The Effectiveness of Ionized Water as a Radiodecontaminant for ^{99m}Tc-Pertechnetate and ^{131}I

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Immediate and complete decontamination procedures are essential to restore the functionality, precision, accuracy, and safety of tests done within the nuclear medicine facility. Decontamination is a simple procedure that, if performed correctly, effectively reduces exposure brought about by spills. The determination of a suitable radiodecontaminant may be beneficial in decontaminating patient beds, collimators, probes, and machines. **Methods:** Two surface types (i.e., stainless steel and vinyl) were contaminated with a predetermined activity of $^{99m}TcO_4$ and ^{131}I. After air drying, static images of the contaminated surfaces were obtained using a γ-camera to determine the activity counts on each surface before and after decontamination procedures. Different decontaminant contact times (i.e., 5, 10, and 15 min) were used for each decontaminant (i.e., ionized water, 10% bleach, detergent solution, a negative control [no treatment], and a positive control [a commercial radiodecontaminant]). Differences between the effectiveness of ionized water and the other decontaminants against $^{99m}TcO_4$ and ^{131}I at different contact times were measured, and the mean percentage activity removed (%AR) was compared using 2-way ANOVA at the 0.05 level of significance. **Results:** $^{99m}TcO_4$ and ^{131}I contaminants had %ARs of greater than 80% after 5 min of contact time for ionized water and the other decontaminants. At 15 min contact time, ionized water was not as effective as the other decontaminating agents for ^{131}I on vinyl surfaces. There was no significant interaction between the effects of the decontaminants (%AR) and the contact times with stainless steel and vinyl for either $^{99m}TcO_4$ or ^{131}I. **Conclusion:** For $^{99m}TcO_4$ and ^{131}I on stainless steel surfaces, ionized water is an effective decontaminant at contact times of 5, 10, and 15 min. For $^{99m}TcO_4$ on vinyl surfaces, ionized water is also an effective decontaminant at contact times of 5, 10, and 15 min. For ^{131}I on vinyl surfaces, ionized water is as effective as 10% bleach, detergent solution, and a commercial radiodecontaminant at contact times of 5 and 10 min.

Key Words: radioactivity decontamination; nuclear medicine technology; radiation safety; ^{99m}Tc pertechnetate; ^{131}I; ionized water

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Contamination and exposure to ionizing radiation from spills may cause detrimental health effects. Exposure to ionizing radiation is an occupational risk that may lead to radiation-induced cancer, such as leukemia, skin cancer, and thyroid cancer (*1–4*). Repeated exposure to radioactive contaminants may cause a worker's thyroid to absorb high radiation doses and increase the risk of developing thyroid cancer (*5*).

When a piece of equipment or a workstation is contaminated by generated radioactive sources such as $^{99m}TcO_4$ and ^{131}I, immediate clean-up is necessary to restore the equipment's utility or the safety of the workstation. Rapid and complete decontamination is essential to restore the functionality, precision, and accuracy of diagnostic tests done within the nuclear medicine facility. The goal of the decontamination process is to completely remove the radioactive material without spreading it and damaging contaminated workspaces (*6*). A specific decontaminant must be identified; however, no specified, standardized agent is used in nuclear medicine facilities.

Decontamination procedures are essential and should be done immediately to ensure that there is no unnecessary exposure of nuclear medicine patients and staff. Furthermore, preventing excessive radiation exposure and promptly decreasing the probable impact of ionizing radiation on human health and the environment are two measures for radiation protection. Decontamination is a simple procedure that, if performed correctly, effectively reduces exposure brought about by spills. Use of an efficient decontamination protocol by staff familiar with standardized decontamination practices contributes to a facility's radiation safety procedures and assures other workers that no radioactive material has been accidentally released into their environment.

This study determined the effectiveness of ionized water as compared with 10% bleach, a detergent solution, a negative control (no treatment), and a positive control (Radi-Clean, a commercial radiodecontaminant; Capintec) as a radiodecontaminant against fixed minor spills of 111 MBq of $^{99m}TcO_4$ and 37 MBq of ^{131}I using contact times of 5, 10, and 15 min. The spills were placed on continuous vinyl and stainless steel surfaces, the facility's most common work surfaces.

