Effectiveness of Lead Lenses in Reducing Radiation Exposure[1]

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Optically ground prescription lenses of glass, leaded glass, and plastic were exposed to radiations that simulated routine angiography. Radiations transmitted through the lenses were measured. Plastic provided no protection, regular glass provided moderate protection, and high lead content glass reduced radiation transmission by approximately 70%. A brief review of the literature concerning the biological effects of radiations to the eye is included.

INDEX TERMS: Cataracts • (Eyeball, effect of radiation on, 2[24].470) • Diagnostic radiology, radiation dose • Radiations, protective and therapeutic agents and devices • Radiology and radiologists

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RELATIVELY HIGH DOSES of radiation can damage the conjunctiva, iris, sclera, and blood vessels of the retina. The lens of the eye, however, is the critical site, for it may sustain irreversible damage from a relatively low dose of radiation. Low doses will produce only a temporary reaction in the other ocular structures (1).

The sensitivity of the lens to radiation is felt to be due to the failure of normal cell replacement (2). The lens is surrounded by a capsule. On the anterior surface beneath this capsule is a layer of flattened or cuboid cells which comprise the epithelium of the lens and allow for normal metabolism of the lens. At the peripheral border or equator of the lens these cells become progressively elongated and are transformed into the structure of the lens proper. Von Sallman demonstrated that cytologic damage from radiation to the lens consists of a temporary cessation of mitosis, cell death, and occasional abnormal mitosis producing bizarre cells (3, 4). Because of the enveloping capsule of the lens, these damaged or bizarre cells cannot be sloughed but instead are pushed or migrate to the posterior pole of the lens where early radiation-induced cataract is first clinically manifest (5). Subsequent changes may also be observed in the anterior pole, with progressive opacification of the cortex eventually forming a mature and nonspecific cataract (6).

Until now the only protective devices have been heavy cumbersome lead goggles. These are generally not used because of the inconvenience and discomfort. Commercially available prescription lenses for ordinary glasses are made of either plastic or glass. There are two basic types of glass lenses, and these differ significantly in lead content. Ordinary glass lenses called "crown glass" are used by most people. A less commonly used glass known to opticians as "hi-lite", happens to have a relatively high lead content which allows for a thinner lens than would otherwise be required. It is normally used as a substitute for extremely thick lenses. This experiment was designed to determine if significant protection from radiation is provided by wearing the high lead content glass instead of ordinary glass or plastic lenses.

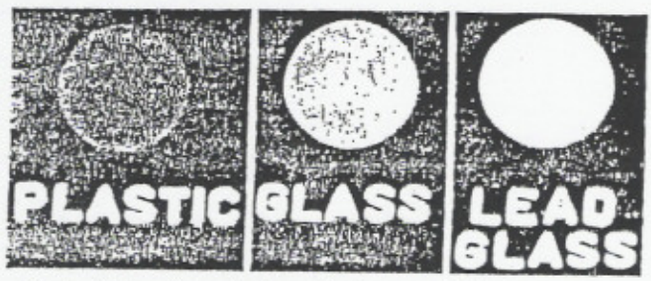

Fig. 1. This radiograph shows the lucency of plastic, the lucent center of the glass lens, and the opacity of lead content glass.

MATERIALS AND METHODS

Lenses of plastic (CR39), glass (crown glass) and high lead content glass (hi-lite) each with a diameter of 4.5 cm and power of −4.00 diopters were used. A radiograph was made of the three lenses (Fig. 1). A thermoluminescence dosimeter and a small ionization chamber were used to measure the transmission of radiations through these three lenses. The dosimeter was a LiF(TLD-700), 1.27-cm diameter disk. TLDs were exposed and read out in a Teledyne TLD-7300C. The ionization chamber was a Physikalisch Technische Werkstatten (PTW) precision chamber connected to a Keithley-602 electrometer.

