MINIMIZING EXPOSURE IN NUCLEAR MEDICINE
THROUGH OPTIMUM USE OF SHIELDING DEVICES

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ABSTRACT

Exposure to radiation from nuclear medicine nuclides can be minimized through the use of various shielding devices. This paper reviews the dose reductions achieved through use of various syringe shields, lead aprons, leaded gloves, and several types of eyeglass lenses for ^{67}Ga, ^{99m}Tc, ^{131}I and ^{201}Tl. We have found that a combination of devices can best provide for minimizing doses.

INTRODUCTION

With an increase in the number of nuclear medicine procedures (NCRP, 1989) exposure control for the nuclear medicine technician becomes an increasing concern. Exposure to the technician can occur during the preparation and measurement of the dose, during injection and during imaging of the patient. According to Murphy (1986), exposure to the technician has increased in recent years due to the use of higher activities of ^{99m}Tc and participation in more time-consuming and more complex imaging procedures.

A variety of personal shielding devices are available for users of radiation sources in medicine. Several investigators show reduced exposure from x-rays with the use of lead aprons (Smith and Willhoit 1970) (Gill 1980) (Boothroyd 1987) (Russell and Hufton 1988). Syringe shields are effective devices for reducing exposure to radionuclide workers (Neil 1969) (Takaku and Kida 1972) (Henson 1973) (McElroy 1981). Prescription eyeglasses with leaded lenses as well as some prescription lenses with heavy metal content have also been shown effective in reducing transmission of x-rays to the eye (Richman et al.1976) (Young et al.1978) (Agarwal et al.1978) (Moore et al.1980) (Cousin et al.1987).

With the exception of syringe shields, most shielding studies have concentrated on protection from diagnostic x-rays. Few studies have dealt with shielding against the higher energy and mixed spectra of nuclear medicine nuclides. Huda and Gordon (1989) discovered that the use of lead aprons in a private nuclear medicine clinic led to a 50% reduction of the yearly whole-body dose.

Our assessment of the radioprotective properties of commercially available lead aprons, syringe shields, eyeglass lenses, leaded plate glass and lead-loaded rubber gloves for the four common nuclear medicine radionuclides listed earlier is presented.

MATERIALS

Radionuclides were obtained from our nuclear medicine department. The ^{99m}Tc, ^{201}Tl and ^{67}Ga were in 3 ml syringes and were standard nuclear medicine doses or kit preps. The ^{131}I was evaluated in a capsule, not a syringe, since it is not normally administered from a syringe. The physical data for these nuclides are listed in Table I.

The lead aprons used were designated as being 0.5 mm and 1.0 mm Pb equivalent. The leaded vinyl had an indicated Pb equivalence of 0.6 mm. A Pro-Tec II™ tungsten syringe shield (Atomic Products Corp.) and a Modified NIH Tungsten syringe shield (Atomic Products Corp.), both with leaded-glass viewing ports, were evaluated.

Fourteen eyeglass lenses were evaluated. The degree of curvature of the lenses varied from flat to common values of curvature (2 to 9 diopters). The thickness of each lens was determined by measuring five points on each lens and determining the average. Leaded plate glass with a 1.5 mm Pb equivalence at 65 kVp was evaluated. Lead-loaded rubber gloves equivalent to 2.3 mm of aluminum at 60 kVp were also evaluated for their shielding potential. We also evaluated the attenuation of a standard lab coat and ordinary latex gloves.

Table I. Physical Data (a) of Nuclear Medicine Nuclides

Isotope	Half Life	Gamma Energy	Beta Energy
^{201}Tl	3.04 days	Hg X-rays (72.9%)	none
		135 keV (2.65%)	
		167 keV (10.2%)	
^{99m}Tc	6.01 hours	140.5 keV (87.9%)	none
^{67}Ga	3.26 days	93.3 keV (38%)	none
		184.6 keV (23.9%)	
		300.2 keV (16.1%)	
		393.6 keV (4.3%)	
^{131}I	8.04 days	80.1 keV (2.6%)	247 keV (2.0%)
		284.3 keV (5.8%)	333 keV (6.6%)
		364.4 keV (89.8%)	606 keV (89.8%)
		636.7 keV (6.4%)	

(a) E.R. Squibb & Sons, 1980

METHODS

Exposure rates were measured with an Eberline RO-3 Ion Chamber. Figure 1A indicates the basic experimental setup used to collect the exposure rate data. Data were collected with a beta shield in front of the ion-chamber.

