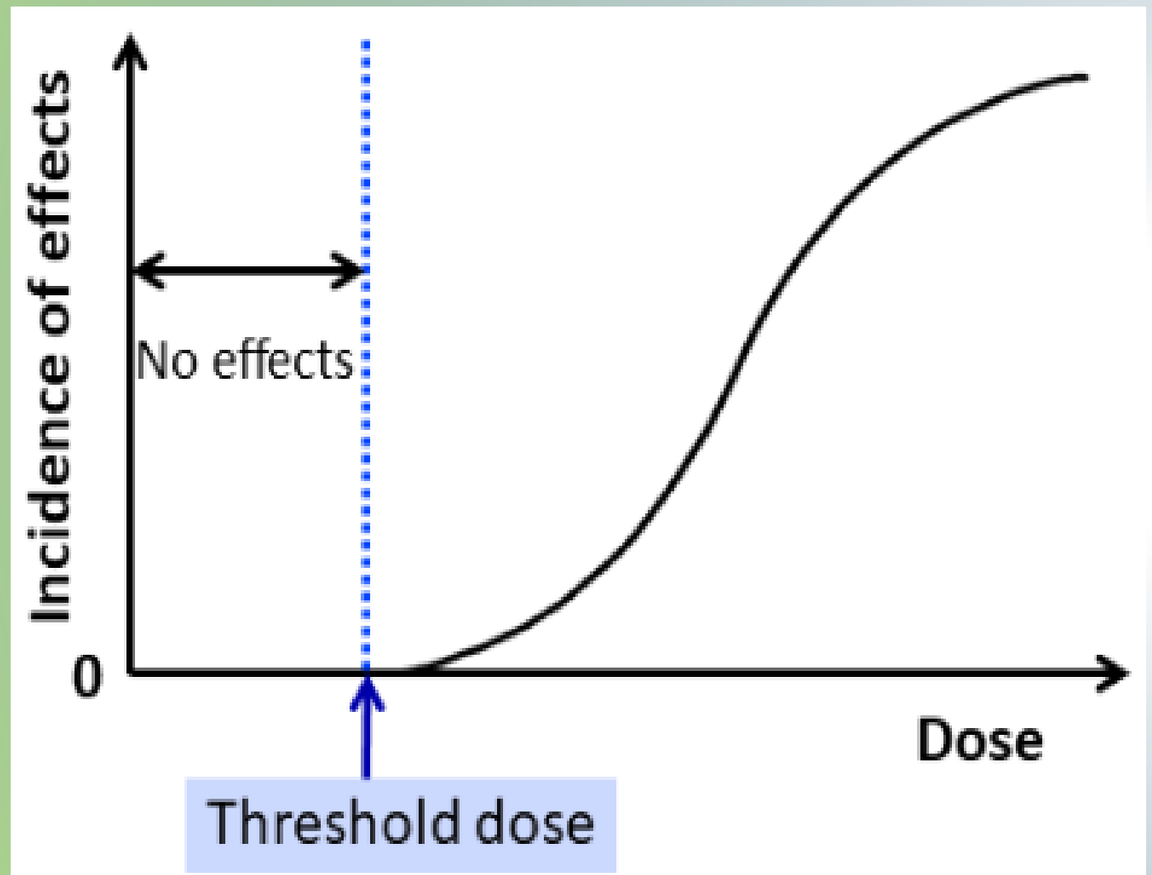
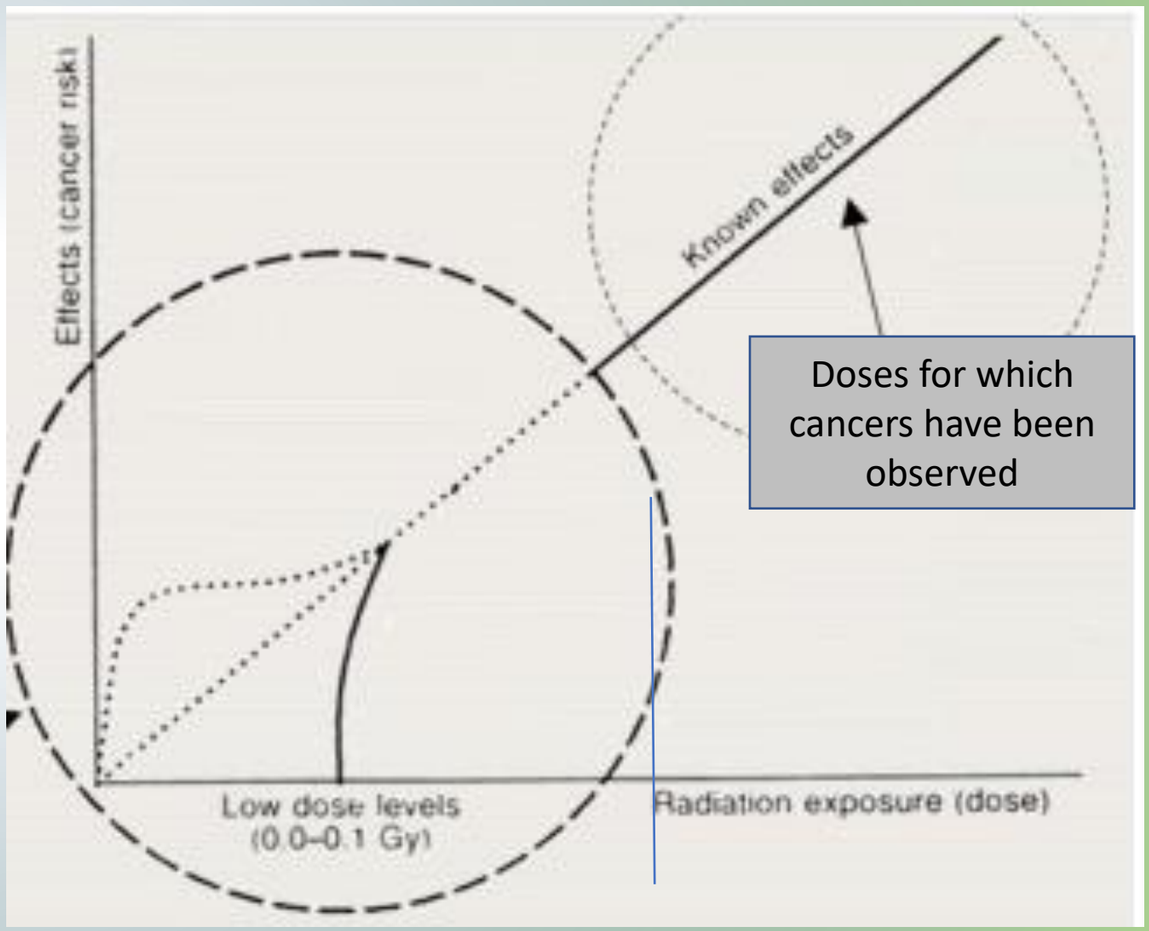
Health effects of ionising radiation

