**Radiation and cataract**

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Cataract is clouding of the eye lens. The lens is made up of mainly water and protein. Over time, protein can build up, clouding the lens and obstructing and diffusing the light passing through the eye. This makes lens sight blurred or fuzzy which cannot be corrected by wearing glasses. Although most cases of cataract are related to the aging process, occasionally children can be born with the condition, or a cataract may develop after eye injuries, inflammation, and other eye diseases.

Cataract (not related to radiation) is the most frequent cause of blindness worldwide. There are several risk factors, including exposure to sunlight, ionizing radiation, alcohol and nicotine consumption, diabetes and systemic use of corticosteroids.

1. [Which part of the eye does cataract affect?](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CAT_FAQ01)
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12. [How efficient are personal protection tools?](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CAT_FAQ12)
13. [Is there a risk of cataract after several years of work in a catheterization laboratory?](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CAT_FAQ13)
14. [What are the typical eye lens doses associated with diagnostic and therapeutic interventional procedures?](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CAT_FAQ014)
15. [How can eye lens dose be measured more effectively?](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CAT_FAQ015)
16. [Is there a correlation between staff eye lens doses and patient dose?](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CAT_FAQ016)

**1. Which part of the eye does cataract affect?**

There are three predominant forms of cataract depending on their anatomical location (Fig.1) in the eye lens: cortical, nuclear and posterior sub-capsular (PSC). As a person ages, any one type, or a combination of any of these three types, can develop over time. The most common type of age-related cataract, caused primarily by the hardening and yellowing of the lens over time, is "nuclear" cataract. “Nuclear” refers to the central portion of the lens, called the nucleus. "Cortical" refers to the lens cortex, which is the peripheral (outside) edge of the lens. "Posterior" is the back surface of the lens and "subcapsular" because it is beneath the lens capsule, which is a small "sac", or membrane, that encloses the lens and holds it in place.

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| --- | --- |
| [Eye Lens](https://rpop.iaea.org/RPOP/RPoP/Resources/images/content/img-catract.jpg) | [Cataract](https://rpop.iaea.org/RPOP/RPoP/Resources/images/content/img-catract1.jpg) |

Figure 1. Figure showing location of the lens of the eye (left) and different parts in the eye lens (right).

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**2. Is cataract caused by ionizing radiation different from that caused by age?**

Yes, but not exclusively. Ionizing radiation is generally (but not exclusively) associated with posterior sub-capsular and sometimes cortical opacities. Historically, PSC opacification was thought to be a characteristic of the radiation damage to the lens, although more recent data suggest that radiation induced opacities can be found in the lens cortex as well. Various studies have found that nuclear cataracts are not associated with radiation exposure. Age related cataracts are most commonly found in the nuclear region and cortical cataracts are commonly found in diabetic patients.

Cataractogenic radiation damage starts at the anterior surface, where dividing cells form a clear crystalline-protein fiber that migrates toward the posterior pole of the lens, the posterior subcapsular (PSC) region. Radiation damage (by multiple mechanisms) results in aberrant crystalline protein folding and dysregulation of lens cell morphology. This PSC opacification was thought to be the only typical lesion related to radiation damage to the lens, but recent data suggest that radiation induced opacities can be found in the lens cortex as well. It is important to note that many other confounding risk factors contribute to lens opacities, for example, age, diabetes mellitus, corticosteroids use, smoking or ultraviolet radiation exposure.

Although much work has been carried out in this area, the exact mechanisms of radiation cataractogenesis are still not fully understood [ [AI](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#AI); [KL](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#KL)].

Age related cataract is primarily caused by gradual clouding, hardening and yellowing of the lens over time. Changes in the water content of the lens fibers create clefts, or fissures, that look like the spokes of a wheel pointing from the outside edge of the lens in toward the center. These fissures can cause the light that enters the eye to scatter, creating problems with blurred vision, glare, contrast, and depth perception.

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**3. Is it possible to diagnose radiation-induced eye lens injuries?**

Yes, by use of a slit lamp and observing the eye after dilation. The possible approach includes scoring of posterior sub-capsular opacities, even those that have not yet progressed to cause significant visual disability. If there is absence of other known risk factors for lens opacity, then a causal relationship between such lens opacification and X ray exposure could be concluded.

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**4. Is there a unique system of classification of radiation induced opacities?**

No, but there is reasonable understanding that the Merriam-Focht criteria that allow scoring radiation-induced opacities are acceptable. In the past, the LOCS (Lens Opacities Classification System) in its various versions has been widely used by ophthalmologists; however, it needs further standardization to achieve interobserver agreement [ [MF](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#MF); [RE](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#RE); [CH1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CH1)].

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**5. How to treat cataract?**

The only way to treat cataract is by surgery. This involves removing the opacified lens, leaving the capsule that contains it intact. A plastic lens is inserted and, therefore, there is no need to wear special glasses after the operation. Surgery is only indicated when lens opacity progresses to a stage to cause visual disability.

