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# The Eyes Have It

Lindsay Machan, MD

**The ocular lens is one of the most susceptible structures in the body to radiation damage. Unfortunately, much of the traditional academic and regulatory thinking on thresholds to develop radiation-induced opacities or cataracts has proven to be false. Individual vulnerability to the effects of radiation is extremely variable, largely because each individual is variably genetically equipped to repair the damage caused by radiation. Therefore many people, including some unsuspecting interventional radiologists may have no, or almost no, threshold at all for cataract development after radiation injury. For most others, if there is a threshold it is a fraction of what was previously thought. These new data have become apparent during the same time period when unprecedented numbers of physicians and medical staff have been exposed to unprecedented doses of scatter radiation as the number and complexity of fluoroscopic guided procedures has exploded. Increased rates of radiation lens damage have already been documented in physicians and support staff working in interventional medicine. As there is a latency period of years to decades for lens injury to fully evolve it is quite possible the true incidence will not be known for some time. Strategies to minimize the potential risks encountered in interventional medicine include radiation safety best practices, passive and personal barrier protection, and philosophical approach to interventional radiology practice. Ignore this article at your peril.**
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## Overview of Background Data

Exposure of the ocular lens to ionizing radiation can damage the posterior aspect of the lens, resulting in opacities or cataracts (Fig. 1). For years it was "known" that development of radiation associated cataracts required a dose threshold as high as 8 Sv. It is now evident that the lens, one of the most radiosensitive tissues in the body, is far more radiosensitive than previously thought.[1,2] In fact, thresholds for the development of radiation injury to the lens may not exist at all; at the least they are a fraction of prior assumptions.[3] The number and complexity of fluoroscopic procedures have increased dramatically in the past decade so that operators, support staff, and patients are exposed to levels of radiation not encountered since the earliest days of roentgenology. It is alarming to think that as most radiation-induced lens damage takes years or decades to develop, the full effects of this increased radiation exposure are not yet known.

All dose exposure guidelines have been premised upon the assumption that everyone of a specific age is equally sensitive to radiation injury. It has become apparent this is not true. Biological responses to ionizing radiation are for the most part genetically mediated, therefore each of us is variably vulnerable to not only the damaging effects of radiation but also the way that damage is physically expressed. Genetic predisposition to the harmful effects of radiation including lens opacities has been demonstrated in animal models[4] and in humans with Ataxia-telangiectasia.[5] In the former article Worgul made the prescient comment "(testing for the altered expression of radiation repair genes) may influence the choice of individuals destined to be exposed to higher than normal doses of radiation, such as astronauts." At that time he was unaware of interventional radiology. He may be proven correct. Recent research documents that the magnitude of expression of certain genes associated with radiation repair varies significantly between different interventionists immediately after exposure to scatter radiation.[6]

Studies of astronauts[7] and radiation clean up workers[1] were the first to show occupational risk of radiation-

Department of Radiology, University of British Columbia, Vancouver, British Columbia, Canada.

Address reprint requests to Lindsay Machan, MD, Department of Radiology, UBC Hospital, 2211 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2B5. E-mail: lindsay.machan@vch.ca

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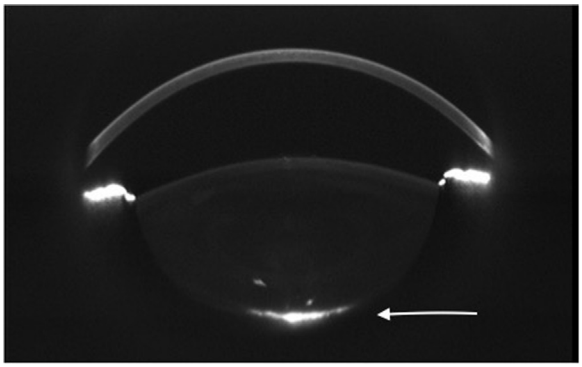

**Figure 1** Posterior cataract. Image of the anterior chamber and lens of the eye using a Scheimpflug scope demonstrating sclerosis of the posterior subcapsular region of the lens (arrow).