Exposure rates were measured at four distances from the radiation source: 8.5 cm, 18.5 cm, 38.5 cm and 68.5 cm. In each case, measurements were obtained comparing attenuated with unattenuated beams, the ratio of which provided the percent transmission. The thickness of the 14 lenses varied considerably. Percent transmission was adjusted with first-order exponential corrections to account for lens thickness. The reported percent transmission is normalized to 2.2 mm and represents the average of determinations made at the four distances.

Measurements were taken to determine the best location for the eyeshield in relation to the syringe and ion chamber. The data indicated that the eyeshield should be placed as close to the syringe as possible in order to expose the entire sensitive volume of the ion chamber (Figure 1B and 1C). The eyeshield consisted of 0.64 cm lead with a 3.2 cm diameter hole cut in the center. The eyeglass lenses and the leaded plate glass were placed in a holder across the opening in the lead.

The syringe shields were evaluated in four different orientations with respect to the ion chamber: viewing port, tungsten side, plunger end and needle end. Figure 2 illustrates these orientations. Measurements were taken in each position to determine the percent attenuation provided by the syringe shield.

The lab coat, lead aprons and the leaded vinyl were suspended from supports that allowed them to hang down in front of the ion chamber (figure 1). The latex and leaded rubber gloves were cut open and taped across the front of the ion chamber.

RESULTS

Percent transmissions for the four nuclides and various shielding devices are listed in Table II. The higher energy ^{131}I yielded the highest percent transmission for each shielding device. ^{67}Ga yielded transmission values similar to ^{99m}Tc for most of the lenses, but it yielded somewhat higher values than did ^{99m}Tc for all of the other devices. With its low energy gamma, ^{201}Tl was the easiest to shield.

Syringe shields provide significant protection when properly used. However, the user must be aware that the protection of the syringe shield varies considerably with respect to its orientation and emits a high intensity cone of radiation at each end. The Protec II syringe shield attenuated better at the plungerend of the syringe and the NIH syringe shield attenuated better at the needle end. Figure 3B compares the percent transmission of the various devices for each nuclide tested.

Lead aprons reduce exposure to the torso by 5 to 72 percent depending on the nuclide. Exposure to the eyes is significantly reduced with the use of leaded glass lenses. The Aura X-ray glass decreases exposure to the eyes by 18 to 82 percent, depending on the isotope.

The leaded plate glass (Schott RD-50) is very effective against the gamma ray from ^{99m}Tc and ^{201}Tl (95% reduction). Even for the higher energy gamma ray emitters of ^{67}Ga and ^{131}I, the reduction in exposure is 73% and 42% respectively. This finding is consistent with the manufacturer's data.

DISCUSSION

Syringe shields supply the single largest protection factor for whole-body and extremity dose, and they should be used whenever possible. The user should be cognizant of the position of the plunger with respect to the hand and torso during handling to keep exposure to a minimum. In situations where the use of a syringe shield is not possible (dose measurement, difficult veins), expediency and alternate protective devices are important for reducing exposure, i.e., working behind a leaded glass shield, using tongs, using shielded carrying devices, and modified injection procedures.

A 0.5 mm lead apron can reduce trunk exposure by 5 to 72 percent. One mm lead aprons could reduce exposure by 22 to 85 percent. However, the additional weight might make these uncomfortable to wear for an extended period of time. Two piece leaded aprons are available that would reduce the discomfort of extended wear.

