Evaluation of Shielded Syringe Carriers for Transporting Radioactive Doses

Norman B. Levit and Mary Ogiela-Bazner

University of New Mexico Radiopharmacy, College of Pharmacy, Albuquerque, New Mexico

We evaluated four commercially available lead-lined syringe carriers typically used for transportation of radiopharmaceutical unit doses to determine their ability to safely contain radioactivity. The United States Department of Transportation (DOT) "performance criteria" were utilized as parameters to judge relative effectiveness. However, because specific design assessments are left to the user's discretion, we tested all four syringe carriers for: weight and thickness of lead; efficacy in attenuating radiation emitted from the most commonly shipped radiopharmaceuticals; effectiveness in prevention of leakage from the enclosed syringe; and compliance with DOT regulations. One syringe carrier model was found to safely contain radioactive emissions from both high- and low- energy radionuclides; while a second model was shown to provide adequate containment only when used for lower energy radionuclides (e.g., technetium products). Two other models were evaluated as less effective in several parameters including containment of fluids.

Special shielded carriers have been developed for syringes containing radioactive doses in order to safely transport the doses from one location to another (e.g., from centralized radiopharmacies to area hospitals). These doses are usually delivered by radiopharmacy-owned vehicles or by common carrier (*1*). The transportation of radiopharmaceuticals by common carrier is regulated by DOT under the "Hazardous Materials Regulations" (*2-4*). Regulatory bodies that routinely govern operation of vehicles owned by centralized radiopharmacies are both DOT and NRC (or its equivalent in Agreement States). In addition, some state, county, and local agencies may also regulate vehicle operation (e.g., placarding of vehicle). Standards for hazardous materials containers and their transport are outlined in Tariff No. 31, effective March 31, 1977. However, because regulations prescribe the "performance criteria", but do not provide specific regulatory approval of design, the shipper must make his own assessment of the effectiveness of a particular shielded carrier relative to federal performance requirements (*2-4*).

This project was conducted so that the general nuclear medicine community could have a basis for determining the relative ability of typical syringe carriers to attenuate radioactivity and contain internal fluid leakage should it occur during dose transportation.

We evaluated commercially available shielded syringe carriers for: (a) weight and thickness of lead, (b) efficacy in attenuating radiation emitted from the most commonly shipped radiopharmaceuticals, (c) effectiveness in preventing any leakage from the enclosed syringe, and (d) compliance with DOT regulations.

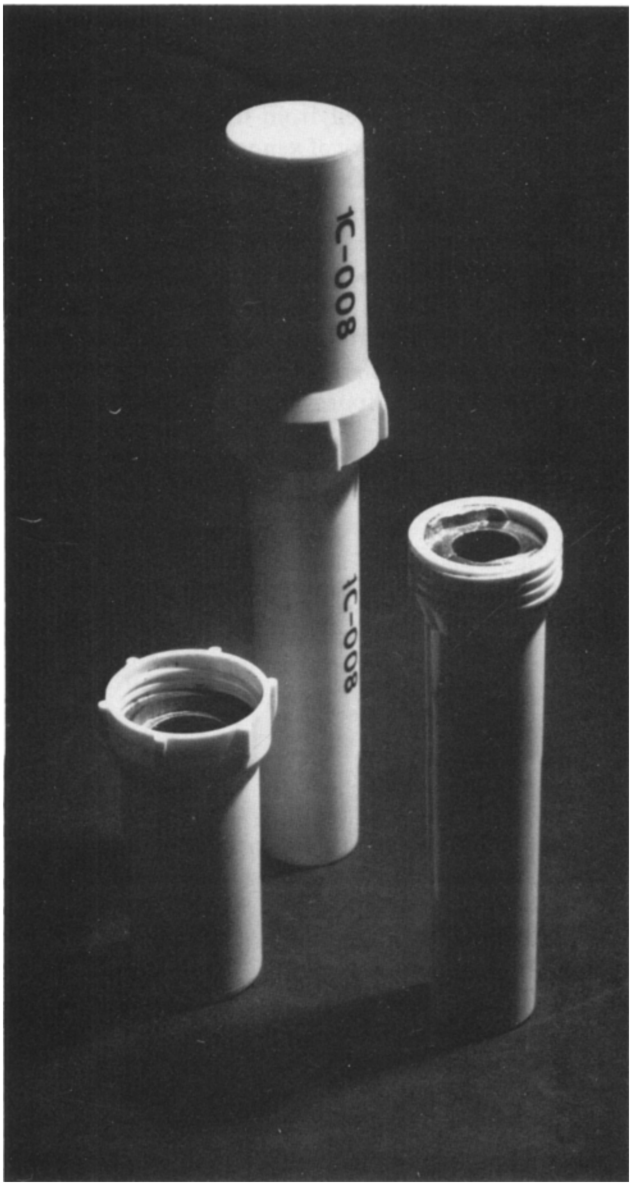

FIG. 1. Syringe carrier shield, 1 C-008 with screw-on top and continuous plastic coating.