Deterministic effects
(hair loss, cataract, skin injury..)



~ 250mGy

Stochastic effects
(cancers, leukemias, hereditary effects…)



100mGy

Radiation Induced skin injuries

Effect	Typical threshold absorbed dose (Gy)	Hours of fluoroscopic 'on time' to reach threshold* at: Usual fluoroscopic dose rate of 0.02 Gy min^{-1}	High dose rate of 0.2 Gy min^{-1}	Time to onset of effect†
Early transient erythema	2	1.7	0.17	Hours
Main erythema	6	5.0	0.50	10 days
Temporary epilation	3	2.5	0.25	3 weeks
Permanent epilation	7	5.8	0.58	3 weeks
Dry desquamation	10	8.3	0.83	4 weeks
Moist desquamation	15	12.5	1.25	4 weeks
Secondary ulceration	20	16.7	1.67	>6 weeks
Late erythema	15	12.5	1.25	6–10 weeks
Dermal necrosis	18	15.0	1.50	>10 weeks
Dermal atrophy	11	9.2	0.92	>14 weeks
Invasive fibrosis	10	8.3	0.83	–
Telangiectasis	12	10.0	1.00	>52 weeks

* Time required to deliver the typical threshold dose at the specified dose rate.
† Time after single irradiation to observation of effect.

Wagner LK et al. (1994). Potential biological effects following high x-ray dose interventional procedures. J Vasc Inter Radiol, 5, 71-84.

Examples of deterministic effects in Interventional Radiology (IR) (i)

Skin necrosis (estimated Skin dose ~20 Gy)

(a) (b) (c) (d)

(a) 6-8 weeks after multiple coronary angiography and angioplasty procedures.
(b) 18-21 months after the procedures showing tissue necrosis .
(c) Close-up photograph of the lesion shown in (b).
(d) Photograph after skin grafting.

Bey E. et al. Brûlures par irradiation « approche thérapeutique innovante ». Ann Chir Plast Esthet Elsevier Masson 2010;55(5): 354-362

Examples of deterministic effects in IR (ii)

Radiodermitis

Embolisation of 5 aneurysms
Of the gastroduodenal artery:
2 interventions
6 days apart in 2010
Requiring 45 and 152 minutes

Estimated skin dose ~20 Gy

Bey E. et al. Brûlures par irradiation « approche thérapeutique innovante ». Ann Chir Plast Esthet Elsevier Masson 2010;55(5): 354-362

Known IR incidents in France since 2007 (source: IRSN)

