EYE-OPENER: WHY THE LENS NEEDS PROTECTION FROM RADIATION



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Imaging the Individual

Learning Objectives

Introduction

Background:	Recent evidence indicates that the radiosensitivity of the ocular lens is considerably higher than previously assumed. Nevertheless, awareness and compliance with lens protection measures remain far lower than for the use of lead aprons. Therefore, renewed emphasis on education regarding lens protection is warranted.
 Goal:	In this educational exhibit, we will explore the answers to **six key questions (Q1-Q6)** listed below together with you.

Questions:

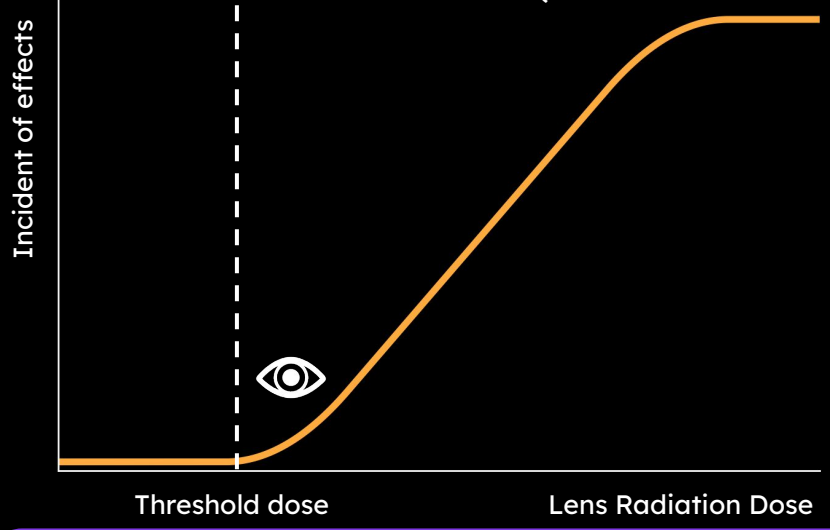
1. **How much more radiosensitive is the lens than other organs, and why?**
2. **How do radiation cataracts differ from age-related cataracts clinically?**
3. **Which procedures deliver the highest lens dose, how many are safe per year, and how much do protections reduce that dose?**
4. **For students and residents with brief, intermittent exposure, is it acceptable to forgo protections according to our current understanding?**
5. **When staff must be near the patient for fluoroscopy, radiography, or CT, where should they stand—besides “farther away”—to keep lens dose as low as possible?**
6. **Which eyewear shapes and specifications work best, what precautions matter, and how can we boost routine use?**

Cataract Formation: Threshold Dose?

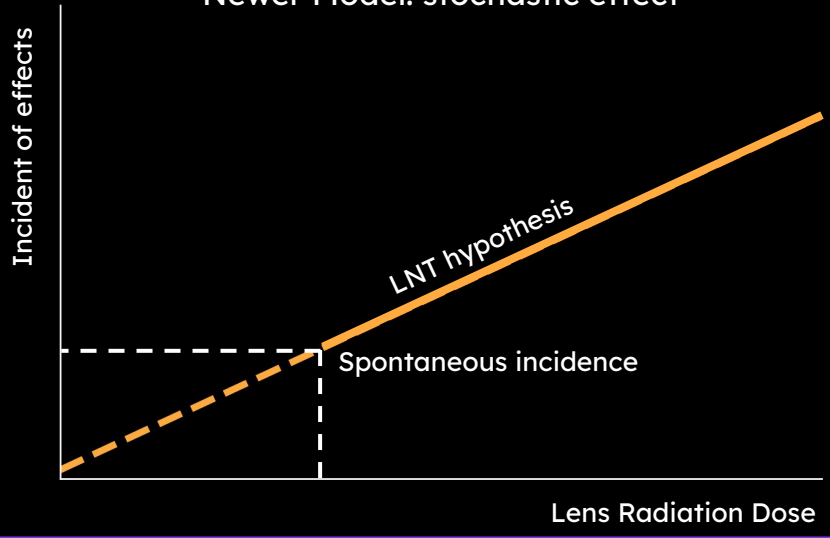
Introduction

Until recently, radiation-induced effects on the crystalline lens have generally been regarded as a tissue reaction.

Traditional Model: tissue reaction (deterministic effect)



Newer Model: stochastic effect



The threshold dose is operationally defined as the exposure associated with a 1% incidence in the exposed population. Cataract formation has generally been classified as a tissue-reaction that only occurs after a threshold has been reached. In contrast, stochastic effects such as development of cancers are modeled under the linear-no-threshold (LNT) hypothesis where any exposure is associated with increase in risk. Emerging evidence suggests that even at low doses, the occurrence of cataract increases approximately in proportion to dose; cataracts behave stochastic-like at low doses.

Studies Indicating Lower Thresholds or Non-Tissue-Reaction

Citation	Population [N/Studies]	Endpoint/Metric	Low-dose signal [Stochastic-like?]
Little MP et al., 2018, Eur J Epidemiol (USRT)	US radiologic technologists [Eligible ~67k; 12,336 cataracts; 5,509 surgeries; mean lens dose 55.7 mGy]	Excess hazard ratio per mGy = 0.00069 (cataract)	Association significant when restricting to <100 mGy cumulative lens dose. [Supports risk at very low doses; less distinct threshold.]
Little MP et al., 2020, Occup Environ Med (USRT)	US radiologic technologists [~67k; 11,345 cataracts; 5,440 surgeries]	EAR = 94 per 10^4 PY·Gy (95% CI 47–143)	Additive risk elevated even at <100 mGy (p=0.004). [Compatible with low-dose risk; threshold less clear.]
Ainsbury EA et al., 2021, Environment International	HCWs incl. interventional cardiology, technologists; A-bomb survivors Narrative review [21 studies]	Lens opacities/cataract; epidemiology+clinical+ biology; research gaps	<0.1 Gy & low dose rates (<0.005 Gy/h) discussed in some studies; more data needed. [Uncertain strict threshold; stochastic-like features debated.]
Hamada N., 2023, Radiation Research (Review)	Multiple cohorts (occupational & environmental) Narrative review	Cataract risk reported below 0.5 Gy; threshold less evident with longer follow-up	Explicitly notes increased risk <0.5 Gy. [Calls for reconsideration of tissue-reaction framework (stochastic-like features possible).]
Villeneuve PJ et al., 2025, Radiation Research	Ontario nuclear power plant workers [60,874 workers; 2,939 cataract surgeries]	Linear excess risk = 0.055 per 100 mSv (95% CI −0.042–0.163)	Lifetime doses rarely >30 mSv; suggests risk at very low cumulative doses. [Consistent with low-dose risk; no threshold demonstrated.]

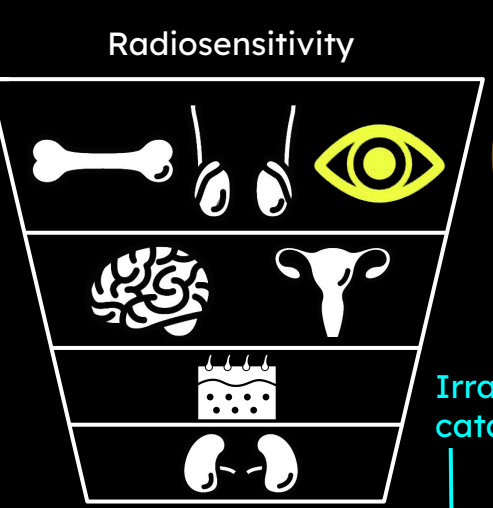
Radiosensitivity of the Lens

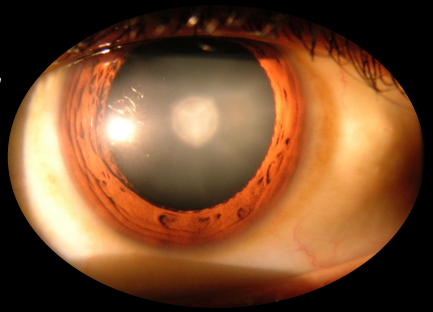
Introduction

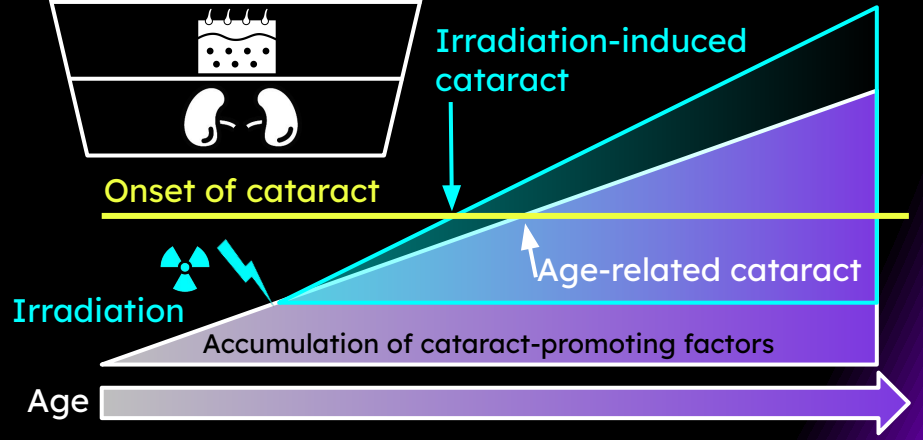
The lens is highly radiosensitive; radiation increases cataract risk and accelerates onset.

Tissue/Organ	Conditions	Threshold*
Bone Marrow	Depressed hematopoiesis	~0.5 Gy
Testes	Temporary sterility	~0.1 Gy
Crystalline lens	Vision-impairing cataract	0.5 Gy
Brain	Cognitive defects	1-2 Gy
Ovaries	Permanent sterility	3 Gy
Skin	Temporary hair loss	~4 Gy
Kidneys	Renal failure	7-8 Gy

*Threshold of acute exposure







The crystalline lens is especially sensitive to radiation; exposure increases cataract incidence and advances onset by adding to common factors like age/UV—shifting onset earlier as illustrated.