For reprints contact: Norman B. Levit, UNM Radiopharmacy, College of Pharmacy, Albuquerque, NM 87131.

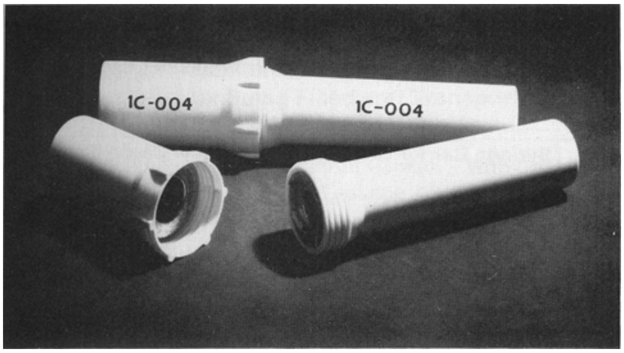

FIG. 2. Syringe carrier shield, 1 C-004 with screw-on top, continuous plastic coating.

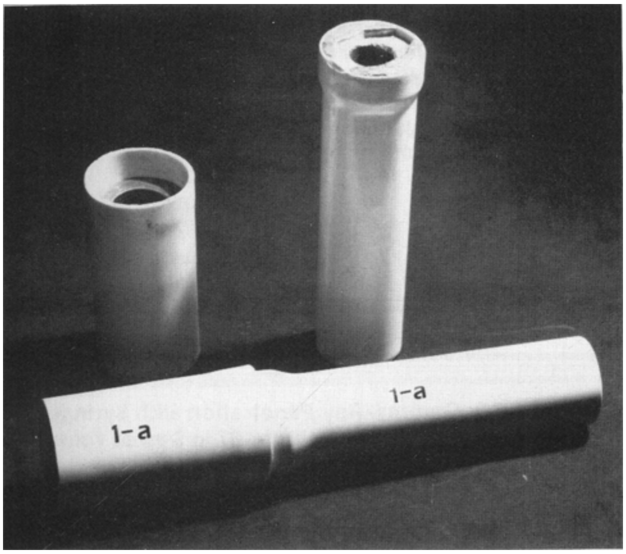

FIG. 3. Syringe carrier shield, 1a with slip-on top, plastic coating.

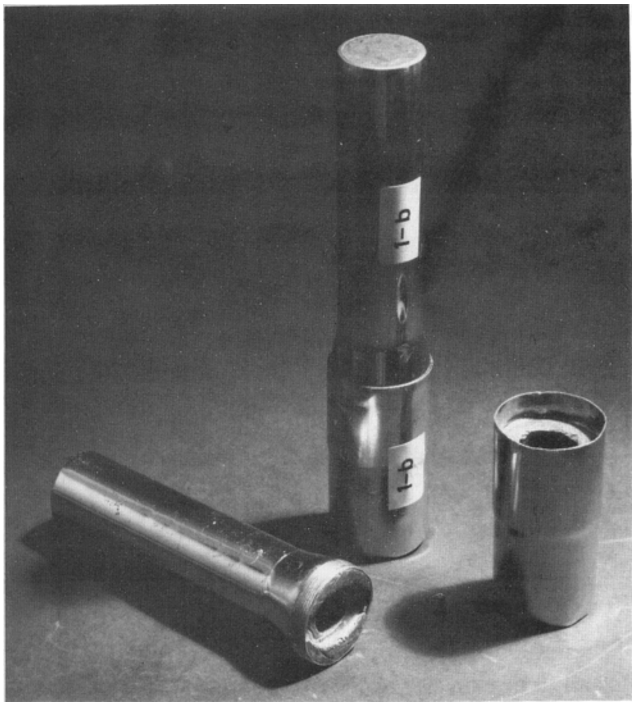

FIG. 4. Syringe carrier shield, 1b with slip-on top, steel covering.