induced eye disease. In the first report on a large number of health workers, a 1983-2004 cohort study of 35,705 initially cataract-free US radiology technologists, aged 24-44 years, reported 2382 cataracts and 647 cataract extractions.[8] A total of 25% of the cataracts occurred before 50 years of age. In the occupational cataracts and lens opacities in interventional cardiology (O'CLOC) study,[9] one of the largest studies on physicians, 106 French interventional cardiologists were compared with a control group of 99 unexposed nonphysicians. Posterior subcapsular opacities were 3 times more common in the cardiologists, after correcting for age, sex, smoking, and other variables. Surprisingly the literature specifically assessing interventional radiologists is sparse. Vano in a case series on cataract development in interventional radiology suites not optimized for interventional work found dot-like subcapsular cataracts in multiple staff members.[10] Worgul reported on 59 interventional radiologists attending an educational conference who volunteered for eye examination using a Scheimpflug camera, finding no lens opacification in 53%, posterior subcapsular dot-like opacities in 37%, and posterior subcapsular cataracts in 8%.[11] There was a tendency for cataract risk to increase with years of interventional work and wearing protective eyewear appeared to reduce the risk of radiation-induced eye changes. In addition, significant increase in cataracts in nursing and technical staff have been demonstrated.[8,12]

These data compelled the International Commission on Radiological Protection (ICRP) to issue 2 new recommendations.[13] The first is that the threshold should now be considered 500 mGy, which is about 4 times lower than previously thought. The second is that the annual dose limit should be set at an average of 20 mSv per year, with no year exceeding 50 mSv. The current limit set by the Nuclear Regulatory Commission (NRC) is 7.5 times higher. These IRCP recommendations have not as yet been adopted by the NRC in the United States, thus are advisory rather than regulatory.

All medical personnel exposed to radiation should inform their eye care specialist. The possibility of radiation-induced disease may not even occur to an ophthalmologist. Cataracts are classified by location into nuclear, cortical, and posterior subcapsular subtypes. Radiation exposure results in posterior subcapsular cataract formation. Posterior cataracts may be harder to detect clinically as they are best seen by a nonsubjection Scheimpflug slit-imaging scope or optical coherence tomography, neither of which are in common use. Although posterior cataracts can occur in patients who are diabetic or on long-term systemic steroids they are far less common than traditional age-related cataracts which are located more anteriorly within the lens. Posterior lens opacities decrease contrast sensitivity before visual acuity, as opposed to most age-related cataracts which interfere with visual acuity first. Therefore, routine eye chart screening may not detect an issue.

It should be remembered that even after successful surgery cataracts are likely to have a negative impact on one's visual proficiency. The American Academy of Ophthalmology does not sanction cataract surgery when visual acuity is 20/40 or less, yet even an uncorrectable 20/25 visual acuity might constitute impairment to some interventional operators. One should understand that 20/25 is considered an excellent surgical outcome.

# Methods to Minimize Lens Dose

Strategies to reduce dose to the lens can be divided into reducing the radiation dose used during the procedure, barrier protection, personal protective devices, and (for lack of a better descriptive term) personal discipline. It is critical to note that all of the described measures to reduce dose to the lens are additive. While any intervention can result in significant scatter radiation to the operator, procedures identified as resulting in a particularly high lens exposure include embolization, vertebroplasty, and transjugular intrahepatic portosystemic shunt creation.[14] It is prudent to pay particular attention to radiation safety when performing these procedures.

## Reducing the Amount of Radiation Used

Reducing total radiation used diminishes the dose to all 3 groups at risk (operator, associated medical staff, and patient). Dose reductions greater than 10-fold can be achieved, in some cases with minimal effort, expense, or compromise of ability to perform the procedure.

Radiation to the eye during fluoroscopic procedures principally is due to scatter radiation from the patient.[15] The lower the radiation emitted from the source, the lower the scatter radiation. The most expensive means of achieving this is to use modern equipment, as digital flat-panel detectors and real-time dose monitoring available on fixed and portable fluoroscopic machines potentially convey major dose reductions. However, these benefits are not realized without using the following basic measures:

(A) Lower the fluoroscopy frame rate as much as possible.
(B) Collimation. The higher the collimation the greater is the scatter dose reduction. Even 1 cm horizontal