^{90}Y-Labeled Resin Microsphere Spills: A Pilot Study to Determine Efficient Cleanup Practices

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^{90}Y-labeled resin microspheres (RMs) are selective internal radiation therapy agents encased in microscopic resin spheres and then suspended in water for injection. The ^{90}Y-RM package insert includes a recommended cleanup procedure for contamination spills. However, after a local hospital recently experienced a clinical incident, we explored the efficiency of the recommended cleanup procedure. The aim of this investigation was to demonstrate the effectiveness of different cleaning procedures and compare these with the recommended procedure. **Methods:** Controlled spills of ^{90}Y-RMs were placed in the middle of 10 independent 0.09 m^2 (1 ft^2) tile sections of an existing vinyl tile floor. Each 0.09 m^2 (1 ft^2) area was surrounded by absorbent pads and was further contained within 0.28 m^2 (3 ft^2) 1.9-cm (³⁄₄ in)-thick plywood box enclosures. Three cleaning methods were implemented: damp paper towels (recommended procedure), adhesive paper, and a Swiffer wet mop (SWM). A calibrated Geiger counter was used to determine the maximum precleaning and maximum postcleaning exposure within the tile sections. Percentage exposure reduction was calculated for each cleaning trial, and because of the low sample size, nonparametric exact Kruskal–Wallis tests were used to determine differences in percentage exposure reduction among cleaning types. All statistical tests were conducted assuming a 5% chance of a type 1 error. **Results:** Both damp paper towels and the SWM were superior to adhesive paper (P = 0.0006 and P = 0.0005, respectively). There was no difference between damp paper towels and the SWM, nor did the variability of the cleanup methods differ (P = 0.6826 and P = 0.2501, respectively). **Conclusion:** Damp paper towels and the SWM decontaminated the controlled spills equally. This finding indicates that the SWM can effectively clean up ^{90}Y contamination.

Key Words: ^{90}Y; contamination; cleanup; microspheres

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One form of radiation therapy for liver tumors is ^{90}Y-labeled resin microspheres (^{90}Y-RMs) (SIR-Spheres; Sirtex) (*1–4*). ^{90}Y-RMs are biocompatible radioactive spheres about 20–60 μm in diameter (approximately one fourth the diameter of a human hair) and are manufactured with approximately 40–80 million particles per vial (*1–4*). Additionally, ^{90}Y-RMs have a 64.1-h half-life and emit pure β-emissions with a maximum energy of 2.27 MeV (*1,2,4*).

A vial of ^{90}Y-RMs is shipped in doses of 3 GBq (81 mCi) of ^{90}Y-RMs calibrated for a particular time and suspended in 5 mL of water (*2*). The vial can be kept at room temperature but has to be used within 24 h after the calibration time (*2*). At our institution, it is the responsibility of the nuclear medicine technologist to prepare and confirm the prescribed dose before injection. This process has the risk of contamination from an unintentional spill. Each microsphere, though embedded in resin, can roll, bounce, and even—if allowed to dry—become airborne (*4*). The inspiration behind this study came after a recent spill at a local hospital. When preparing a dose for a patient, a technologist accidentally dropped a needle cap of ^{90}Y-RMs onto the hot-lab floor. The technologist tried to contain the spill on the basis of the manufacturer's recommendation but soon discovered it had spread into the hallway and into an adjacent department. The local radiation safety officers were contacted; they discovered that the ^{90}Y-RMs had spread via the bottoms of shoes, and they suspected that dry spheres were moving through the air circulation. Regardless of efforts to contain the spill, the ^{90}Y-RMs still spread significantly beyond the primary spill area, causing widespread contamination. Although the current study did not include the potential air-circulation contamination, this event did inspire us to determine the best method to decontaminate and clean up dry ^{90}Y-RMs.

Previous research has shown many methods and ideas for cleaning up radioactive contamination in the nuclear medicine department (*5–7*). Some research suggests using various solutions or solvents such as soap, water, Radiacwash (Biodex), and even different chemicals (*5–6*). Mountford recommends an extensive list of cleaning substances for radioactive contamination, including various chemicals such as potassium iodide and sodium bisulfite (*7*). Additionally, each research study recommends various methods, including towels, brushes, and cloths, when cleaning up radioactive contamination (*5–7*). However, most of the sparse evidence is focused on wet-spill contamination. Only one, Mountford,

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mentions dry radioactive contamination (*7*). In that article, Mountford mentions that dry contamination needs to be cleaned up using a base that will speed hydrolysis, as well as a detergent made to reduce surface tension (*7*). Also, he recommends the use of a chelate made to dissolve precipitates of metal hydroxides (*7*). Lastly, he mentions that the area should be mopped with disposable towels while wiping toward the center of the contamination area (*7*). However, this article was written in 1991 and does not consider ^{90}Y-RMs and possible contamination from dry resin spheres.