Hospital Centers	Date of the incident	field	Number of patients	Skin dose	Contextual information
Lyon	July 2007	Cardiology Rythmology	1	~16 Gy	Incorrect use of the equipment
Strasbourg	End of 2008-start of 2009	Neuroradiology	10	~ 2-14 Gy	Use of non optimised protocols
Clermont Ferrand	August 2009	Vascular IR	1	~ 15 Gy	Use of non optimised protocols
Angers	November 2010	Vascular IR	1	~ 20Gy	Old equipment, non optimised protocols
Lagny sur Marne	6 angioplasties from March to December 2011	Cardiology	1	35-60 Gy	Long fluoroscopy exposure time
Avignon	March 2012	Vascular IR	1	~ 4 Gy	-
Pointe à Pitre	April 2012	Cardiology Rythmology	1	~30 Gy	Long fluoroscopy exposure time

Trigger and alert levels in Interventional Radiology

- Appropriately selected reference values, indicating an increased risk of tissue reactions on the skin.
- The trigger level is set in relation to the threshold dose for tissue reactions at which 1% of all individuals exposed demonstrate the expected tissue reaction.

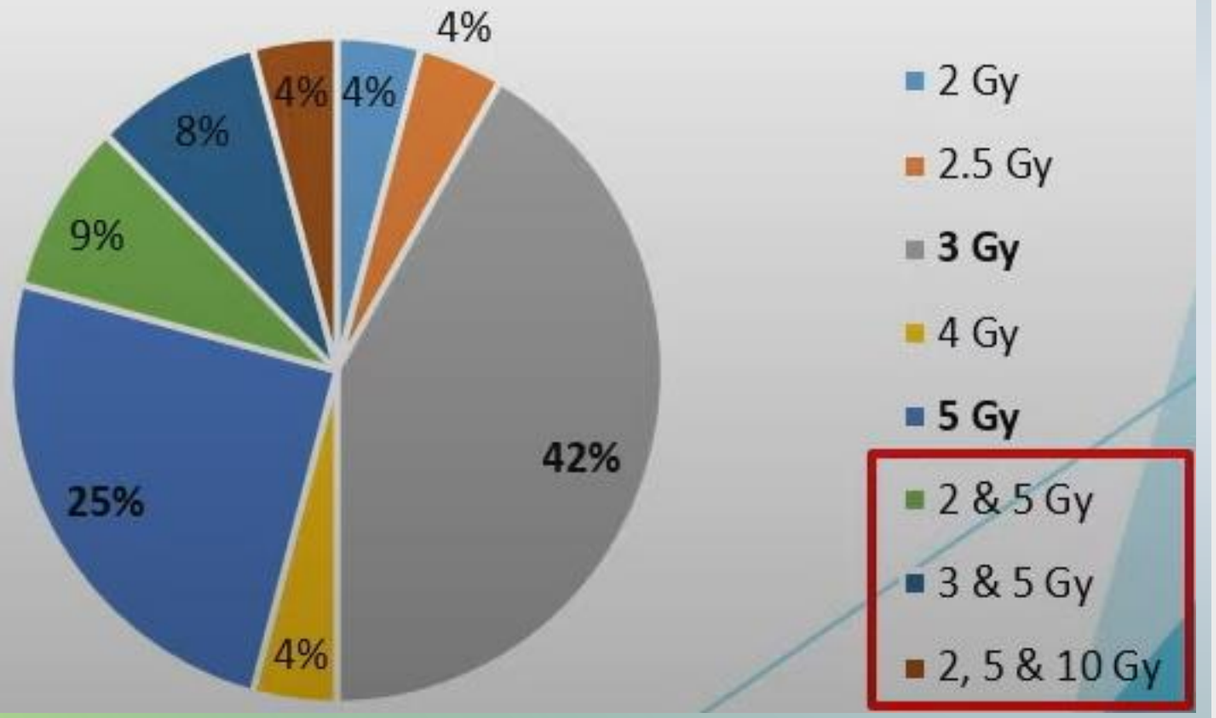
Dose Metric	During the procedure		
	Action level	Subsequent alert level	Trigger level For patient follow-up
Peak Skin Dose	2 Gy	0,5 Gy	3 Gy
Cumulated incident Air kerma at the ref. point	3 Gy	1	5
Kerma Air Product (100 cm^2 x-ray field)	300 $Gy.cm^2$	100 $Gy.cm^2$	500 $Gy.cm^2$
Fluoroscopy time	30 min	15 min	60 min

Vano E et al. ICRP publication 135: diagnostic reference levels in medical imaging. Ann ICRP. 2017;46(1):1-144.
Stecker MS et al. Guidelines for patient radiation dose management. J Vasc Interv Radiol. 2009;20(7 Suppl: S263-S273273