Evolution of Occupational Lens Protection

Introduction

Radiation protection for the crystalline lens has a long history.

1897 The first case of radiation cataract was reported in rabbits.

1903 The first case of radiation cataract was reported in humans.

1949 2 papers on cataracts in atomic bomb survivors and cyclotron workers were published.

1950 ICRP designated the ocular lens as a critical organ.

1954 ICRP recommended the first set of lens dose limits for workers and public.

1977 ICRP classified cataracts as “non-stochastic effects” (renamed “tissue reactions”).

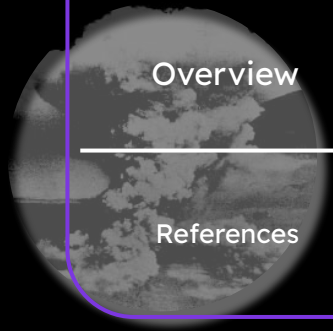
2011 ICRP recommended reducing an occupational dose limit for the lens.

2016 NCRP recommended reducing an occupational dose limit for the lens.

2021 In Japan, the legally mandated lens dose limit follows the ICRP recommendations.

Scientific Evidence Underpinning the Threshold Revision

Threshold defined by long-term follow-up of atomic-bomb survivors and Chernobyl liquidators*.



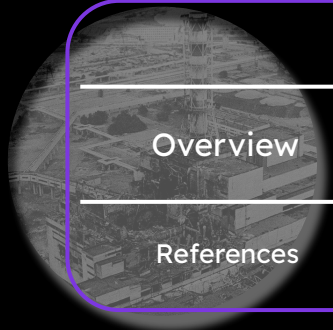
Acute exposure threshold: 0.5 Gy.

Overview

Based on atomic-bomb survivor data, cataract outcomes assessed 55–57 years post-exposure showed significant increases in posterior subcapsular and cortical cataracts. In addition, a significant increase in cataract surgery prevalence was observed.

References

Minamoto, A., Taniguchi, H., Yoshitani, N., et al. Cataract in atomic bomb survivors. Int. J. Radiat. Biol. 80, 339–345, 2004.
Neriishi, K., Nakashima, E., Minamoto, A., et al. Postoperative cataract cases among atomic bomb survivors: radiation dose response and threshold. Radiat. Res. 168, 404–408, 2007.



Fractionated/protracted-exposure threshold: <0.5 Gy.

Overview

Among Chernobyl cleanup workers 12–14 years after exposure, posterior subcapsular and cortical cataracts were significantly increased, with an estimated threshold of 0.34–0.5 Gy.

References

Worgul, B.V., Kundiyev, Y.I., Sergiyenko, N.M., et al. Cataracts among Chernobyl clean-up workers: implications regarding permissible eye exposures. Radiat. Res. 167, 233–243, 2007.

*Chernobyl liquidators were the civilian and military personnel mobilized to clean up after the 1986 Chernobyl nuclear disaster, many of whom received high radiation doses during firefighting, decontamination, and construction work.

Former Threshold Dose for Lens Exposure

Before 2011, thresholds were believed to differ by exposure duration.

Before 2011	Threshold: Total dose received in a single brief exposure (Gy)	Threshold: Total dose received in highly fractionated or protracted exposures (Gy)	Threshold: Annual dose rate if received yearly in highly fractionated or protracted exposures for many years (Gy/year)
Minor opacities	0.5-2.0	5	>0.1
Vision impairing cataracts	5.0	>8	>0.15

Before 2011 150 mSv/year

After 2011 100 mSv/5 years (not exceeding 50 mSv in any single year)

Practically 20 mSv/year

→ 0.5 Gy (after 2011)

Historically, for low dose-rate (protracted or fractionated) exposures, the cumulative dose required to induce radiation cataract was considered higher than that for an acute exposure. From 2011 onward, the ICRP has used 0.5 Gy as the lens threshold regardless of whether exposure is acute, fractionated, or protracted. In addition, the annual dose limit for the lens has been practically reduced to less than one-seventh of its former value.

Changes in ICRP Guidance on Radiation Protection For Lens

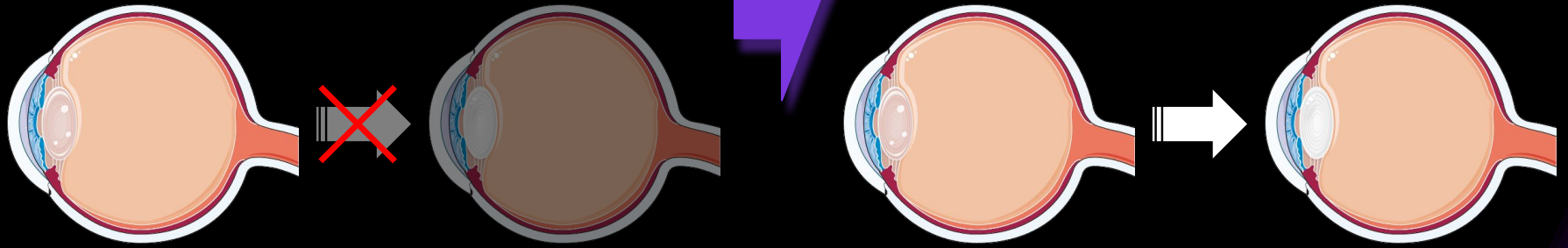
Today, threshold values are focused on preventing vision-impairing cataracts.

Before 2011

Because minor lens opacities do not invariably progress to vision-impairing cataracts (VICs), separate threshold doses were specified for minor opacities and for VICs.

After 2011

On the basis that minor opacities can progress to VICs, a single (unified) threshold was adopted without separating endpoints.

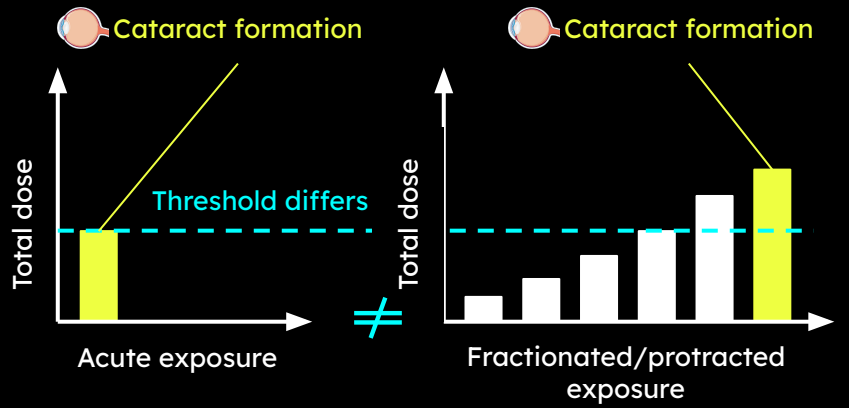


Changes in ICRP Guidance on Radiation Protection For Lens

Threshold is total-dose–based, not exposure-pattern–dependent.

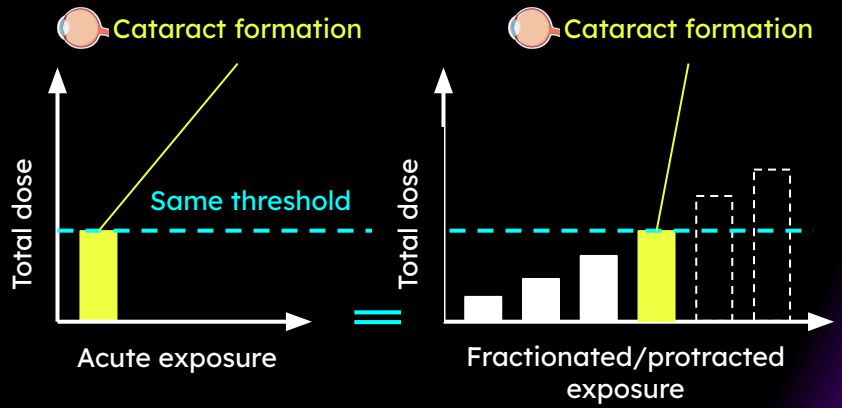
Before 2011

Assuming a dose-rate (protraction) effect, different thresholds were specified for acute versus fractionated/protracted exposures.



After 2011

Assuming no material dose-rate effect, the threshold is specified in terms of cumulative dose, irrespective of whether exposure is acute or chronic/protracted.

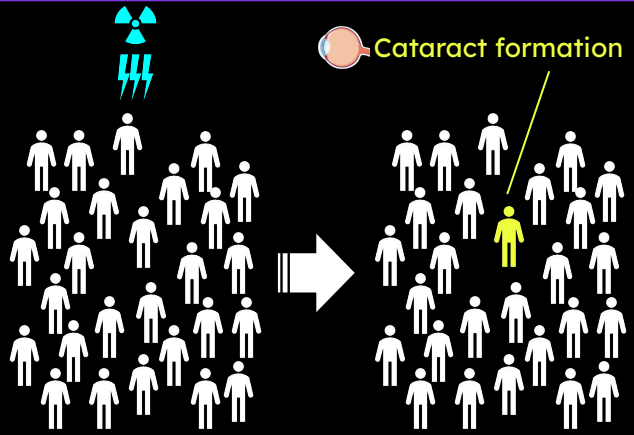


Changes in ICRP Guidance on Radiation Protection For Lens

Current practice considers not only the incidence of cataract but also the latency to onset.

Before 2011

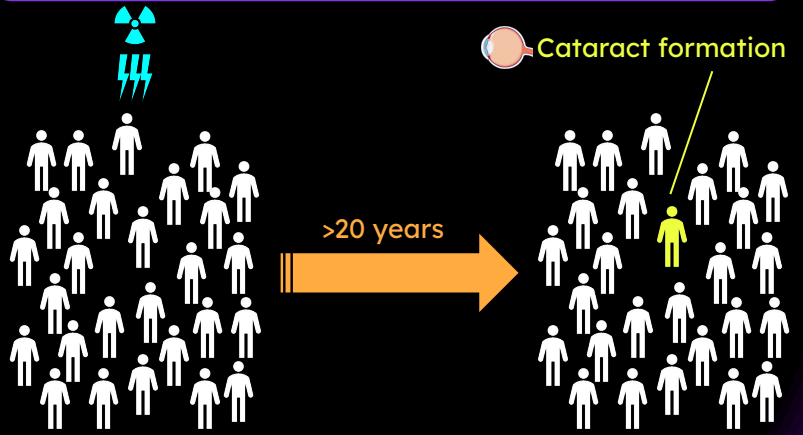
Previously, threshold values did not highlight the time interval from exposure to cataract formation because the follow-up intervals of available research were too short.