Materials and Methods

Four different syringe carriers were evaluated: the 1 C-008 (Fig. 1) and the 1 C-004 (Fig. 2) (General Design Development, Albuquerque, NM), and the 1a (Fig. 3) and 1b (Fig. 4), both formerly made by Ainsworth Co. (Albuquerque, NM). The General Design models are made of no less than 95% lead, and the top and bottom interlock by means of threads molded into the plastic housing. The top and bottom of the Ainsworth carriers slide together and the junction is usually sealed with masking tape. In the Ainsworth models, the covering is not continuous. Neither Ainsworth model is currently in production, but since many of these carriers are still in use, we felt they should also be evaluated.

In all following tests, six of each type of carrier were tested and the average results reported. Each carrier was weighed and the thickness at critical points was measured (Table 1). Attenuating effectiveness of the carriers (both surface and transport index readings) was evaluated with syringes containing: (a) approximately 350 μCi of I-131 (Table 2), (b) 7 mCi of Ga-67 (Table 3), and (c) 100 mCi of Tc-99m (Table 4). Transport index is defined as the highest radiation dose measured in mrem/hr at 1-m distance from any accessible surface of the container.

Leakage of liquid was tested by placing 2.0 ml of a nonradioactive rose bengal solution in each carrier, sealing the carrier, wrapping it in absorbent paper, and subjecting it to conditions at least as strenuous as those normally associated with transportation. Syringe carriers were transported for a full day in the UNM radiopharmacy truck on its usual delivery route. The carriers were then packed in a DOT box and transported by common carrier to and from a client 200 miles from the radiopharmacy (*2–4*). The carriers and surrounding absorbent paper were then examined for evidence of leakage, which would be indicated by stains on the outside of carriers and absorbent paper.

At this time, we felt that placing a very thin rubber gasket between upper and lower parts of carriers might increase their ability to contain internal fluid leakage. This was done and all subsequent testing of the carriers was accomplished with the gasket in place. The gasket improved containment characteristics and did not change attenuation characteristics. It is now an integral part of the General Design carriers (Table 5).

Further tests for leakage were performed by filling the carriers with 2.0 ml of rose bengal solution, wrapping them in absorbent paper, placing them horizontally in an Eberbach shaker, and shaking for 5 min at a rate of 120 strokes per min (Table 6). A drop test was performed by filling the carriers with 2.0 ml of rose bengal solution, wrapping them in absorbent paper, and subjecting them to a free drop of 6 ft onto concrete. They were allowed to remain on the concrete for 30 min to allow for seepage and then examined (Table 7).

Compliance of each carrier with applicable DOT regulations was evaluated by comparing test results with these regulations.

Results

As shown in Table 1, carrier 1 C-004 contains 50% (by weight) more lead then model 1 C-008, 11% more than model 1a, and approximately the same amount as 1b. The tops of 1 C-004 and 1 C-008 are 35% thicker than those of 1a and 1b, and the bottoms have 43% greater thickness. With the exception of 1 C-008, carrier walls are essentially equal in lead thickness.

TABLE 1. Measurements of Weights and Thickness of Lead.

Carrier No.	Total Weight (g)	Lead Thickness (cm)				
		Syringe Carrier Cover		Syringe Carrier Body		
		Side	Top	Carrier Wall at Top	Carrier Wall at Bottom	Base
1 C-008	780	0.31	1.19	0.63	0.39	1.11
1 C-004	1536	0.63	1.11	0.95	0.63	1.27
1a	1364	0.79	0.71	0.79	0.63	0.63
1b	1516	0.71	0.79	0.95	0.63	0.71

Table 2 indicates that carrier 1 C-004 attenuates gamma rays of I-131 as well as or better than other carriers when measured at the top, bottom, and junction. It has 27% more attenuating properties for this isotope than either 1a or 1b, and 74% more than 1 C-008. The same carrier (1 C-004) also attenuates gamma rays of Ga-67 better than any of the other carriers measured at all points tested, as seen in Table 3, with the most notable differences being the reading at the middle of the carrier's body. At this point, 1 C-004 attenuates these emissions 69% better than 1 C-008 and 53% better than either 1a or 1b.

Table 4 shows all external survey readings to be very low (measured in mR/hr). Attenuation of gamma-ray emissions from Tc-99m is considered essentially complete for all four of the carriers tested.