The aim of this study was to determine the most efficient way to decontaminate dry ^{90}Y-RMs no longer in suspension. The manufacturer's recommendation to decontaminate ^{90}Y-RM spills is to use damp paper towels; however, the effectiveness of this method is not well published, nor has it been explored against other cleaning methods (*8,9*). The objective of this study was to compare the percentage exposure decrease for cleaning up dry ^{90}Y-RM contamination using 3 different methods: damp paper towels (manufacturer's recommendation), adhesive paper, or a Swiffer (Procter and Gamble) wet mop (SWM).

MATERIALS AND METHODS

This project was reviewed by the University of Oklahoma Health Sciences Center Institutional Review Board and by the University of Oklahoma Health Sciences Center Radiation Safety Office, which approved the project (approval 10023) with stipulations for controlled and contained spills. As part of the containment, the radiation safety office required the entire laboratory floor to be covered in absorbent pads except for ten 0.09 m^2 (1 ft^2) commercial vinyl (Standard Excelon Imperial Texture; Armstrong) tile sections, and less than 370 kBq (10 μCi) of ^{90}Y-RMs were to be used to contaminate each section. The 0.09 m^2 (1 ft^2) tile sections were contaminated and cleaned with each different method and are referred to as contamination sites.

Because the area of the laboratory approved for the project was quite small (~6.1 × 6.1 m [~20 × 20 ft]), construction of multiple half-value barriers for each contamination site was required to prevent crossover exposure readings from other contamination sites. Half-value layer calculations for ^{90}Y-RMs indicate that 1.9-cm (3/4 in) plywood would effectively block cross-contamination exposure. Four sheets of 1.9-cm (3/4 in) plywood were purchased, and resources from the University of Oklahoma Tom Love Innovation Hub were used to fabricate ten 0.28 m^2 (3 ft^2) plywood boxes. These boxes were made larger than the required 0.09 m^2 (1 ft^2) contamination sites so that the entire contamination site could be cleaned without interference from the plywood. All 10 boxes were set up with absorbent paper in the laboratory, and the radiation safety office reviewed the setup (Fig. 1).

FIGURE 1. Absorbent pads and 0.28 m^2 (3 ft^2) plywood sample boxes ready for controlled ^{90}Y-RM spill.

^{90}Y-RMs were donated from a local hospital, and a nuclear pharmacist drew 10 equivalent ^{90}Y-RM samples. Since a dose calibrator is difficult to use for a pure β-emitter such as ^{90}Y-RMs, especially for the kilobecquerel amounts used in this investigation, doses were drawn and the mass of each dose was measured and recorded. A microbalance was used to ensure that each dose contained approximately like masses, assuming the amount of ^{90}Y-RMs in each was comparable. Each donated vial of ^{90}Y-RM had a manufacturer-indicated activity concentration, which was not altered. We assumed that the specific concentration of a homogeneous solution of ^{90}Y-RMs in solution was approximately 1 g/mL; thus, an estimated activity of each syringe was calculated.

The contents of each syringe were carefully expelled into the center of a corresponding contamination site from a height of 1 cm and allowed to dry overnight. The following day, after donning gowns, gloves, and protective shoe covers, the investigators and radiation safety officers surveyed each contamination area with a Ludlum model 3 (serial number: 171990) Geiger counter with an attached Ludlum model 44-9 (serial number: PR 175216) pancake probe. Survey measurements were conducted at approximately 1 cm above the contamination site. The maximum exposure rates (mR/h) of the sites were measured and recorded as the precleaning maximum exposure rate.

After the precleaning exposure measurements, the contamination site was cleaned using damp paper towels by a single investigator; this individual was responsible for all cleaning throughout the investigation. Each contamination site was cleaned in a circular motion from the outside toward the center. The investigators and radiation safety officers surveyed the postcleaning sites with the Geiger counter, and the maximum postcleaning exposure rates were recorded (mR/h). All 10 samples from each contamination site were cleaned by the same investigator using the same cleaning method in 1 day. After the cleanup day, the lab was closed down, and all access was denied for 30 days for decay of the ^{90}Y-RMs (10 × 64.1-h half-life of ^{90}Y). Once this decay time passed, new samples of ^{90}Y-RMs were weighed and the cleanup procedure was repeated using contact paper and the SWM. The contact paper was paper with an adhesive underside. This adhesive side was pressed against the center of the contamination site and repeated in a circular fashion toward the outside of the contamination site. The SWM is a commonly available tool that has detachable wet cleaning pads attached. A new cleaning pad was used for each contamination site and was disposed of between contamination sites. The SWM was placed at the edge of the contamination site and was moved circularly toward the center of the contamination site. In total, 10 samples for each cleaning method were obtained.