1% incidence of VICs in the exposed population, studied for a shorter duration.

After 2011

ICRP Publication 118 instead uses a practical threshold corresponding to a 1% risk of cataract including occurring after a long latency, i.e., more than 20 years following exposure.



Emphasize late-occurring effects.

1% incidence of VICs in the exposed population studied for a longer duration.

What Makes the Crystalline Lens Highly Radiosensitive?

There are mainly four reasons why lens are particularly radiosensitive.

1. Slow DNA repair

- In peripheral lens epithelial cells, DNA repair is significantly slower than other tissues.
- Genomic instability and apoptosis risk are high.

2. Minimal epithelial cell turn over

- Lens has avascular nature to maintain transparency.
- Due to the nutrient-deficient environment, epithelial turnover is markedly reduced.
- Damaged epithelial cells tend to persist.

3. Limited antioxidant capacity

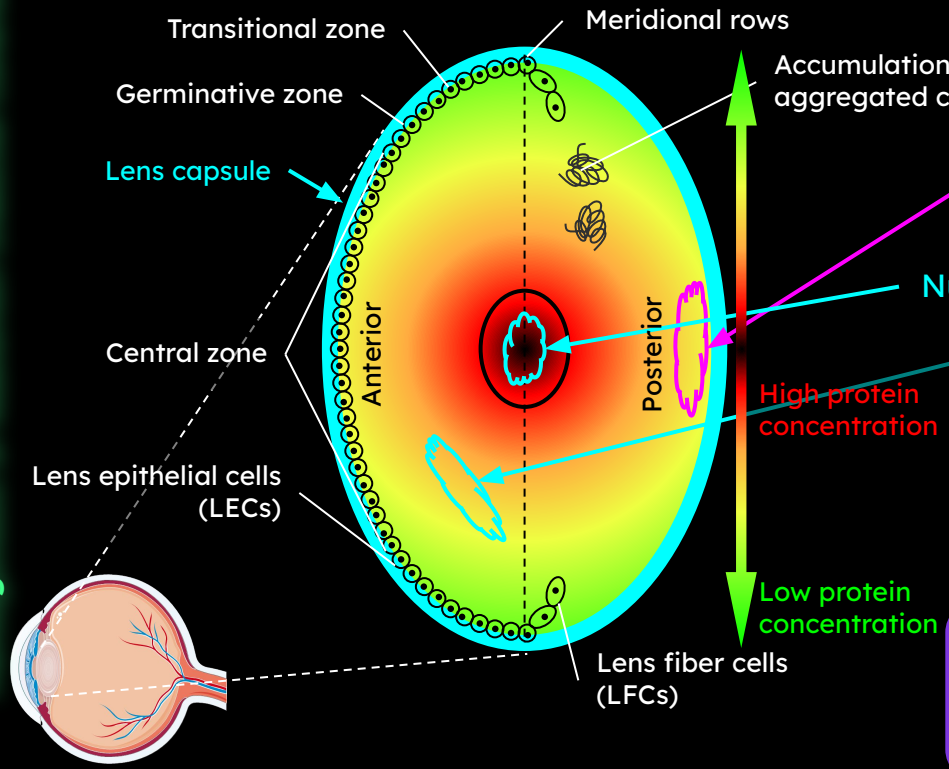
- Crystallin, which is abundant in the lens, is highly susceptible to oxidation.
- Due to the lens's limited vascular supply and low metabolic rate, antioxidant reserves are not replenished efficiently once depleted.
- Consequently, oxidized crystallins tend to accumulate.

4. Environment favoring abnormal cell accumulation

- While abnormal cells in the skin are eventually sloughed off, cells in the lens persist.
- Aberrantly differentiated fiber cells derived from epithelial cells remain within the lens tissue.
- The key issue is that, once abnormal differentiation occurs, its consequences are not cleared.

Structure of Crystalline Lens and Its Damage from Radiation

Damage from radiation accumulates in lens and is linked to characteristic cataract phenotypes.



Posterior subcapsular cataract (PSC)

PSC is the cataract subtype most linked to radiation, with faster progression and earlier visual loss than cortical/nuclear cataracts.

Nuclear cataract

Cortical cataract

Aging mainly yields cortical/nuclear cataracts; these can occur after radiation but less often than PSC.

At meridional rows, LECs differentiate into LFCs, shed organelles to stay translucent, and produce crystallins; radiation can upset this process through DNA damage and protein changes, leading to opacity.

Estimated Lens Doses in Interventional Radiology

Vano et al. estimated radiation doses using a phantom under low- and high-exposure scenarios.

Type of procedures	Lens dose/procedure (mSv)		No. of procedures to reach 20 mSv	
	Without protection	With protection	Without protection	With protection
Hepatic chemoembolization	0.27-2.14	0.016-0.064	9-74	312-1250
Iliac angioplasty	0.25-2.22	0.015-0.066	9-80	303-1333
Neuroembolization, head	1.38-11.20	0.083-0.336	2-14	60-241
Neuroembolization, spine	1.44-11.00	0.086-0.329	2-14	61-233
Pelvic embolization for fibroids	0.41-3.43	0.025-0.103	6-49	194-800
Pulmonary angiography	0.19-1.49	0.011-0.045	13-105	444-1818
TIPS creation	0.41-3.72	0.025-0.112	5-49	179-800

In a worst-case scenario, the cumulative annual lens dose can exceed 20 mSv after only a single-digit number of procedures. The use of protective measures—leaded eyewear and a ceiling-suspended shield—substantially reduces lens dose and, accordingly, allows a much higher procedural count before reaching the annual dose.

Medical Procedures with High Radiation Exposure to Lens



High-Risk Procedures and Exposure Estimates

The procedures listed below are more likely than others to exceed the 20 mSv/year lens dose limit.

Procedure types	Lens dose/procedure (mSv)	No. of procedures to reach 20 mSv/year
Urology	0.026 (mean)	769
Orthopedic Surgery	0.050	400
Interventional Cardiology	0.023-0.236 (mean)	85-870
ERCP	0.094 (mean, under-couch X-ray tube) 0.055 (mean, over-couch X-ray tube) 2.8 (maximum)	7-363

While the summary presented here draws primarily on reports from the International Atomic Energy Agency (IAEA), numerous publications document even higher occupational lens doses. Compared with interventional radiologists, non-radiology physicians generally demonstrate lower adherence to protective eyewear (supporting data will be shown in later slides). Under worst-case assumptions, cumulative annual lens exposure in such settings can plausibly reach several tens of millisieverts.

⚠ **The risk of lens exposure extends beyond radiologists.**

Three Basic Strategies to Prevent Lens Exposure to Radiation

Protective Strategies: Time, Distance, Shielding

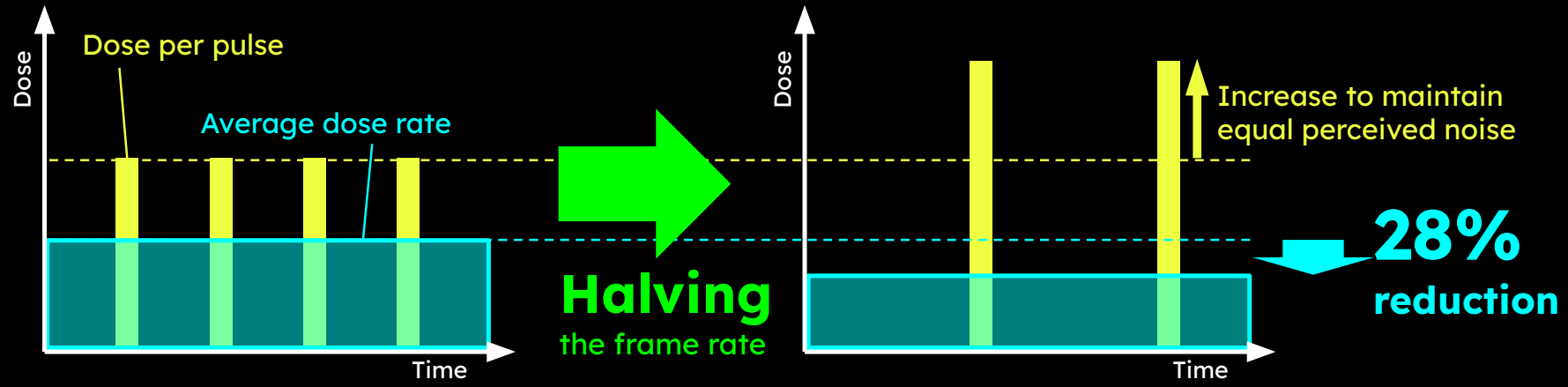
Radiation protection should be practiced by combining time, distance, and shielding.



1. Time	2. Distance	3. Shielding	Combined strategy
Minimize beam-on time.	Know where the scatter radiation is coming from.	Minimize the radiation field and wear PPE properly.	Maximize protective efficacy.
Reduce the fluoroscopy frame rate.	Maintain 2 m separation from the source.	Collimation, operator positioning, lead goggles and ceiling-mounted shields reduce dose.	Mutually compensate for the weaknesses of each strategy.
Shielding rate of each strategy			
30%	75%	40-90%	Max effect

Frame Rate vs. Diagnostic Capability in Fluoroscopy

Reducing the frame rate from 15 to 7.5 fps maintains image quality while lowering lens dose by approximately 30%.