Tests for containment of internal fluid leakage under these different experimental conditions are shown in Tables 5, 6, and 7. When these results are examined, it is evident that both models 1 C-008 and 1 C-004 (when equipped with gaskets) prevented external fluid leakage in 100% of the tests, whereas 1a prevented external leakage in 16.67%, 33.3%, and 33.3%, respectively, in the trials in which it was subjected. Model 1b prevented external leakage in 0%, 33.3%, and 33.3% of its trials (i.e., transportation test, shake test, and drop test).

TABLE 2. Gamma-Ray Penetration with Syringe Containing 362 μCi of Iodine-131 in 2 ml of Volume. (Measured in mR/h on the surface.)

Carrier No.	Top	Junction	Middle	Bottom	at 1 m (T.I.)
1 C-008	0.20	6.5	25.0	0.50	0.05
1 C-004	0.20	2.0	6.5	0.35	0.05
1a	0.25	3.5	9.0	0.65	0.05
1b	0.30	2.0	9.0	0.45	0.10

TABLE 3. Gamma-Ray Penetration with Syringe Containing 7.47 mCi of Gallium-67 in 3 ml of Volume. (Measured in mR/h.)

Carrier No.	Top	Junction	Middle	Bottom	at 1 m (T.I.)
	Surface Readings				
1 C-008	0.45	8.0	55.0	1.00	0.15
1 C-004	0.30	2.5	11.6	0.75	0.08
1a	0.40	3.0	25.0	2.00	0.10
1b	0.40	5.5	25.0	1.00	0.10

TABLE 4. Gamma-Ray Penetration with Syringe Containing 100 mCi of Tc-99m in 1.0 ml. (Measured in mR/h.)

Carrier No.	Top	Junction	Middle	Bottom	at 1 m (T.I.)
	Surface Readings				
1 C-008	0.10	0.20	0.40	0.04	0.04
1 C-004	0.06	0.40	0.05	0.04	0.04
1 a	0.07	0.50	0.10	0.09	0.05
1 b	0.04	0.065	0.09	0.04	0.04

Conclusion

Syringe carrier 1 C-008 and 1 C-004 both adequately contained internal fluid leakage. Federal regulations require that absorbent material sufficient to absorb twice the volume of liquid contained be incorporated into the packaging of each individual container. Under certain conditions, this material may be on the outside of the carrier (*2–4*). All four carriers tested attenuated I-131 and Ga-67.

The 1 C-004 carrier complied with all DOT regulations for all of the radionuclides tested. The 1 C-008 carrier attenuated technetium as well as the 1 C-004. However, since the 1 C-008 is lighter in weight and less expensive than model 1 C-004, it is preferred for Tc-99m doses.

We recommend that a rubber or plastic gasket be inserted in both of the older types of carriers (1a and 1b). The newer screw-capped carriers were evaluated and found to be superior to the older slip-on cap models with respect to attenuation of radiation, containment of fluids, and ease in handling.

TABLE 5. Containment of Internal Fluid Leakage by Carriers after Being Filled and Transported.

Syringe Carrier No.	Without Gasket Leakage	With Gasket
1 C-008	1 of 6	In all six leakage was prevented
1 C-004	1 of 6	In all six leakage was prevented
1a	5 of 6	No change
1b	6 of 6	No change

TABLE 6. Containment of Internal Fluid Leakage after Shake Test.*

Syringe Carrier No.	Leakage
1 C-008	0
1 C-004	0
1a	5 of 6
1b	4 of 6

*All syringe carriers were fitted with gaskets.

TABLE 7. Containment of Internal Fluid Leakage after a Drop Test.

Syringe Carrier* No.	Leakage
1 C-008	0 of 6
1 C-004	0 of 6
1a	4 of 6
1b	4 of 6

*All syringe carriers were fitted with gaskets.

References

1. Rhodes BA, Croft B: Operating a radiopharmacy. In *Basics of Radiopharmacy*. St. Louis, CV Mosby, 1978, pp 148–154

2. Graziano RM: Tariff No. 31, *Hazardous Materials Regulations of the Department of Transportation*, Washington, DC, 1977, pp 18–260

3. DOT: *A Review of the Department of Transportation (DOT) Regulations for Transportation of Radioactive Materials*, Washington, DC, DOT, Materials Transportation Bureau, Office of Hazardous Materials Operations, 1977, pp 12–35.

4. The Federal Register, 49CFR, Dept. of Transportation Materials Transportation Bureau Part IV. Washington, DC, The National Archives of the United States; parts 171–177, 1976

5. All about radioactive packages, a guide for supervisors at cargo terminals. Washington, DC, DOT, NRC, 1978, pp 1–10