The outcome variable of interest was the percentage decrease in exposure (mR/h) from each cleaning method. This percentage decrease is defined by Equation 1:

TABLE 1
Descriptive Statistics for Each ^{90}Y-RM Cleaning Method Used

Cleaning method	Label	*n*	Mean	SD	Median	Minimum	Maximum
Damp paper towels	Measured mass (mg)	10	64.9	5.2	64.0	58.0	76.0
	Estimated activity (μCi) of spill	10	1.8	0.1	1.7	1.6	2.1
	Percentage exposure decrease	10	98.1	2.5	99.0	91.7	99.9
	Precleaning exposure (mR/h)	10	102.0	59.2	70.0	50.0	200.0
	Postcleaning exposure (mR/h)	10	1.8	1.9	1.0	0.1	5.0
Adhesive paper	Measured mass (mg)	10	119.3	8.0	118.0	107.0	135.0
	Estimated activity (μCi) of spill	10	2.2	0.1	2.1	1.9	2.5
	Percent exposure decrease	10	72.8	20.8	78.2	29.6	92.5
	Precleaning exposure (mR/h)	10	105.0	24.9	105.0	55.0	140.0
	Postcleaning exposure (mR/h)	10	29.7	27.5	17.5	6.0	95.0
SWM	Measured mass (mg)	10	115.3	12.5	116.5	90.0	130.0
	Estimated activity (μCi) of spill	10	1.8	0.2	1.9	1.4	2.1
	Percentage exposure decrease	10	98.7	1.8	99.2	93.8	99.9
	Precleaning exposure (mR/h)	10	81.4	28.8	77.5	48.0	150.0
	Postcleaning exposure (mR/h)	10	1.0	1.5	0.5	0.1	5.0

Curie conversion factor: μCi × 37 = kBq.

$$\% \text{ exposure decrease} = \frac{\text{precleaning maximum exposure} - \text{postcleaning maximum exposure}}{\text{precleaning maximum exposure}} \times 100. \qquad \text{Eq. 1}$$

Descriptive statistics for mass, estimated activity, and percentage exposure decrease were computed among each cleaning method and reported. Because of the low sample size, nonparametric exact Kruskal–Wallis tests were used to determine differences in percentage exposure decrease among the 3 cleaning methods. Additionally, nonparametric Dwass, Steel, Critchlow, and Flinger multiple-comparison adjustments were used to examine individual method differences. Among methods that indicated no difference in percentage exposure decrease, the variability of each method was examined using nonparametric Ansari–Bradley tests of dispersion. All statistical tests were conducted assuming a 5% chance of a type 1 error, using SAS software (version 9.4).

RESULTS

Descriptive statistics among each cleaning type are presented in Table 1. Damp paper towels and the SWM were superior to adhesive paper (Fig. 2). Both damp paper towels and the SWM cleaned up a higher percentage than did adhesive paper ($P = 0.0006$ and $P = 0.0005$, respectively). However there was no significant difference between damp paper towels and the SWM ($P = 0.6826$, Fig. 3). Additionally, there was no difference in cleaning variability between damp paper towels and the SWM ($P = 0.2501$).

DISCUSSION

Both damp paper towels and the SWM cleaned up a higher percentage of ^{90}Y-RMs than did adhesive paper. However, between damp paper towels and the SWM there was no significant difference in decontamination amount or variability of ^{90}Y-RMs. This finding indicates that both methods consistently cleaned up the same amount, with little difference in the statistical variability of cleaning. However, when descriptively examining the cleanup method's box plot (Fig. 3), one might conclude that with further investigation using a larger sample size, the SWM might provide a more consistent method of cleanup. The manufacturer's recommended method cleaned well; however, we suggest that the SWM could be explored further as a cleaning method because it may be a more efficient and ergonomic option for large areas, such as the one encountered at the local clinic.

One strength of the study was that the spill was contained. Knowing where the contamination was gave the investigators the opportunity to clean up the contamination to the best of their ability. This is also a major weakness of the study. Realistically, an individual may not know the spill boundaries, nor would the spill have plywood boxes surrounding the area to help keep the microspheres from bouncing or spreading. These enclosure boxes, although required to prevent cross

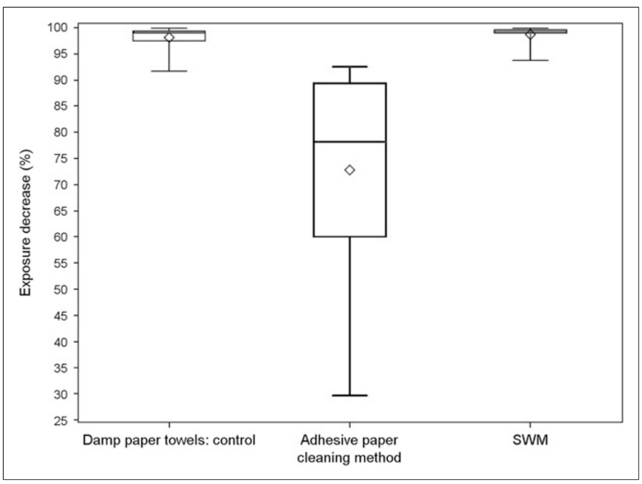

FIGURE 2. Percentage exposure decrease among all ^{90}Y-RM cleaning methods.