Typically, when the fluoroscopy frame rate is halved, the per-pulse dose increases by √2 to maintain the perceived noise level (as “visibility”). Consequently, reducing the frame rate from 15 fps to 7.5 fps does not simply halve the dose; in theory it yields a reduction to 1/√2 (≈ 0.72×).

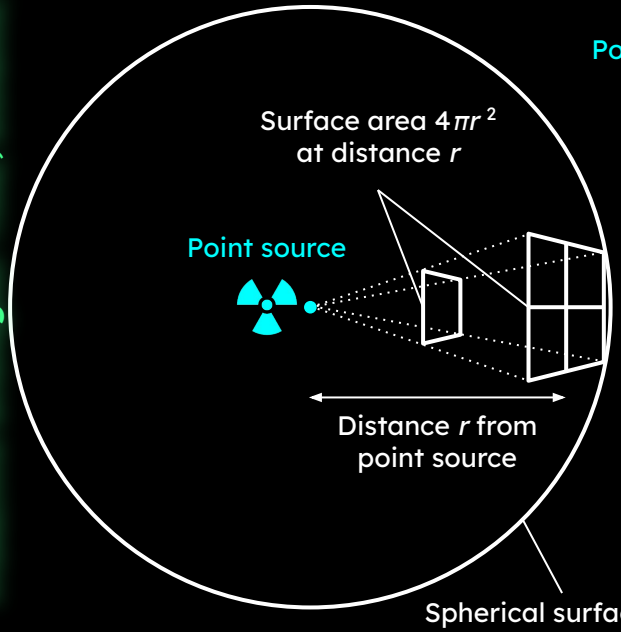
Randomized Trial Comparing 15 fps and 7.5 fps

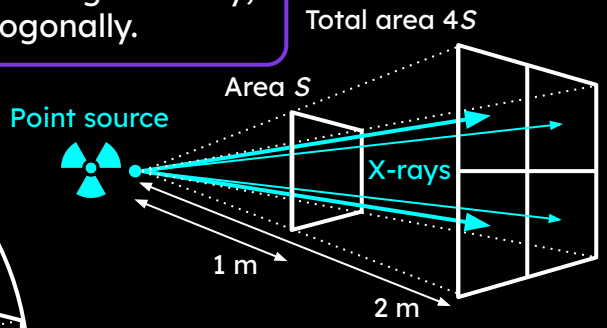
Abdelaal et al. (2014) contrasted 15 fps versus 7.5 fps during diagnostic coronary angiography (DCA) and percutaneous coronary intervention (PCI). Consistent with the theoretical estimate, operator dose decreased by about 30% in the 7.5-fps group, with no significant differences in beam-on time or procedure duration.

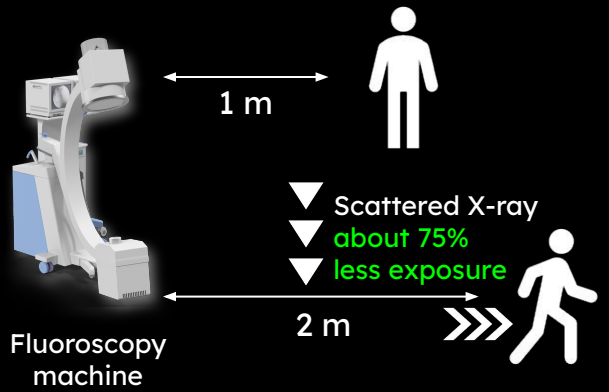
Inverse Square Law

At short operator–patient distances, measured exposure can exceed inverse-square predictions.

X-rays emitted from a point source diverge radially, intersecting spherical surfaces orthogonally.





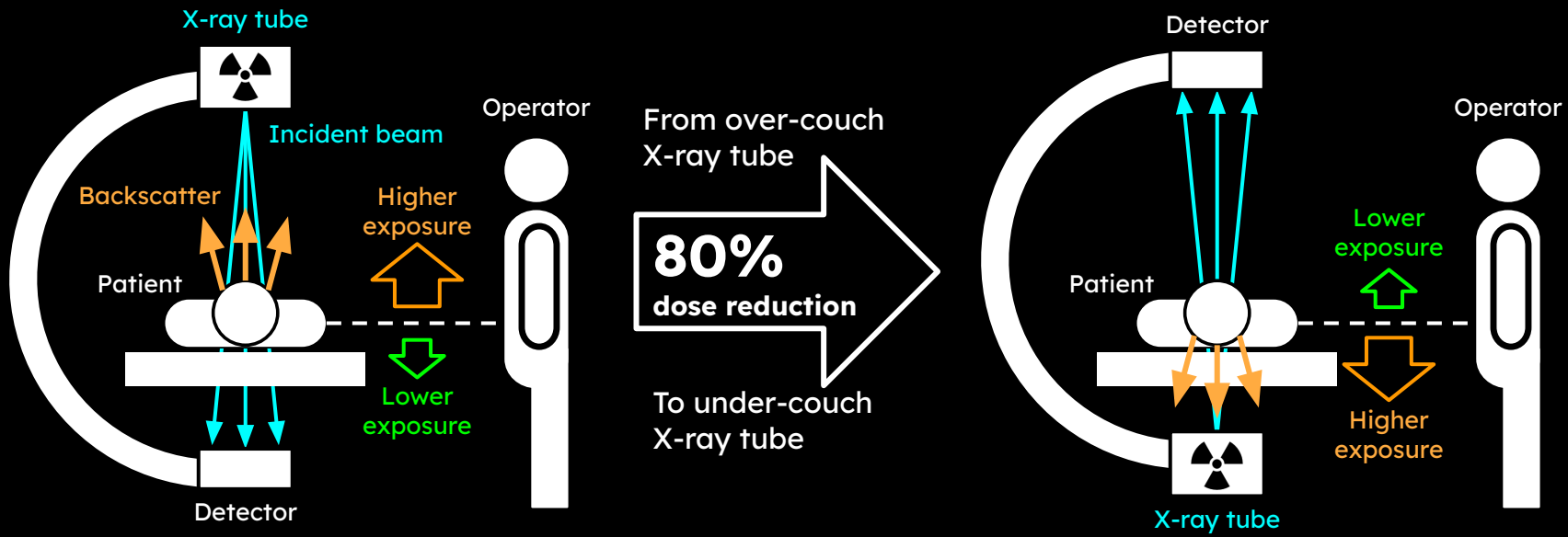


If an area S receives four "rays" at 1 m, it receives only one at 2 m; thus dose falls with distance squared.
Theoretically, increasing distance from 1 m to 2 m reduces dose by 75%, and from 1 m to 3 m reduces dose by 89%.

When the operator is within tens of centimeters of the patient, measured doses can exceed those predicted by point-source geometry because the source of scatter is a broad area of tissue, not a point source. In this case, the inverse-square law is invalid.

General Characteristics of Scattered X-ray

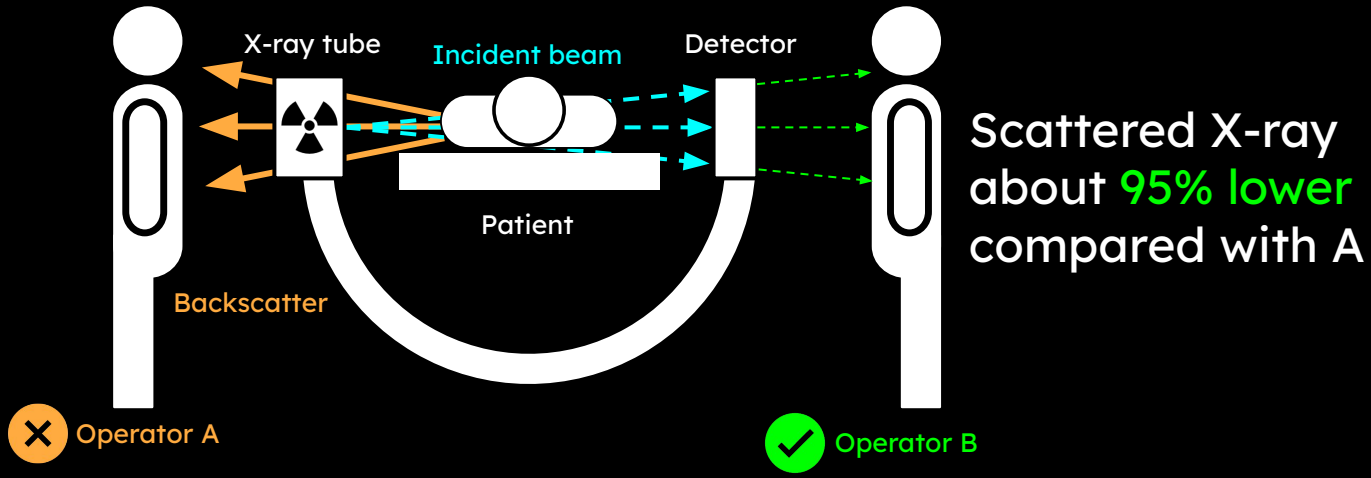
Patient scatter includes backscatter directed opposite the incoming beam.



Occupational exposure arises predominantly from patient-scattered radiation rather than the primary beam. Under typical diagnostic conditions, ≥95% of incident photons are attenuated within the patient (absorbed or scattered back toward the X-ray tube side), whereas only 1-5% transmit toward the detector.
With a C-arm fluoroscopy system, using an under-couch X-ray tube can reduce exposure by approximately 80% compared with an over-couch configuration, according to IAEA TECDOC 1731.

Best Position to Avoid Scattered X-ray

With distance fixed, operator dose is highly position-dependent.