Most eye glasses, whether prescription or used solely for radiation protection, can significantly reduce exposure from ^{201}Tl. The effectiveness of eyeglasses for reducing exposure from ^{99m}Tc and ^{67}Ga is highly dependent on the lens. Those who wear prescription glasses should discuss with their optometrist the possibility of

Table II. Average Percent Transmission for Various Materials

Shielding Material	Average Thickness mm	Average Percent Transmission (a) ^{99m}Tc	^{201}Tl	^{67}Ga	^{131}I
Aura X-ray glass	2.6	23	18	50	82
B&L Crown Glass	2.6	80	56	77	94
Cobourn High-Lite glass	2.0	81	48	80	95
Custom Optics Tan 3 glass	2.2	82	54	85	95
B&L Ray Ban G-15 glass	2.2	84	58	87	94
Coburn Crown glass (b)	4.0	84	64	87	93
Corning Photogray Extra glass	2.9	88	67	92	95
Schott S-3 Crown glass (b)	16.5	88	79	90	93
Schott S-1005 Hi-Lite glass(b)	14.6	88	80	91	95
Optima Hyper Index 1.6 plastic	2.2	89	69	89	97
Schott S-1 Crown glass (b)	8.0	90	79	91	95
Gentex polycarbonate	3.2	96	83	93	96
Silor CR-39 plastic	2.4	98	80	92	94
Sola 39 plastic(UV-400 coating)	2.2	99	78	91	97
Schott RD-50 Pb plate glass	6.5	5	5	27	58
Aura X-ray glass (from above)	2.6	23	18	50	82
Lead Apron	1.0	16	15	40	78
Leaded Vinyl	0.6	19	18	45	89
Lead Apron	0.5	36	28	59	95
Lead-Loaded Rubber Glove		85	50	90	99
Latex Glove		93	99	104	100
Lab Coat		94	99	102	100
Pro-Tec II Syringe Shield					
Pb Window		6	6	33	--
Side		4	4	28	--
Plunger		40	45	43	--
Needle		88	81	72	--
Modified NIH Syringe Shield					
Pb Window		7	11	33	--
Side		4	7	24	--
Plunger		62	87	74	--
Needle		75	71	78	--

(a) Due to a wide variation in lens thickness, we normalized transmission data to 2.2 mm thickness.

(b) Uncut lens blanks

selecting a lens with higher than normal density. If the additional weight of the lens is acceptable to the wearer, then radioprotective glasses are preferable.

Lab coats and latex gloves provide insignificant shielding from external radiation. However, the leaded rubber glove reduced exposure by 50% for ^{201}Tl and 10 to 15 percent for ^{67}Ga and ^{99m}Tc respectively. A major complaint about the use of any gloves, and especially leaded rubber gloves, is the loss of tactile sense. Ullman (1989) pointed out that cutting the tips off disposable lead gloves can increase the usefulness and increase tactile sensation. A pair of latex gloves over a pair of detipped leaded-rubber gloves can decrease hand exposure without compromising touch.

Exposure reduction can also be enhanced through handling and injection procedures that maximize distances and minimize handling times.

CONCLUSIONS

The overall number of nuclear medicine procedures performed in the United States is the highest in the world, and this number has doubled between 1972 and 1982 (Mettler et al.1985). Since the majority of nuclear medicine procedures (approximately 85%) use ^{99m}Tc (Huda and Gordon 1989) (BEIR 1980), these procedures are responsible for a considerable proportion of the annual dose to nuclear medicine and radiology personnel. Table III compares annual dose ranges to these groups from various studies reported in the literature. Our studies indicate that the use of a lead apron during dose preparation and injection could decrease annual doses by as much as 50%. The use of syringe shields could reduce exposure by 96%. The use of leaded eyeglasses could decrease exposure to the lens of the eye by 80%.

Table IV illustrates the dose reduction obtainable for various organs with the use of various combinations of shielding devices for a ^{99m}Tc source. Optimum use of the available shielding options can reduce a technician's whole body dose. Dose reduction to specific organs such as the eye and the gonads (fetus) can also be accomplished easily.