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**6. How much radiation dose to the eye lens is necessary for the production of radiation injuries?**

A number of studies in the last decade indicate that there is risk of lens opacities at doses below 1 Gy and the threshold may range from none to 0.8 Gy [[NA](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#NA); [NE](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#NE); [WO](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#WO)]. However, the International Commission on Radiological Protection ([ICRP) has recently accepted the threshold of 0.5 Gy](http://rpop.iaea.org/RPOP/RPoP/Content/News/ICRP-statement-threshold-eye-lens.htm).

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**7. How soon after a radiation exposure can one expect to see radiation-induced eye lens injuries?**

Many years or decades could pass before radiation-induced eye lens injuries become apparent. At relatively high exposures of few Gy, lens opacities may occur within a few years; however, at lower doses and dose rates (< 1 Gy), lens opacities may occur after many years. The duration of the latency period is inversely dependent on dose [[CH2](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CH2); [MI](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#MI); [NA](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#NA); [NE](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#NE); [WO](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#WO); [HS](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#HS); [BL](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#BL)].

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**8. Is there a specific dose limit for eyes?**

Yes, there is. In a recent [statement](https://rpop.iaea.org/RPOP/RPoP/Content/News/ICRP-statement-threshold-eye-lens.htm), ICRP now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv.

Previously, according to, the annual dose limit for lens of the eye was 150 mSv in terms of equivalent dose. The threshold for deterministic effects was considered to be 5 Sv for chronic and 0.5-2.0 Sv for acute exposures.

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**9. Which health professionals are at risk of radiation induced eye lens injury?**

Many of them: interventional cardiologists, interventional radiologists, also possibly other doctors using fluoroscopy in operating theatres and paramedical personnel who remain close to the patient during the procedure. These individuals may be within a high-scatter X radiation field for several hours a day during procedures. The risk for eye lens injuries is particularly high for high workloads unless suitable protective tools and proper operational measures are not used.

Further details about eye lens radiation dose management are

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**10. Which factors can affect eye lens dose in fluoroscopy procedures?**

There are many factors that can be patient, equipment or practice related.

Patient related factors are:

* complexity of clinical problem (fluoroscopy time and number of images)
* size of the patient.

Equipment related factors are:

* geometry-position of the X ray tube (undercouch/overcouch)
* use of biplane systems and performance characteristics of X ray system, including the settings of dose in the machine done by local engineer

The scatter radiation distribution in overcouch systems is such that radiation dose to the lens of the eye may be relevant if eye protection is not utilized. Therefore, the use of undercouch systems is recommended in addition to personal protective devices for staff.

Practice related factors are:

* use of protective devices
* (position vs. X ray tube and patient, projections used, exposure setting, collimation, catheter insertion site, etc.)
* workload and physician’s experience and skill [ [MA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#MA1); [VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1); [RE](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#RE)].

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**11. How can I manage eye lens exposure and prevent eye lens injuries?**

[Best practice](https://rpop.iaea.org/RPOP/RPoP/Content/Documents/Whitepapers/poster-staff-radiation-protection.pdf) includes the use of celling suspended screens, wearing leaded glass eyewear, positioning of the X ray tube below the table as far away from the patient as possible and positioning oneself as far away as clinically possible from the X ray tube and patient.

Maintaining X ray equipment in optimum operating condition, using pulsed fluoroscopy, minimizing fluoroscopy time, limiting radiographic images, collimation and reduced use of magnification will help reduce X ray exposure to staff as well as to patients. Anything that increases the amount of radiation exposure e.g. longer fluoroscopy times, more radiograph images generated, proximity to the radiation source, positioning the X ray source above the patient, and a person’s closeness to the patient will increase the radiation dose and potential risk from ionizing radiation.

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**12. How efficient are personal protection tools?**

Currently available protective measures and devices (lead glass screens and eye wear) are quite effective and practical for day-to-day use. Proper and regular use of these radiation protection tools is among the most efficient ways to manage eye lens dose and prevent lens injuries.

Use of leaded glasses alone reduced the lens dose rate by a factor of 5 to 10; scatter-shielding screens alone reduced the dose rate by a factor of 5 to 25. Use of both simultaneously is even more efficient than either used alone, reducing the dose rate by a factor of 25 or more. Available estimation on effectiveness of protective devices indicates that their appropriate use can lead to situations where radiation cataract risk in interventional medical procedures may be effectively controlled. The use of protecting tools can and should be extended to include other staff members in the interventional room, such as nurses or technicians and, where applicable, the anesthetist [[DA](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#DA); [KI](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#KI); [RE](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#RE); [VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1)].

Results from recent demonstrated a dose dependent increased risk of posterior lens opacification for interventional cardiologists and nurses when radiation protection tools were not utilized [[VA2](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA2), [CI](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#CI)].

