Cataract Development in Vascular Intervention

An analysis of risk and the appropriate preventive measures.

BY KEVIN SEALS, MD; HARRY TRIEU, BS; STEPHEN KEE, MD; AND EDWARD WOLFGANG LEE, MD, PHD

The lens is a highly radiosensitive tissue that is susceptible to cataract development when exposed to radiation. Radiation exposure is associated with posterior subcapsular cataracts, an uncommon cataract type that often develops secondary to diabetes or the use of systemic corticosteroids.[1] A point of contention in the literature is whether radiation-induced cataractogenesis is a stochastic or deterministic phenomenon. Researchers have historically believed that radiation-induced cataracts form deterministically, above a certain exposure threshold dose, and with damage to multiple cells.[2] New data suggest that cataracts may form stochastically, however, without a threshold dose and potentially in response to the damage of a single cell.[3] If cataracts develop deterministically, increased exposure levels will result in more severe cataracts. Conversely, if cataracts develop stochastically, dose will influence the probability but not the severity of cataract development. A stochastic mechanism is of interest because it suggests that any radiation dose, however low, has some potential to induce cataractogenesis.

The lens of an interventionist is exposed to radiation primarily due to scatter from the patient, and these lens exposure doses are significant.[4] Despite the need for excellent stereotactic vision in interventional work, interventionists often pay little attention to basic lens protection practices. Data show that leaded eyeglasses are worn by < 30% of operators, and dosimeter use is inconsistent.[5,6] Interventionists may be reluctant to practice basic lens protection due to the discomfort associated with leaded eyeglasses or a lack of radiation safety knowledge.[7] Of note, educational endeavors in radiation safety have been shown to both increase leaded eyeglass use and decrease interventionist dose, highlighting the utility of and need for educational materials.[8,9]

This article explores radiation-induced cataractogenesis from the perspective of the interventional physician. We discuss the data linking radiation exposure and cataract development, the lens dose typical of various procedures, and our latest understanding of the optimal techniques for lens protection. We will use this analysis to reach general conclusions of utility to the interventional physician.

RADIATION EXPOSURE AND CATARACT DEVELOPMENT

A significant body of literature has established a link between radiation exposure and cataract development in interventional physicians. One study found that posterior subcapsular opacities are three times more common in interventional cardiologists than the general unexposed population, although increased risk was not seen in interventionists wearing leaded eyeglasses at least 75% of the time.[7] These posterior subcapsular opacities, which represent an intermediate stage in cataract formation that occurs prior to the development of symptomatic cataract, suggest a significant cataractogenesis risk. The Retrospective Evaluation of Lens Injuries and Dose (RELID) trial consisted of multiple studies and offered further support for cataract risk in interventional work.[10-13] In all RELID studies, interventionists had a significantly increased risk of posterior lens opacification relative to a control group without prior radiation exposure. Two of these studies showed increased cataract risk with increased total lens dose, and one found that physicians with opacities had more years of work experience and less use of dosimetry, leaded eyeglasses, and protective screens.[12,13] The latter study also revealed a positive correlation between lens dose and cataract severity.

In conjunction with decades of research across diverse populations linking radiation exposure and cataracts, these data provide convincing evidence that interventional physicians are at risk of cataract development. However, the current data have some limitations, most notably, relatively small sample sizes and a reliance on operator recall to quantify past radiation exposure. In the future, larger prospective trials using dosimetry for dose quantification will be essential for refining our understanding of cataract risk in interventional physicians.

QUANTIFYING LENS EXPOSURE

A large and growing body of literature quantifies radiation dose, particularly in interventional procedures. A useful lens through which to view radiation dose data are the International Commission on Radiological Protection (ICRP) guidelines, which define occupational limits for radiation exposure created by an international panel of radiation safety experts. The ICRP guidelines state that cataracts may develop above a threshold cumulative absorbed dose of 0.5 Sv. Further, they recommend an annual occupational dose limit of 20 mSv to minimize the risk of cataract development.[14]

The Optimization of Radiation Protection of Medical Staff (ORAMED) study offered a rich source of data describing lens dose in interventional radiology procedures, quantifying the dose for nearly 1,300 procedures across 34 institutions.[15] The highest lens dose was seen during embolization, with a mean of 60 µSv per procedure; however, the procedures studied displayed wide dose variability, and most were associated with doses approaching 1 mSv in some cases. The ORAMED study also analyzed lens dose for 16 operators, finding that 37.5% met or exceeded the ICRP occupational dose limit. In another publication from ORAMED, two operators were analyzed, and both were found to exceed the ICRP dose limit at annual doses of 49.3 and 71.6 mSv/year, respectively.[16]

Research by Hidajat et al found that high operator lens doses are associated with the transjugular intrahepatic portosystemic shunt (TIPS) procedure.[17] According to this study, physicians performing 50 TIPS procedures annually would exceed the ICRP dose limit, even when ceiling-suspended screens are used for lens protection. Another study used a phantom to estimate operator lens dose in a variety of procedures, finding the highest doses in cranial neuroembolization (11.2 mSv), spinal neuroembolization (11 mSv), and TIPS (3.72 mSv).[18] Given a standard workload of three to five procedures per day, these data suggest that operators likely exceed the cataract dose limit if lens protection is not used. In addition, this study highlighted the wide variability in lens dose between different fluoroscopic systems, finding that dose varied from 0.37 to 2.44 mSv/hr across seven systems. Dose rate also varied substantially between projections, with the highest doses in left anterior oblique 90° and the lowest doses for the right anterior oblique 30° and anteroposterior projections.