Table III. Yearly Average Dose Rates for Medical Radiation Workers

Country	Years of Data	Avg. Annual Dose (mRem)	Reference
Manitoba, Canada	(1981-85)	210-380	Huda, Gordon, 1989
Australia	(1974-78)	40-80	Huda, Gordon, 1989
France	(1976-79)	50-170	Huda, Gordon, 1989
Taiwan	(1985)	250	Huda, Gordon, 1989
Canada	40 yr. projection	240	Huda, Gordon, 1989
USA	(1975)	350	BEIR, 1980

Table IV. Percent of Dose Rate Reaching Target Organs for ^{99m}Tc

	Percent of Dose		
	Hand	Eye	Gonads
Unshielded	100	100	100
Protec II Syringe Shield (a)	4	4	4
0.5 mm Pb Apron	100	100	36
Leaded Eye Glass	100	23	100
Leaded Rubber Glove	85	100	100
Syringe Shield and 0.5 mm Apron	4	4	1
Syringe Shield and Leaded Eye Glasses	4	1	4
Syringe Shield and Leaded Glove	3	4	4
Syringe Shield, 0.5 mm Apron and Leaded Eye Glass	4	1	1
Syringe Shield, 0.5 mm Apron, Leaded Glove and Leaded Eye Glass	3	1	1

(a) Assumes radiation from tungsten side only.