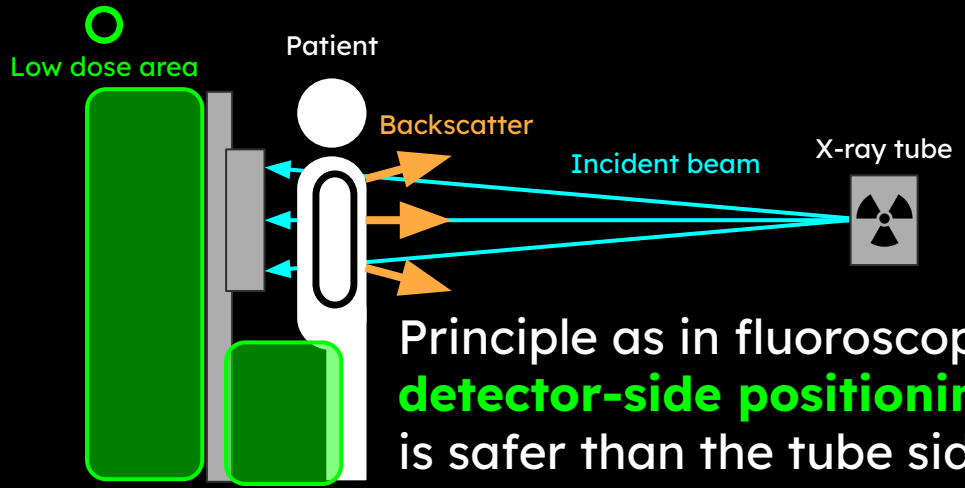
Scattered X-ray about 95% lower compared with A

Stand on the detector side of the fluoroscopy system to reduce avoidable occupational exposure, when possible.

Behavior of Scattered X-Rays During Chest Radiography

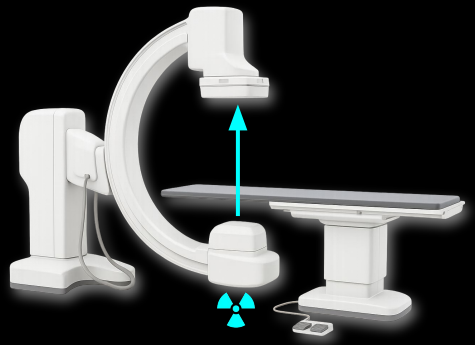
Protective Strategies: Time, Distance, Shielding

For chest radiographs, scatter dose is greater on the X-ray tube side than on the detector side.

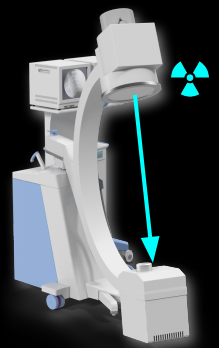


Principle as in fluoroscopy:
detector-side positioning
is safer than the tube side.

Know your equipment



Angiography machine



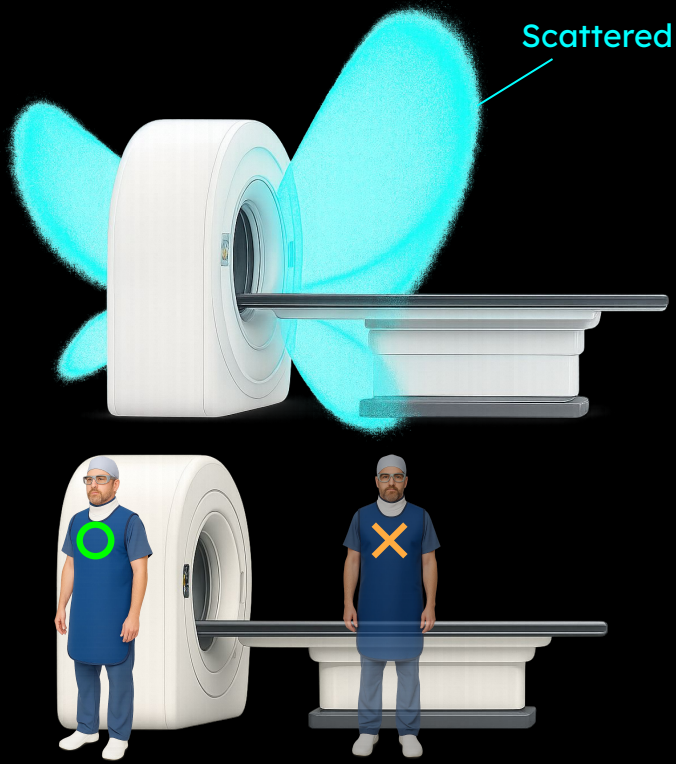
Fluoroscopy machine

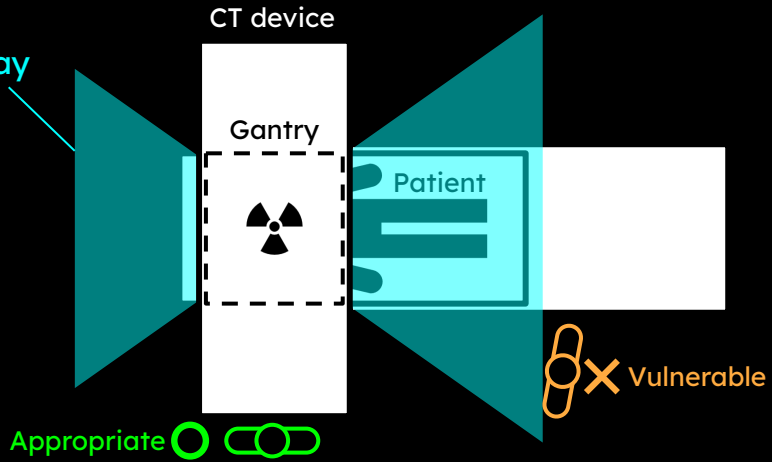
When assisting with diagnostic X-ray imaging, occupational exposure can be minimized by positioning on the detector side. Alternatively, crouching anterior to the patient on the detector side—so that the patient's body is interposed between the operator and the X-ray tube—also reduces scatter dose.

Scatter radiation is strongest backward from the patient where the X-rays enter. Because tube–detector positions differ by system, always confirm their orientation—especially when moving a C-arm.

Behavior of Scattered X-Rays in CT Examinations

Scattered X-rays spread radially in the anterior/posterior directions from the gantry.



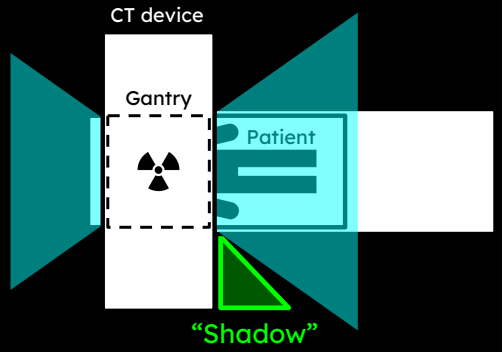


In CT, most scattered X-rays travel forward and backward along the gantry axis, while lateral scatter is limited, resulting in substantially lower dose at the gantry sides. Staff who must stay in the room should position themselves at the gantry's lateral side (e.g., CT-guided biopsy assistants, trainees observing for education).

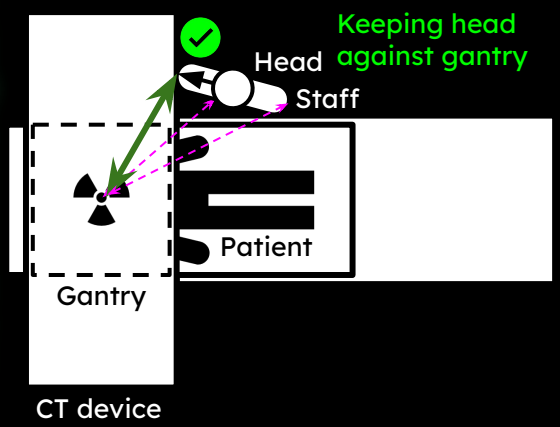
Minimize Occupational Lens Dose during CT Assistance

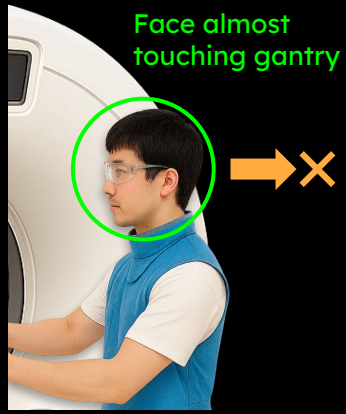
Protective Strategies: Time, Distance, Shielding

If assistance is required during CT scanning, keep your head close to the gantry.



Distance from gantry center	50 cm		62 cm		Close contact	
Eyes	L	R	L	R	L	R
1 cm dose equivalent (μSv)	245	256	137	178	97	42
Reduction rate (%)	Reference value		44	30	60	83