In general, these results highlight the potential for cataract induction in a standard interventional radiology workload. A number of procedures result in particularly high lens exposure, including embolization, vertebroplasty, and TIPS. Dose variability within and across studies is high, often exceeding an order of magnitude. This variability likely relates to factors such as case complexity, operator experience, operator height, patient body habitus, imaging technique, and shield use and placement strategy. The data presented here are most useful in that multiple studies predict a lens dose that approaches or exceeds the ICRP dose limit for cataract formation. It is thus critical that radiologists utilize lens protection and perform careful dosimetry to quantify the dose characteristics of their own clinical practice, finding the position of their own practice setting in the wide range of doses that can characterize a particular interventional procedure.

TECHNIQUES FOR MINIMIZING LENS EXPOSURE

Various techniques can be used to minimize radiation exposure to the physician and support staff during interventional procedures. In this section, we review these approaches and the available data, quantifying the protection they offer.

Leaded eyeglasses represent a fundamental technique for lens protection. Research has shown great variability in the protection afforded by leaded glasses, however, with dose reduction across studies ranging from 35% to > 95%.[19] The level of protection provided by eyeglasses has been found to relate to both radiation angle and eyeglass geometry. One study showed that thicker eyeglasses result in better protection when an operator directly faces the radiation source, whereas a larger, thinner lens offers superior protection when an operator is positioned at increasing angles to the source.[20] In general, the effectiveness of eyeglasses is believed to relate to the fit between a particular eyeglass model and the facial anatomy of the operator, with radiation reaching the lens through gaps created between the glasses and the operator's face.[21] An understanding of this phenomenon can be used to optimize eyeglass design and assist interventionists in eyeglass selection. Although leaded eyeglasses offer an imperfect means of lens protection, data have consistently shown that they offer a significant benefit, including a study revealing a lower rate of cataractogenesis in interventionists when eyeglasses are used consistently.[7]

Ceiling-suspended leaded shields offer another form of lens protection that has generally been found to be superior to that of leaded eyeglasses.[19,22,23] Further, these shields provide protection without the discomfort and inconvenience of wearing eyeglasses. Usage of ceiling-suspended shields has been found to reduce radiation to the left and right eye by a factor of 5.7 and 4.8, respectively.[22] Another study found that shielding reduces lens dose by 98%.[16] Of note, however, the effectiveness of shielding can vary based on the position of the shield. In one study, dose reduction ranged from approximately 20% to 80% depending on shield position.[24] The shield provided optimal protection when abutting the patient and placed adjacent to the access point. Inferior protection was seen when the shield was placed above the patient or moved away from the access point toward the source. Although shielding clearly lowers dose, shield use can be inconvenient and obstructive, and it may not be possible in some procedures due to space constraints.

Radiation-absorbing surgical drapes may also provide effective lens protection. Studies across a variety of interventional procedures have demonstrated that these drapes reduce operator lens dose in a statistically significant manner.[24-27] One study showed that drapes provide significant protection against radiation not blocked by ceiling-suspended shields.[28] Drapes do incur an additional per-procedure cost, although this cost is relatively trivial at $39 USD per drape.[29] There is theoretical concern that, in some positions, the drapes may obstruct the primary beam and cause increased lens dose via automatic brightness control feedback, although this has not been demonstrated in the literature.[27]

A number of other techniques have shown promise in lens dose reduction. Data suggest that formal training in radiation safety and proper dosimeter use reduces lens exposure.[8,9] In addition, a promising general protection technique is the development of improved fluoroscopy systems that use novel hardware and image processing algorithms to substantially reduce patient and operator radiation dose.[30,31] These techniques will likely offer substantial reductions in lens dose as they are further refined. As previously detailed, various approaches offer substantial lens protection. Further research is needed to determine the optimal means of lens protection, both in minimizing lens dose and maximizing operator comfort and function.

CONCLUSION

This literature review allows us to reach a number of important general conclusions. First, radiation-induced cataractogenesis may be stochastic rather than deterministic, and any lens exposure may have associated cataract risk. Next, a wealth of evidence suggests that interventional work increases the risk of cataract development and that standard interventional radiology workloads have the potential to deliver lens doses exceeding the ICRP occupational dose limit. Given the immense variability in per-procedure lens dose, physicians should monitor their own exposure using an above-apron dosimeter. Furthermore, protective measures should be routinely used, including leaded eyeglasses in all cases and protective screens when feasible. Given the data suggesting that radiation safety compliance is poor due to an insufficient understanding of risk, we hope that this article will increase awareness and result in heightened efforts for lens protection. ■

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Kevin Seals, MD
Radiology Resident
Division of Interventional Radiology
Department of Radiology
UCLA Medical Center
David Geffen School of Medicine at UCLA
Los Angeles, California
Disclosures: None.

Harry Trieu, BS
Medical Student
Division of Interventional Radiology
Department of Radiology
UCLA Medical Center
David Geffen School of Medicine at UCLA
Los Angeles, California
Disclosures: None.

Stephen Kee, MD
Professor of Radiology
Division of Interventional Radiology
Department of Radiology
UCLA Medical Center
David Geffen School of Medicine at UCLA
Los Angeles, California
Disclosures: None.

Edward Wolfgang Lee, MD, PhD
Assistant Professor of Radiology
Division of Interventional Radiology
Department of Radiology
UCLA Medical Center
David Geffen School of Medicine at UCLA
Los Angeles, California
edwardlee@mednet.ucla.edu
Disclosures: None.