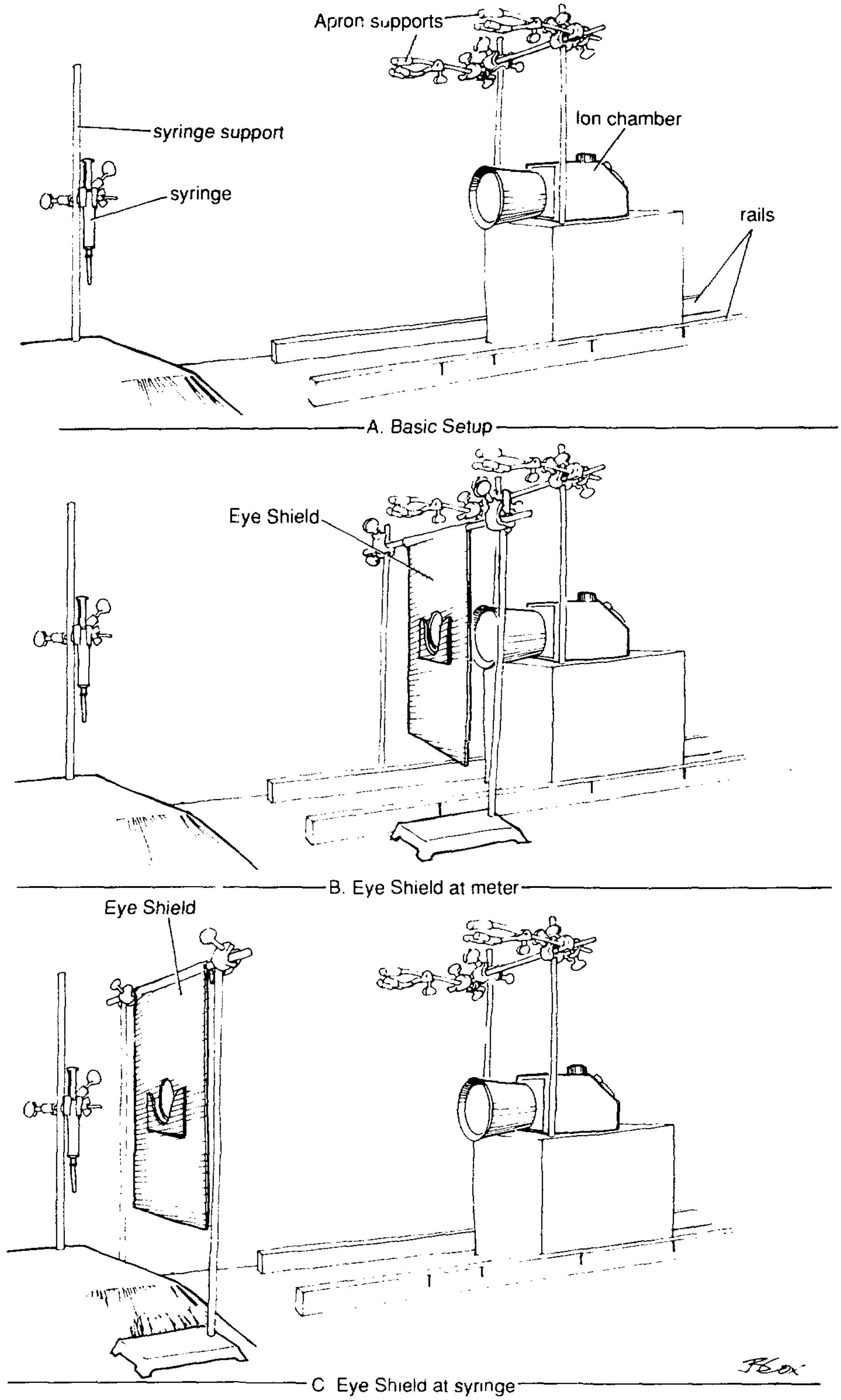


Figure 1. Experimental Setup

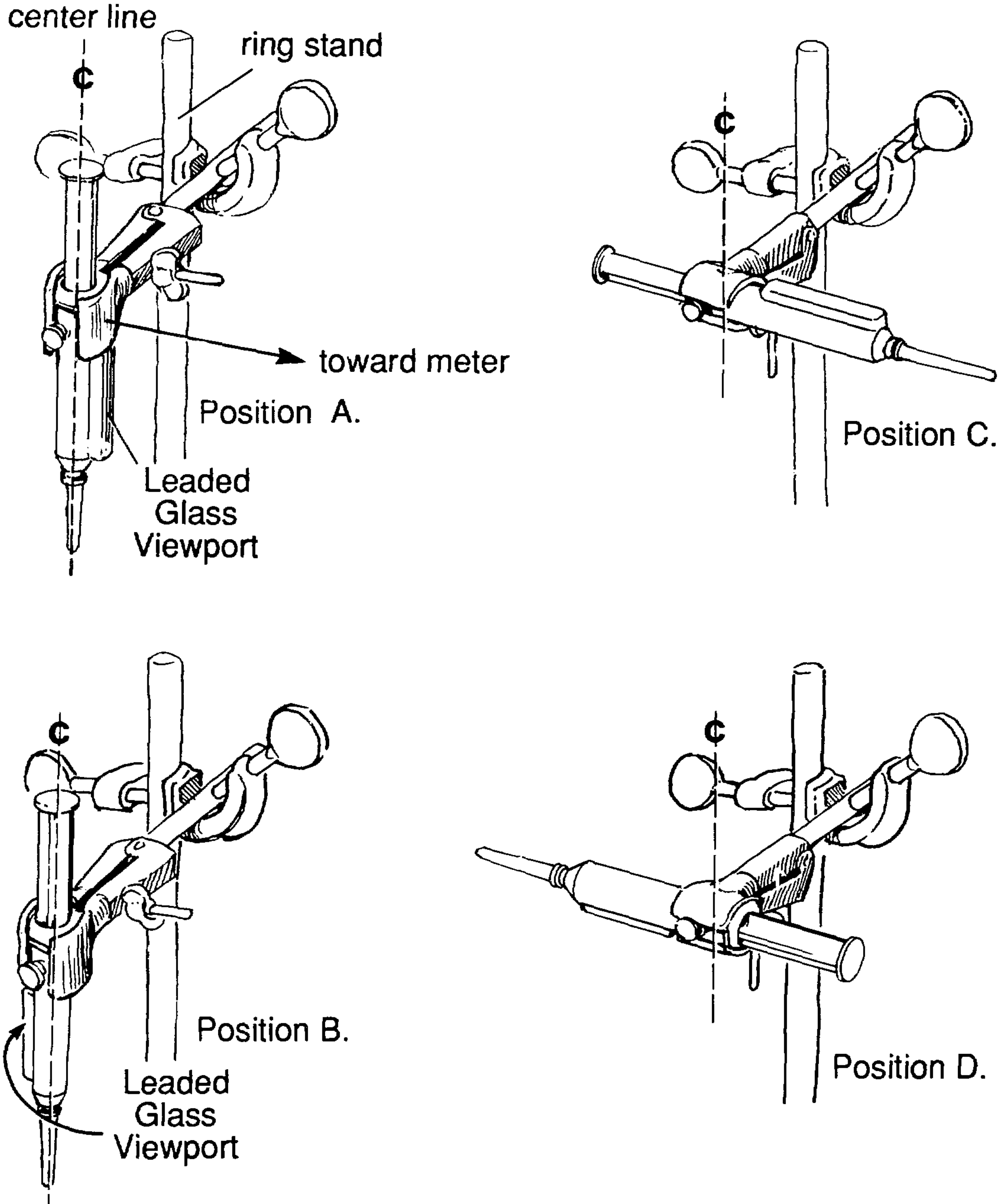


Figure 2. Syringe Shield Orientations