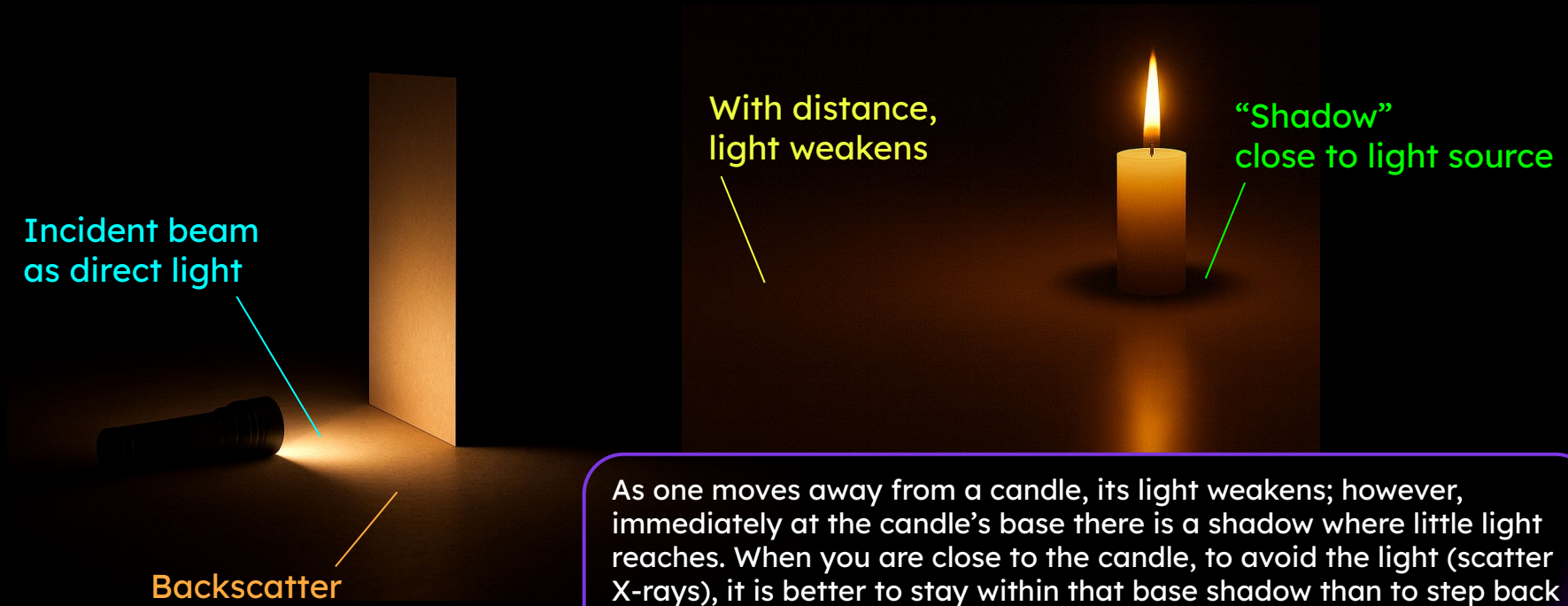




For head CT assistance, slight head repositioning can markedly change lens exposure.
If you stand flush with the gantry's lateral side and keep your feet fixed, keeping your head against the gantry—while staying out of the scan plane—results in less lens dose than pulling your head away; the lateral gantry provides a low-scatter "shadow" that can dominate over the inverse-square benefit.

Visual Explanation

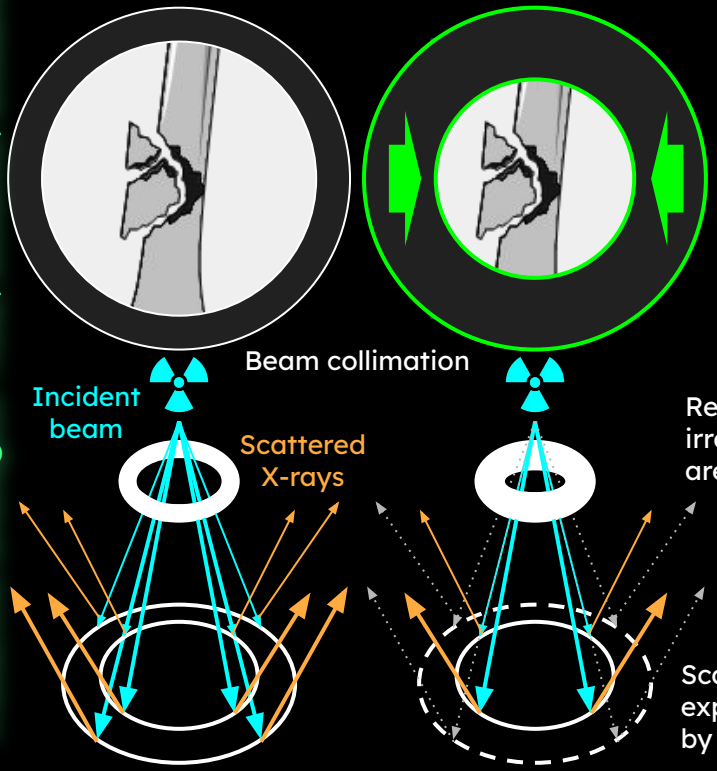
Light and X-rays are both electromagnetic waves and behave similarly.



As one moves away from a candle, its light weakens; however, immediately at the candle’s base there is a shadow where little light reaches. When you are close to the candle, to avoid the light (scatter X-rays), it is better to stay within that base shadow than to step back ineffectively. This is the same principle behind keeping one’s head close to the gantry (outside the scan plane) during CT assistance.

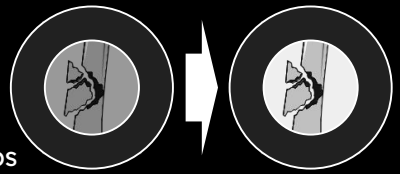
Shielding Effect of Collimation

Optimizing collimation reduces radiation dose to both the patient and healthcare personnel.



Scatter radiation decreases approximately in proportion to the irradiated field area.

With tighter collimation, image receptor brightness decreases because fewer photons reach the detector. Automatic exposure/brightness control (AEC/ABC) typically compensates by modestly increasing tube output. Consequently, halving the irradiated field area reduces scatter dose to approximately—but slightly more than—one half.
The automatic increase is small, and the net dose-reduction from collimation remains dominant.



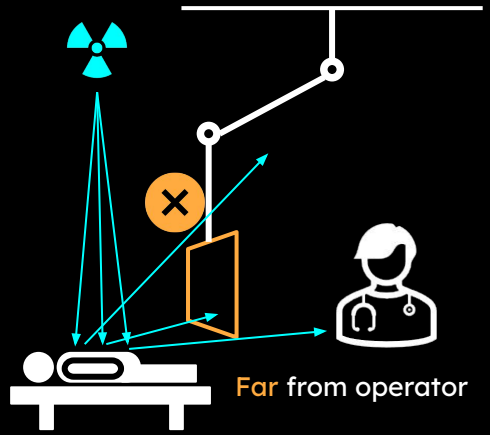
AEC/ABC changes the beam (mA and/or kVp) to keep the picture optimal; when you collimate, it slightly increases output to keep the image bright.

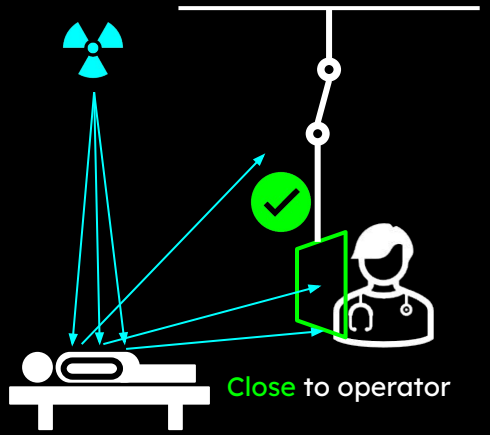
Using Ceiling-Mounted Shields Correctly

Place the shield close to the operator, not the patient or radiation source.



Up to **90%**
dose reduction
if positioned correctly





Ceiling-mounted shields are the most effective protective barriers for reducing radiation exposure to the head including lens.

When correctly positioned, they offer highly effective attenuation; however, improper placement can significantly compromise their shielding efficacy.

- Placing the shield near the patient or radiation source and away from the operator allows more scattered radiation to reach the operator, increasing their exposure dose.
- Incorrect shield positioning can reduce its protective effect by up to 50%.
- The shield should be positioned close to the operator to create a complete shadow.
- This is similar to how one gets wetter in the rain when holding an umbrella high above, whereas holding it closer to the body offers better protection.

Various Types of Radiation-Protective Eyewear

Radiation-protective eyewear is broadly grouped into four main types based on shape.



Front type

A single planar protective lens located only on the anterior aspect.
Typical attenuation ≥0.5 mmPb.



Screen type

A large curved protective lens that covers the anterior and lateral fields of view. To avoid excessive weight, the lens is typically around 0.1 mmPb.



Front and side type

Planar protective lenses on the front and both lateral sides.
Typical attenuation ≥0.5 mmPb, but added lenses increase weight.

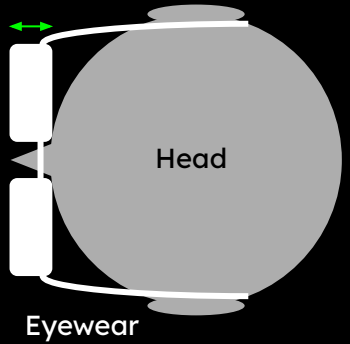


Panorama type

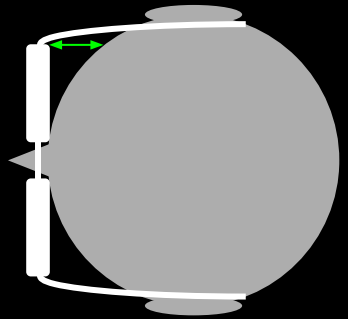
A curved, wraparound lens providing three-dimensional coverage (anterior, lateral, and inferior). Typically <0.1 mmPb, offering light weight.

Three Determinants of Protective Performance

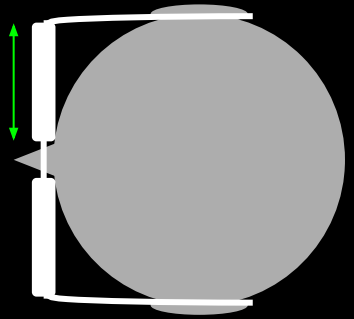
Eyewear efficacy depends not only on Pb-equivalent but also on physical placement.