To obtain accurate dose measurements with the use of a TLD or ionization chamber at the low scatter dose rate of our special procedure table, flouroscopy time would

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Table I: Summary of LiF:TLD (rads) and Ionization Chamber (Coulombs) Transmission Measurements

Trial	Control	Plastic	Glass	Lead Glass
1	7,130	7,141	4,346	2,376
2	6,489	6,635	4,102	2,278
3	6,394	6,191	3,628	2,161
Average LiF: TLD	6,671 (100%)	6,656 (99%)	4,025 (60%)	2,271 (34%)
Average Ion Chamber	1.86×10^{-12} (100%)	1.86×10^{-12} (100%)	1.03×10^{-12} (55%)	0.46×10^{-12} (25%)

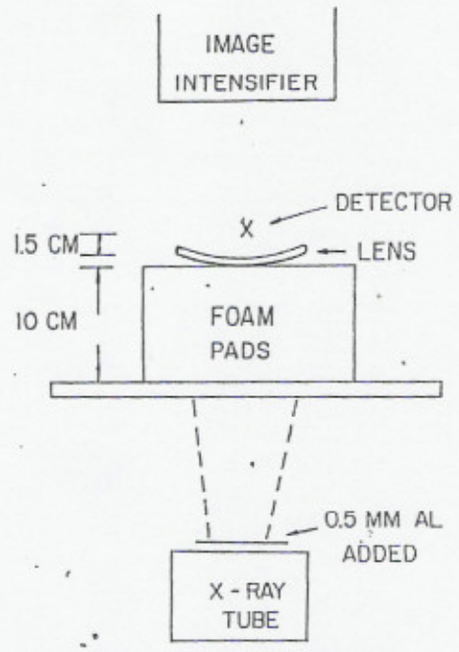

Fig. 2. Experimental setup showing the arrangement of x-ray tube, detector, and image intensifier.

have to be excessively long. To avoid this, measurements were made with the primary beam rather than with the scattered beam. Since the scattered beam generally has a slightly greater h.v.l. than the primary beam (7), an appropriate filter (0.5 mm Al) was added.

The experimental setup is shown in Figure 2. Each lens was placed on a sponge pad 10 cm above the table top to avoid secondary scatter from the table. A LiF:TLD disk was then positioned 1.5 cm from the lens; this simulated the distance between an eyeglass lens and the cornea. Each lens was exposed to a flouroscopic x-ray beam generated at 100 kVp, 4 mA for 2 minutes. Three determinations were made for each lens and for three controls with no lens in place. We corrected for the 38% oversensitivity of the LiF disk at the effective energy of 38 keV of the x-ray beam (8). The same experimental setup was used for measurements made with the ionization chamber connected to an electrometer. Results are summarized in TABLE I.

DISCUSSION

It has been shown that the development of experimental radiation cataracts depends on the animal species (mouse lens 4X more sensitive than rabbit) (9), the fractionation used, and the type of radiation (neutrons more damaging than x rays). Human cataract studies in atom bomb survivors, industrial accidents, and in radiation therapy show that a 1,150-R dose is likely to result in cataracts in 100% of cases (10). Cataracts in mammalian species have been produced with radiation doses as little as 15 R (11) and in humans with as little as 200 R in a single dose (12). With fractionation the threshold dose for cataract production is increased and the time of onset of cataract is delayed (10).

Malsky has shown the average exposure to the eye of an angiographer during a complete cardiac procedure to be approximately 13 mrem with a range of 10–26 mrem (13). Adrian *et al.* have shown the level at the collar to be approximately 3.5 mR, but used less cine time per procedure (14). According to the National Council on Radiation Protection and Measurements (NCRP) the maximum permissible dose to the lens of the eye is 100 mrem per week, 1.3 rem per quarter (13 weeks), or 5 rem per year. Based on the two studies above, an angiographer doing 2–3 examinations per day would approach or exceed the maximum. However, there is, currently no good estimate of the dose required for cataract production in workers exposed to low levels of radiation over an extended period of time. Even in relatively high-dose radiation experiments there is a latency period between exposure and eventual cataract development which may be as long as 20 years with low doses (10).

Prescription lenses available from most optometrists were found to vary greatly in the degree of radiation protection they afforded. Plastic lenses provided no protection, glass lenses moderate protection, and high lead content lenses (hi-lite) reduced radiation transmission by approximately 70%. The thickness of the central portion of the lens will vary depending upon the severity of the myopia; the more severe the myopia, the thinner the central portion of the lens. This in shown by the degree of transmission through the central portion of the glass lens in Figure 1. The lens used in this experiment represents a common prescription for myopic individuals. As the individual becomes less myopic and approaches hyperopia the thickness of the central portion of the lens will increase and provide an increased level of protection. In actual practice, the orientation of the radiation, the lens, and the eye would vary rather than be perfectly aligned as arranged in our study. A portion of scattered radiation would bypass

the lens, and the dose-sparing effect of the leaded lenses would be diminished. This could be partially corrected by wearing two additional lenses along the ear pieces to protect the eye from indirect radiation. the use of high lead content glass instead of plastic or ordinary glass will provide a significant measure of protection without added discomfort or distraction.