Figure 3A. Percent Transmission for 14 Eyeglass Lenses

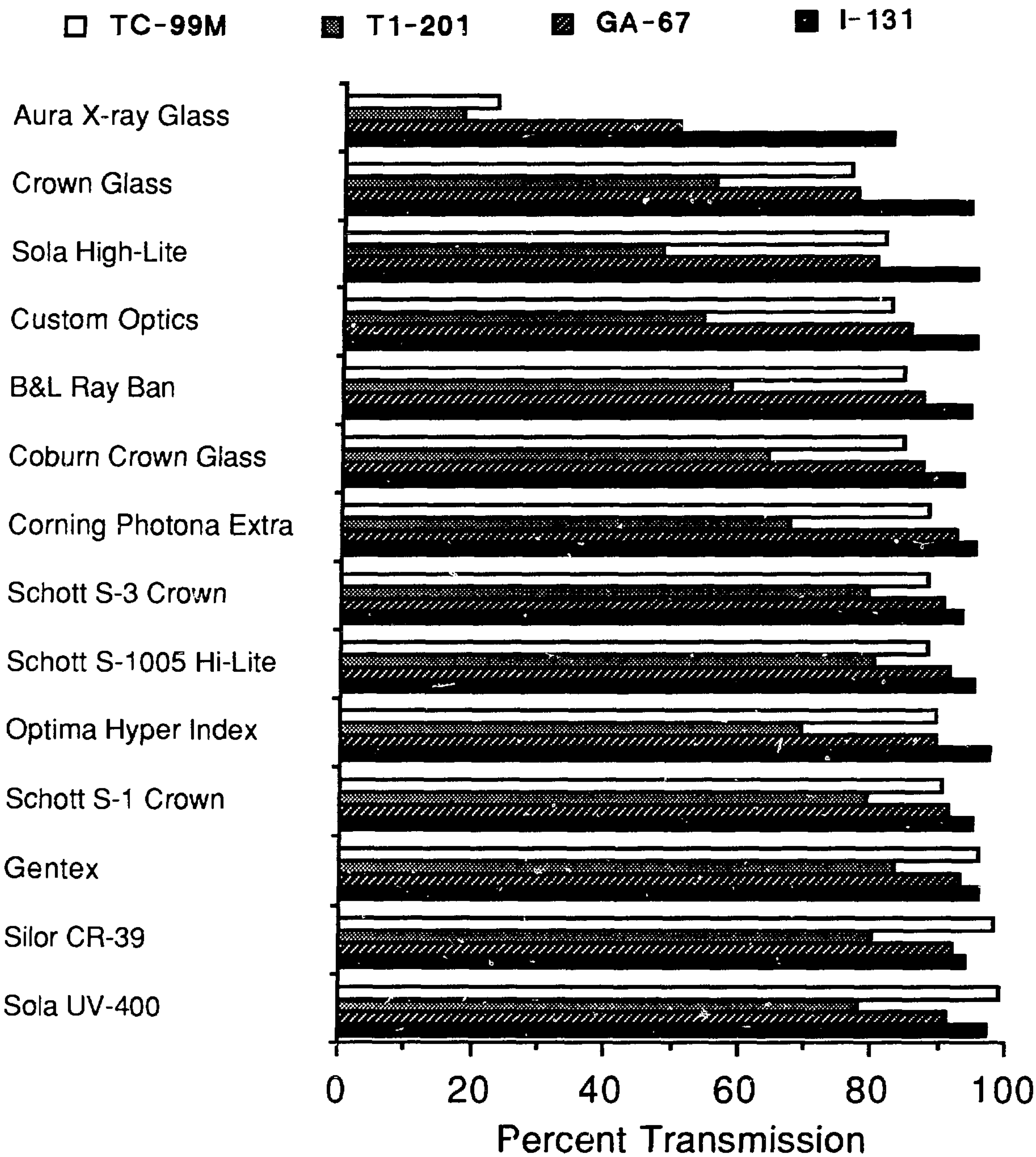
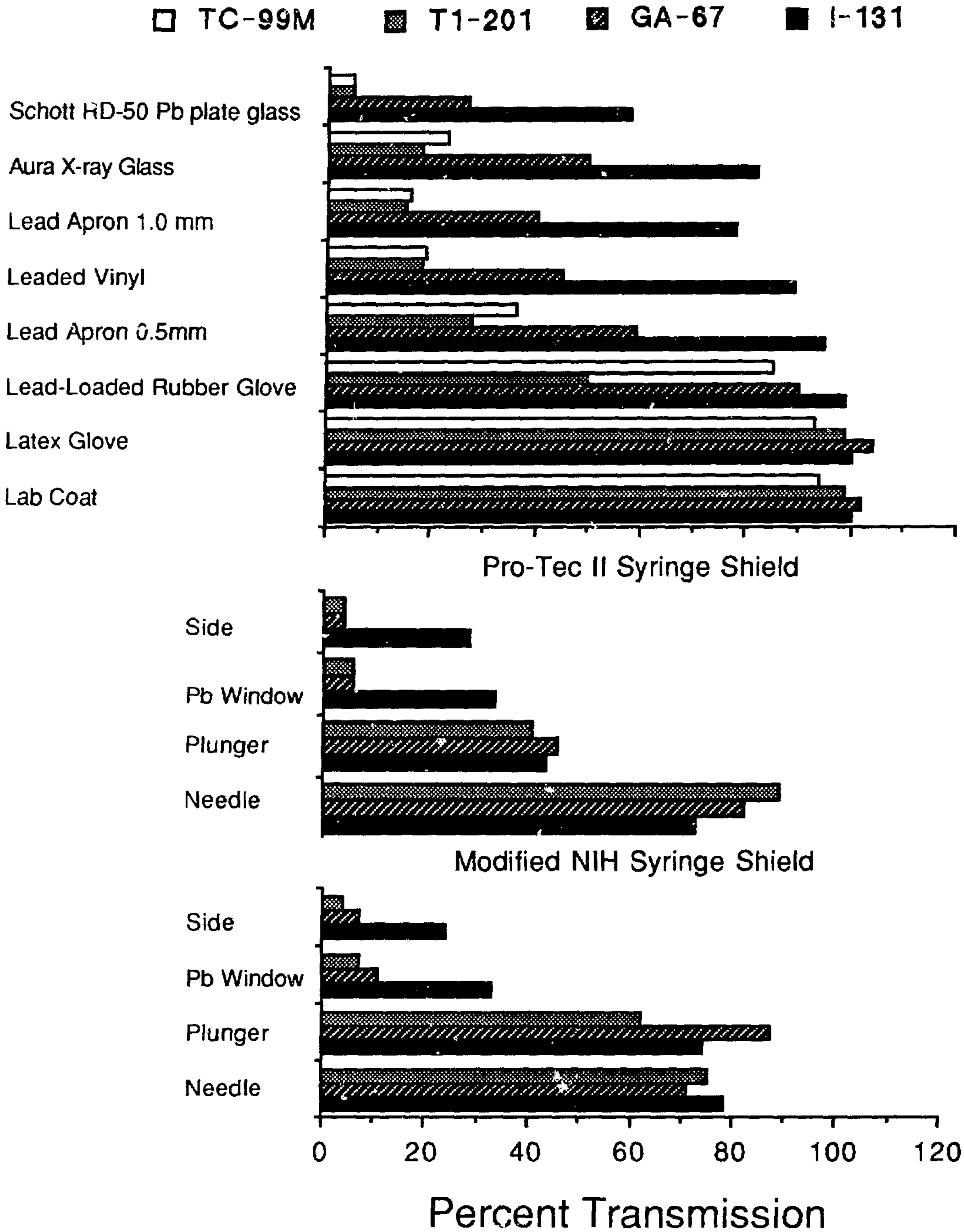


Figure 3B. Percent Transmission for Various Shielding Materials



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