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**13. Is there a risk of cataract after several years of work in a catheterization laboratory?**

If radiation protection devices (most importantly protective screens or lead glass barriers) are not used, then the answer is yes, there is. If radiation protection devices and techniques are properly used, one can keep radiation dose to eye lens below the threshold.

Another point is whether radiation-associated minor opacities progress to become vision-impairing cataracts. Most of the data on this question suggest that a fraction of them progress and earlier high-dose studies suggest that the rate of progression may be dose-related.

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**14. What are the typical eye lens doses associated with diagnostic and therapeutic interventional procedures?**

Available typical values in terms of equivalent dose to the lens of the eye per procedure are presented in Table 1 below:

**Table 1.** Typical eye lens doses for various X ray procedures

|  |  |  |
| --- | --- | --- |
| **Procedure** | **Eye dose (mSv)** | **Remark** |
| Hepatic chemoembolization [[VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1)] | 0.27-2.14/0.016-0.064 | Depending on examination technique and distance from isocenter, unshielded/shielded |
| Iliac angioplasty [[VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1)] | 0.25-2.22/0.015-0.066 | Depending on examination technique and distance from isocenter, unshielded/shielded |
| Neuroembolization (head, spine) [[VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1)] | 1.38-11.20/0.083-0.329 | Depending on examination technique and distance from isocenter, unshielded/shielded |
| Pulmonary angiography [[VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1)] | 0.19-1.49/0.011-0.045 | Depending on examination technique and distance from isocenter, unshielded/shielded |
| TIPS creation [[VA1](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA1)] | 0.41-3.72/0.025-0.112 | Depending on examination technique and distance from isocenter, unshielded/shielded |
| Cerebral angiography [[MA2](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#MA2)] | 0.014 | Shielded |
| CA and PTCA [[EF](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#EF)] | 0.013 | With screen |
| CA and PTCA [[VA3](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#VA3)] | 0.294 | Unshielded |
| EVAR [[HO](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#HO)] | 0.010 | Unshielded |
| Urology [[SA](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#SA)] | 0.026 | Unshielded |
| Orthopedic [[TS](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#TS)] | 0.050 | Unshielded |
| HSG [[SU](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#SU)] | 0.22 | Unshielded |
| ERCP [[OL](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#OL)] | 0.094-0.340 | Undercouch X ray tube |
| ERCP [[BU](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#BU)] | 2.8 | Overcouch X ray tube |

As per reported results, eye lens doses vary considerably. Depending on the method used for dose assessment, use of protective tools and applied working practice, eye lens doses per procedure range from 10 µSv to few mSv. The highest values are related to the overcouch X ray tube geometry and the absence of ceiling suspended screens and glasses.

Unfortunately, there is little useful dosimetry or information on workplace practices relative to ocular exposures of interventional physicians or paramedical personnel during such procedures. As an example, in during various radiation protection training courses, in which cardiologists from over 56 countries participated, responses indicated that only 33%–77% of interventional cardiologists used radiation badges routinely.

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**15. How can eye lens dose be measured more effectively?**

At present, there is no dosimeter specifically designed for routine eye lens monitoring, although the crucial issue is the actual radiation dose to the lens. It is difficult to find reliable dose monitoring data that can provide an accurate estimation of the dose to the eye lens. Direct monitoring of eye dose, for example by use of small semi-conductor detectors clipped onto spectacles, is an ideal approach, but there is currently dearth of data on this method.

In theory, to monitor the eye lens dose, the operational quantity Hp (3) is the most appropriate one as the lens is covered by about 3 mm of tissue. However, this quantity is not commonly in use and respective dosimeters are rarely available. Fortunately, it could be shown that dosimeters designed to measure superficial dose Hp(0.07) are able to sufficiently well estimate the eye lens dose due to photon radiation [].

However, personal dosimetry varies widely among countries. Some countries require the use of a dosimeter outside the apron, whereas others place the device inside the apron. This difference notwithstanding, the literature suggests staff in cardiac catheterization laboratories and interventional suites may not always use personal dosimetry regularly, making retrospective dose estimates, especially those examining cumulative effects of many years of exposure [[GU](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#GU); [RE](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/6_OtherClinicalSpecialities/radiation-cataract/index.htm#RE)].

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**16. Is there a correlation between staff eye lens doses and patient dose?**

Yes, recent studies have established the correlation between dose to lens and dose for the patient in terms of kerma-area product (PKA). Using this correlation, a factor for estimating lens dose without measurements could possibly be found. PKA may be useful as a surrogate measure of eye lens dose to operator if measured dose using eye dosimeter is unavailable. Typically, 1 Gy∙cm2 to the patient resulted in an average of 10 μSv to the unprotected eyes of the primary operator or 1 μSv when protective ceiling suspended screens (without glass eyewear) are used.

However, owing to differences in geometry, X ray equipment, use of protective devices and experience and skill of the operator, all of which strongly influence radiation dose to the operator, it is not straightforward to link patient dose and operator eye lens dose. Therefore, further investigations in this area are needed.

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