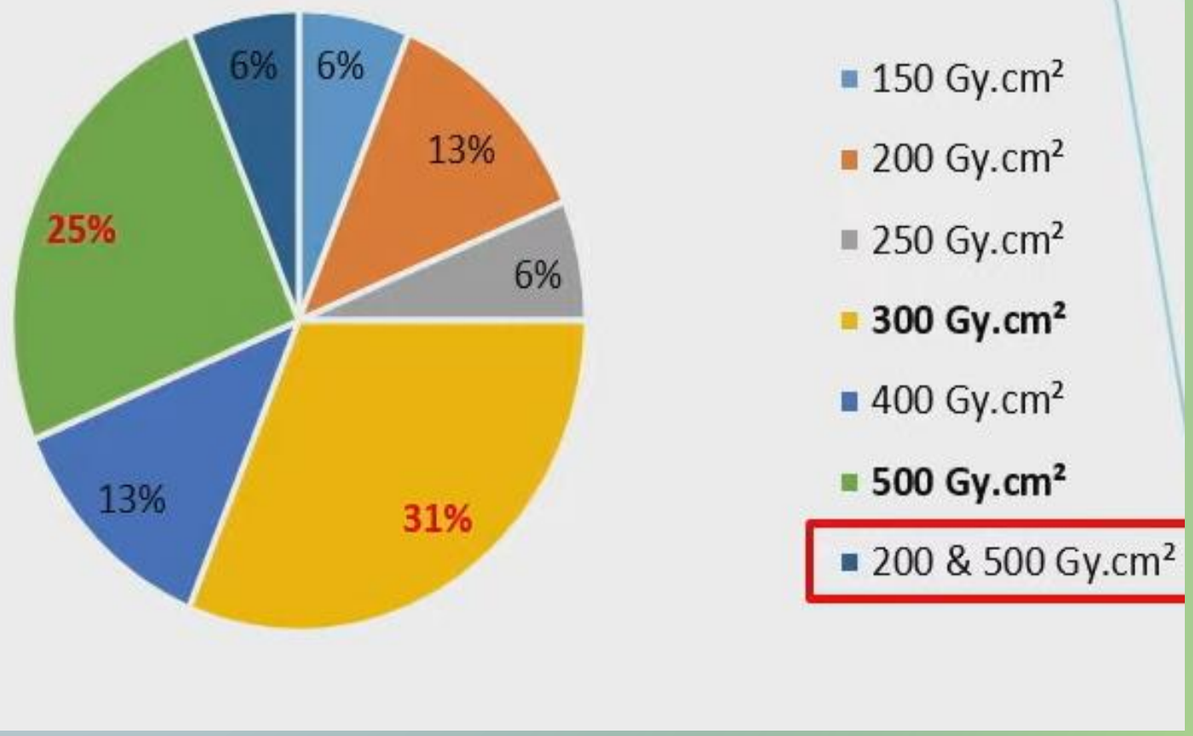
Trigger and alert levels set in France

(data survey 2019-2021, 20 participating centers)

Kair values used by 19 centres



KAP values used by 14 centers



- Heterogeneity in the choice of indicators and values used as well as in actions implemented.
- Need to harmonize/standardize through recommendations?

Hospital center of Pau –trigger and alert level cases 2024

Procedure	KAP (Gy.cm2)	Exposure time (min)	date
Prostatic radioembolisation	691	53	06/01/2024
Prostatic radioembolisation	1207,87	100	28/01/2024
Aortic Radioembolisation	474,16	8	07/03/2024
Prostatic Radioembolisation	429,08	57	07/03/2024
Vascular surgery	514,09	43	02/05/2024
Uterus radioembolisation	634,71	43	07/06/2024
Prostatic radioembolisation	401,93	31	07/06/2024
Radioembolisation of renal spinal metastasis	311	38	26/6/2024
Prostatic radioembolisation	350	37	27/6/2024
Hepatic Radioembolisation	360,39	32	05/07/2024
Radioembolisation (hemorragie de la delivrance)	487	57	14/08/2024
RI angioplasty of digestive artery	428,31	59	23/08/2024

According to internal protocol procedures, the concerned patients have been notified of possible skin reactions.

The role of the medical physicist in preventing skin injuries in IR

- Quality assurance of the fluoroscopic equipment in terms of dose levels and image quality.
- Establishment of local typical dose values for the most common interventional radiology procedures and comparison with the national DRLs.
- Follow-up on patient and staff doses. Available dose management systems and specialized software providing skin dose mapping.
- Informing the interventional radiologist about the trigger levels, the radiological risks associated with IR exposures, and the features of the fluoroscopic unit that provide alerts when dose thresholds are reached.
- Ensuring that the interventional radiologist has received initial training in patient radiation management, radiation safety for both patients and staff, as well as the safe operation of fluoroscopic equipment. The training should cover understanding the most significant tissue reactions and the radiation levels at which they may occur. Both trainees and experienced interventional radiologists must maintain constant awareness of radiation doses and opportunities to minimize exposure for patients and personnel."