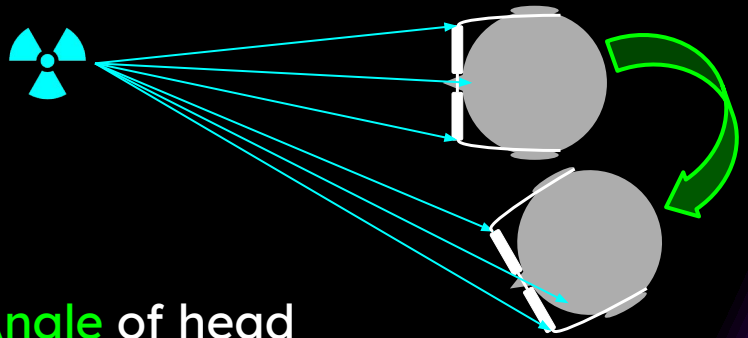
Pb-eq of eyewear



Gap between eyewear and lens



Length of front glass

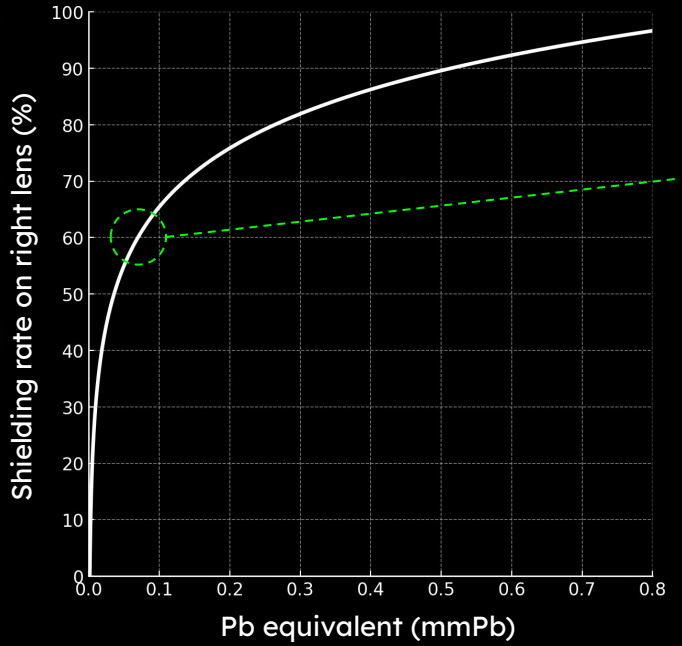


Angle of head

Pb-eq and Eyewear

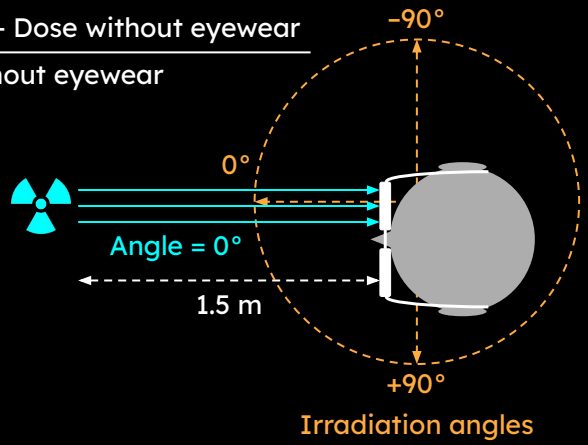
Protective eyewear Pb-equivalent is important, but it is only one factor in overall protection.

The relation between shielding rate (attenuation) and Pb-eq



$$\text{Shielding rate} = \frac{\text{Dose with eyewear} - \text{Dose without eyewear}}{\text{Dose without eyewear}}$$

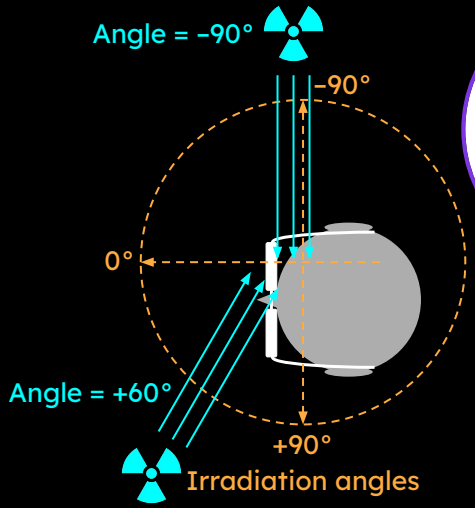
Even with 0.07 mmPb eyewear, a ≥60% reduction can be achieved.



The left panel shows the findings of Hirata et al., obtained with a 120 kVp X-ray beam commonly used in radiology. Using several pairs of protective eyewear with different Pb-eq thicknesses, they measured attenuation. As expected, greater Pb-eq yields higher attenuation; however, beyond a certain thickness, the incremental benefit plateaus, and substantial attenuation is already achieved with eyewear around 0.1 mmPb.

Horizontal Angle of Head Against Irradiation

The horizontal weak points are the gaps at the nose and at the sides.







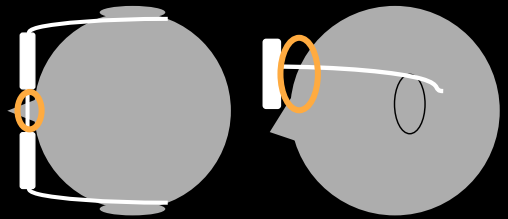
Even with ≥0.50 mmPb shielding, scatter can enter through the nose bridge and side openings.





Shielding is modest (0.07–0.10 mmPb), but the design covers the nose and sides.

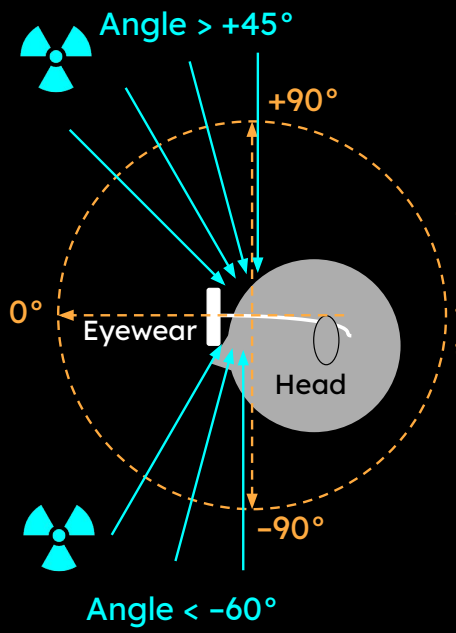
Via nose and side gaps,
attenuation can drop sharply
at specific angles of incidence.

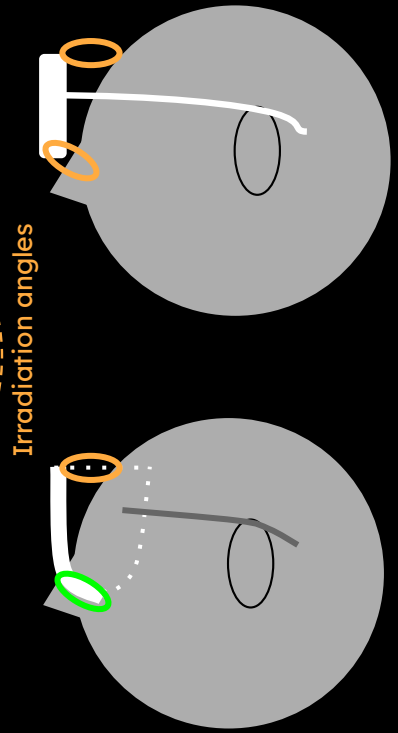


In practice, scatter rarely comes only from straight in front.
Even with a large Pb-eq front shield, it alone does not guarantee consistently high attenuation throughout a procedure across varying angles of incidence.
Nose-bridge and side shields are one of the keys for reliable coverage.

Vertical Angle of Head Against Irradiation

Vertical protection is reduced, though select models can block X-rays coming from below.





Front type eyewear lacks inferior protection.

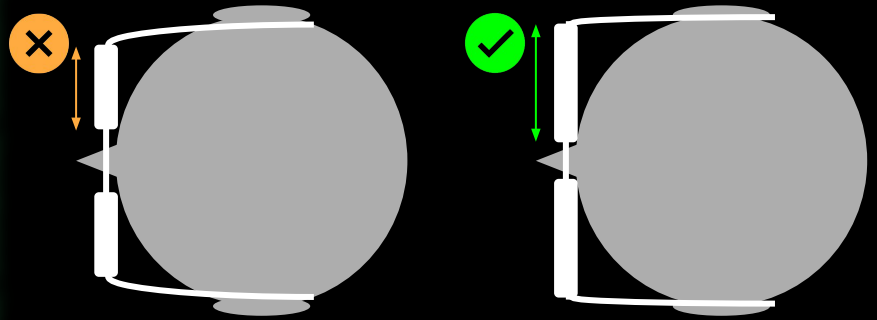
Even eyewear that provides ≥90% attenuation for frontal scatter may afford <30% attenuation for inferiorly incident scatter at −60°, and in some cases nearly 0% at −75°.

Certain eyewear products can block scatter coming from below.

Although panoramic-type eyewear generally has a lower lens lead-equivalent, some products provide ≥80% attenuation for inferiorly incident scatter even at −75°.

Length of Front Glass and Gap Between Eyewear and Lens

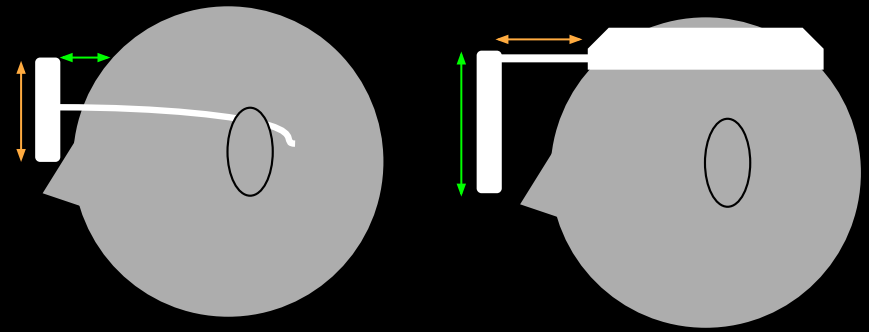
Even with a large anterior lens, attenuation diminishes if gaps are substantial.



Eyewear with a longer top-to-bottom glass generally provides better shielding.



For front-type eyewear with equal Pb-eq, the model with a larger front glass provides better shielding overall, based on angle-integrated performance across −90° to +90°.