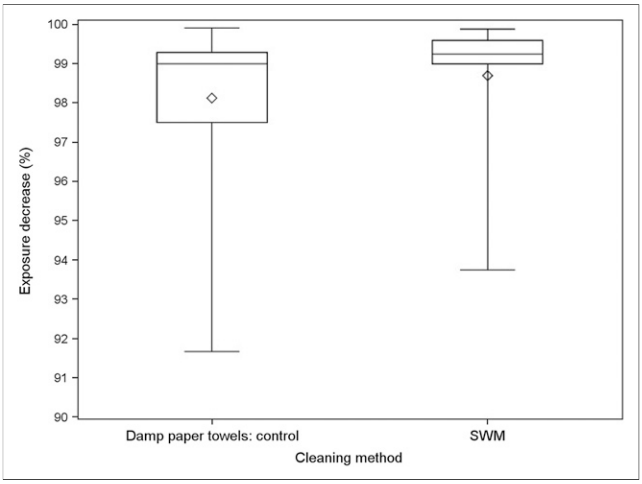

FIGURE 3. ^{90}Y-RM postdecontamination percentage exposure decrease between damp paper towels and SWM (Wilcoxon $P = 0.6826$, Ansari–Bradley $P = 0.2501$).

exposure, also possibly prohibited movement of the dry spheres that may be evident in clinical situations. This could falsely elevate estimates for effective cleaning percentages. Hence, we would like to further explore the possibility of dry ^{90}Y-RMs spread by air-handling systems and examine cleaning methods for that type of situation. Another limitation to the study was the low sample size; however, statistically nonparametric methods were used to limit the assumptions that parametric statistics assume with small samples. Even with nonparametric approaches to the analysis, the variability with lower sample sizes is larger, making differences harder to show. A post hoc power analysis indicates that we are powered between 84.5% and 99.8% for the difference test between damp paper towels and the SWM versus adhesive paper. However, we are only 10%–20% powered to detect differences between the SWM and damp paper towels, since their observed difference was so small. A sample size of 300–400 trials would be required to show a difference between the SWM and damp paper towel, assuming the observed variabilities. However, with both these methods being near 100%, even with this small sample we are confident these methods are adequate for cleanup. Another limitation to the study is that we could not directly measure the activity of the ^{90}Y-RMs. Given the low activities of ^{90}Y-RMs approved for this investigation, we were unable to measure the activity in a dose calibrator. Furthermore, charged particles such as β-emitters interact constantly while inside the dose calibrator, making measurement of their activity difficult and prone to error (*10*). Additionally, ^{90}Y-RMs are a higher-energy β-emitter, meaning the particles are moving more quickly and interacting with fewer molecules while they are in the gas chamber of a dose calibrator (*10*). We did our due diligence in attempting to use the manufacturer's specified activity concentration and measured mass of the ^{90}Y-RM sample to estimate activity for each trial. However, small differences in the activity of the ^{90}Y-RMs in the contamination sites could bias results and could not be controlled in this experiment. Another limitation was that each spill did not contain exactly the same amount of microspheres in solution. Having the same number of microspheres in each solution would lessen variability in each trial but would be difficult, if not impossible, to attain. Lastly, we are limited to the environment in the lab at the time of cleanup. We decided to decontaminate each sample area with the same method on 1 day. This methodology could have opened the door to unmeasured and unknown environmental issues for that particular set of observations. We based this decision on radiation safety requirements and simplicity for data collection while working with these safety requirements. Unknown environmental confounders could bias estimates in either direction, thus limiting the study design.

This study might be recreated and performed with ^{90}Y-labeled glass microspheres (TheraSphere; Boston Scientific). The study might also be performed with a larger sample size and might test cleaning methods different from those used in the current investigation. The idea that ^{90}Y-RMs may spread through air circulation when out of solution might also be explored further.

CONCLUSION

The results of this investigation demonstrate that damp paper towels and the SWM are superior to adhesive paper for decontaminating dry ^{90}Y-RMs no longer in suspension. These findings help to confirm the manufacturer's recommendation. Additionally, these findings indicate a possible alternative, the SWM, to the manufacturer's recommendation. This evidence of effective cleaning methods, including the manufacturer's recommendation, should be considered when establishing department protocols for decontamination procedures.

DISCLOSURE

No potential conflict of interest relevant to this article was reported.

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