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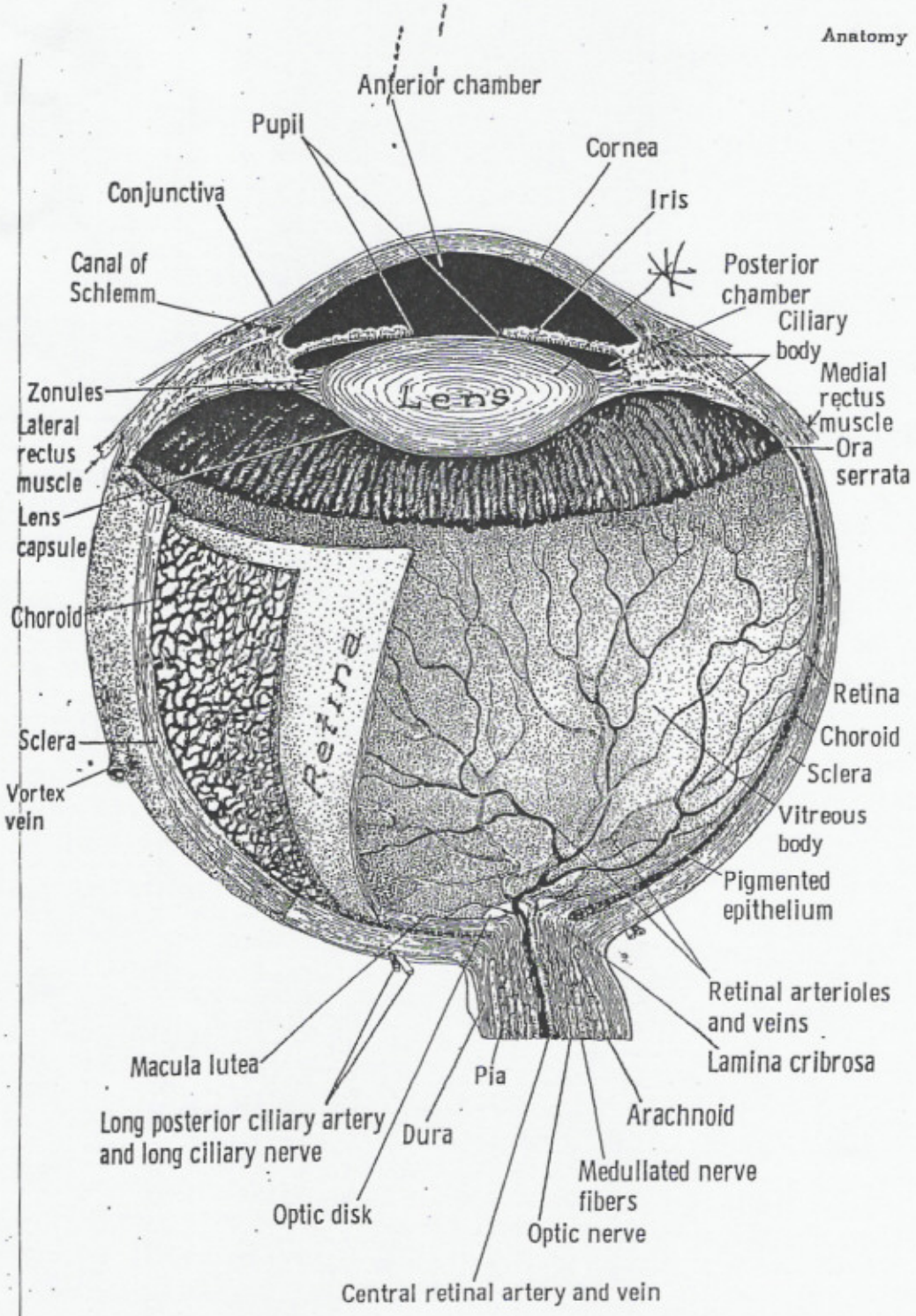

Fig 1-3. Internal structures of the human eye. (Redrawn from an original drawing by Paul Peck and reproduced, with permission, from The Anatomy of the Eye. Courtesy of Lederle Laboratories.)