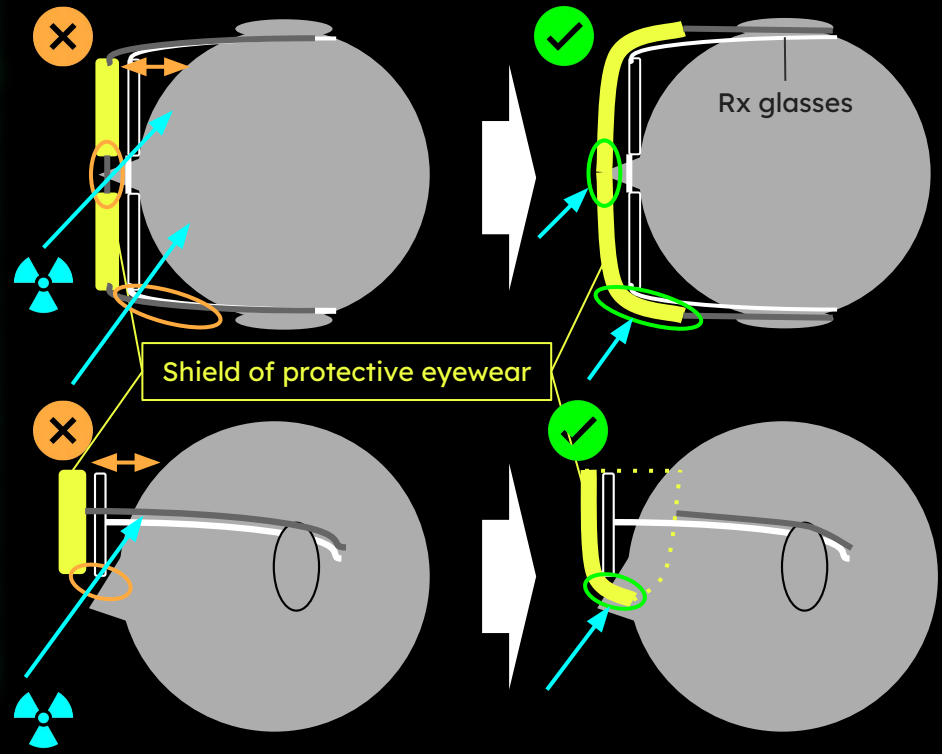
Taller screen-type glass can underperform when eyewear–lens distance is large.



With screen-type glasses, shielding in the horizontal plane is not degraded at the nose gap. However, the bigger gap between eye lens and eyewear can make protection from below worse than with front-type models.

Using Radiation-Protective Eyewear over Rx Glasses

Wearing eyewear over Rx glasses requires careful shape selection to preserve protection.



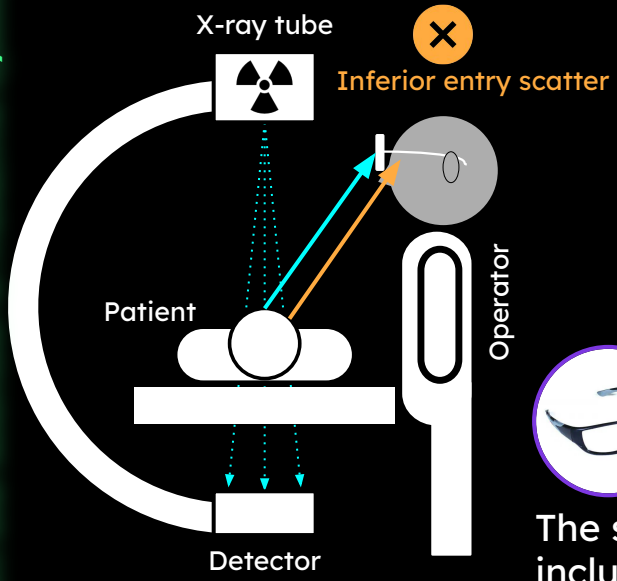
Choose **gap-filling designs**, because **prescription glasses** make the **eye-shield gap enlarged.**

Increasing eye-shield distance from 0.5 cm only to 1.5 cm **reduces efficacy** by roughly **40%.**

Wearing protective eyewear over prescription glasses pushes the shield farther from the eyes, so scatter can leak in at the nose, sides, and from below.
Since a perfect face seal is impractical, pick a design that fills those gaps. Still, design has limits—combine this with proper head position discussed later and other protections based on time, distance and shielding.

Moving Your Head to Protect Crystalline Lens

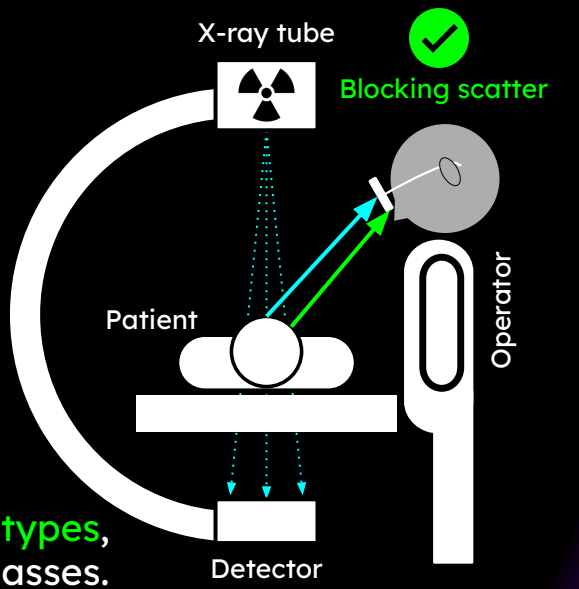
How well scatter from below is blocked depends on how the operator holds their head.



To mitigate leakage from the eye–eyewear gap,
keep the front shield facing the patient
so the shield meets the incoming scatter.



The strategy is effective for all eyewear types, including over gap-prone prescription glasses.



Depending on the eyewear design and operating conditions, the crystalline lens may be left unprotected against inferiorly incident scatter. Therefore, during X-ray emission, it is advisable to maintain a slightly downward head position and keep the gaze toward the patient so that the frontal shield faces the scatter source.

Reasons for the Low Usage Rate of Lead Glasses

Even in specialties with high lens exposure, the rate of protective eyewear usage remains low.

Usage rate of protective eyewear

In Japan

ERCP
35%

Interventional Radiology
75%

Orthopaedic
12-38%

In the U.S.

ERCP
33.4%

Interventional Radiology
54%

Orthopaedic (residents)
21%

Compared with other fields, interventional radiologists tend to wear protective eyewear more often.

Reasons of low usage rate

Insufficient availability of protective eyewear within institutions, e.g. not routinely available or only available at personal expense.

Suboptimal ergonomics—devices are heavy, prone to fogging, and uncomfortable.

Inadequate education and **training** in radiation protection.

Deficient dose monitoring/management leading to underestimation of cataract risk.

Organizational and **cultural barriers** to promoting usage.

How to Improve Usage Rate of Lead Glasses

Personal ownership of protective eyewear resolves both shortage and discomfort.



Almost every physicians/nurses possess a personal stethoscope.



Likewise, staff who work with radiation should have their own pair of protective eyewear.

✕

There are instances in which facility-supplied protective eyewear is insufficient in number.

A contributing factor to low wearing rates is "discomfort," which in part stems from facility-issued eyewear that does not meet individual users' needs.

✓

Eliminates access barriers when facility stock is unavailable, ensuring wearability at all times.

Optimized fit and comfort by selecting frames suited to one's facial anatomy and to whether prescription spectacles are worn.

Customization (e.g., anti-fog coatings/solutions, fit adjustments) is straightforward because the device is personally owned.

How to Improve Usage Rate of Lead Glasses

Higher lead-eyewear use requires system-level rules, not individual awareness alone.

Eyewear use varies by institution/department.

Accordingly, there is a need to standardize institutional policies nationally and internationally.

One way is to introduce pre-procedure briefings —akin to those standardized for surgery— for radiological procedures.



Radiology technicians visually verify the use of personal protective equipment among all participating staff before procedure and encourage them to wear it if they were not wearing it on site.

In one single-institution study, pre-procedure briefings increased eyewear compliance from 37% to 97%, with concurrent improvements in the use of other protective gear and personal dosimeters.

Summary and Answers to the Questions (Q1-Q3)

Conclusion



Q1 **How much more radiosensitive is the lens than other organs, and why?**
The crystalline lens is comparably radiosensitive to bone marrow and the gonads. Owing to its avascular, low-turnover environment, damaged lens epithelial/fiber cells are not shed and persist for life, allowing injury to accumulate.

Q2 **How do radiation cataracts differ from age-related cataracts clinically?**
Radiation cataracts have more posterior subcapsular (PSC) changes. PSC cataracts typically progress faster and impair vision earlier than common age-related nuclear/cortical types. Radiation exposure can also accelerate onset when superimposed on age-related changes.

Q3 **Which procedures deliver the highest lens dose, how many are safe per year, and how much do protections reduce that dose?**
Within IR, neurovascular embolization yields among the highest lens doses; in worst-case conditions, 20 mSv can be reached after only a few procedures. Outside radiology, ERCP and orthopedic fluoroscopy also produce substantial exposure, and eyewear adherence is generally lower than in IR—an additional risk factor.

Summary and Answers to the Questions (Q4-Q6)



Conclusion

Q4 **For students and residents with brief, intermittent exposure, is it acceptable to forgo protections under current literatures?**

Under unfavorable conditions—IR or non-IR—a single procedure can deliver several mSv (up to ~10 mSv) to the lens, so exceeding ICRP annual limits cannot be excluded. Although trainees are unlikely to approach the 0.5 Gy threshold, recent literature reports risk at ≤0.1 Gy and stochastic-like behavior, supporting strict eye protection from the student/resident stage.

Q5 **When staff must be near the patient for fluoroscopy, radiography, or CT, where should they stand—besides "farther away"—to keep lens dose as low as possible?**

Positioning matters: for fluoroscopy, stand on the detector side; for radiography, behind and inferior to the detector; and for CT, along the gantry's lateral sidewall. When assisting with head support in CT, keeping the head close to the gantry (outside the scan plane) can exploit a "shadow" effect that reduces lens dose.

Q6 **Which eyewear shapes and specifications work best, what precautions matter, and how can we boost routine use?**

Weak points of protective eyewear include lateral gaps, the nasal bridge, and the lower rim—especially when worn over prescription glasses. Choose designs with side shields, nasal coverage, and a sealed lower rim; orient the face toward the patient (scatter source) to limit upward/oblique entry. Improve adherence by ensuring sufficient inventory or promoting personal ownership, and by using pre-procedure prompts.

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