Ionized water as a radiodecontaminant has not been comprehensively explored; however, because of the noticeable increase in decontamination rate with the increase of the pH of a solution (*7*), it is theorized that ionized water may be an effective radiodecontaminant.

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MATERIALS AND METHODS

Before data collection, official letters secured all necessary clearances from the administration of the Baguio General Hospital and the Medical Center–Center for Diagnostic and Therapeutic Nuclear Medicine. Despite the absence of human participants, the research protocol was submitted for review to the Saint Louis University Research Ethics Committee and subsequently was approved with protocol number SLU-REC 2022-012 on April 4, 2022.

The 10% bleach solution (Green Cross, Inc.) was prepared by adding 10 parts of sodium hypochlorite to 90 parts of distilled water. The detergent solution (Unilever) was prepared by dissolving 100 g of powder detergent in 1,000 mL of water. The ionized water was prepared with 99% distilled water ionized with 1% potassium carbonate, or a ratio of 99:1. The positive control, Radi-Clean, was used as commercially supplied. Stainless steel and vinyl surfaces measuring 10 × 10 cm (4 × 4 in) served as the contamination surfaces. Absorbent pads were placed beneath them to avoid accidental contamination from the experiment.

Each surface was placed on a steady countertop to avoid unequal flow of the aqueous solution. The 111-MBq dose of $^{99m}TcO_4$ and 37-MBq dose of ^{131}I, determined by a CRC-55tw Capintec dose calibrator (Mirion Technologies), were delivered onto the surface using a needleless tuberculin syringe and allowed to air dry. The contaminated surfaces were placed under a Symbia Intevo Bold (Siemens Healthineers) dual-head γ-camera using an all-purpose low-energy collimator and read for 2 min to obtain radioactivity counts. After 2 min, the counts were recorded and served as a baseline for the initial contamination activity of the surface.

The usual decontamination procedures of the facility's radiation safety protocol were done, and the times for which each decontaminant contacted the surface were set to 5, 10, and 15 min. Because the protocol recommends wet decontamination, the surfaces were misted with the decontaminants and left for the indicated times; the decontaminants were then dried with absorbent paper, starting from the edges and proceeding to the middle. Afterward, the surface was measured again with the same γ-camera. Activity counts were taken at a 13-cm (5.11-in) distance from the surface.

All experiments were done in triplicate. The activity before and after decontamination was expressed as counts, the decontamination effectiveness was expressed as a decontamination factor (DF), and then the percentage of radioisotope activity removed (%AR) was determined. The DF is the ratio of activity before decontamination (A) to activity after decontamination (B) (*8*):

$$\mathrm{DF} = \frac{A}{B}.$$

Decontamination effectiveness is indicated by a %AR higher than that of the negative control or no treatment. The %AR was determined using the following formula:

$$\%\mathrm{AR} = \left(1 - \frac{1}{\mathrm{DF}}\right) \times 100.$$

Statistical Analysis

To determine whether there was a difference in effectiveness between ionized water and the other decontaminants at different contact times, mean %AR was compared using 2-way ANOVA at a 0.05 level of significance. A simple main-effect analysis was done if a significant interaction between the decontaminants and the contact time was found. If there was no significant interaction but there was a significant difference, multiple comparisons using the Tukey honest-significant-difference post hoc test were done.

TABLE 1
Effectiveness of Decontaminants Against ^{99m}Tc-Pertechnetate

Decontaminant	Contact time (min)	%AR: Stainless steel surface	%AR: Vinyl surface
Negative control	5	9.5	5.4
	10	11.1	5.0
	15	12.0	5.3
Ionized water	5	87.3	97.8
	10	88.0	95.6
	15	87.4	96.7
10% bleach	5	89.2	97.6
	10	86.8	96.9
	15	94.9	97.6
Detergent solution	5	84.2	96.7
	10	86.1	93.8
	15	91.3	92.6
Positive control	5	89.6	95.7
	10	90.9	95.6
	15	89.5	96.6

RESULTS

Pre- and postdecontamination readings and the %AR for the surfaces against the decontaminants and contact times were documented. Sample γ-camera images are shown in Supplemental Figures 1–4 (supplemental materials are available at http://jnmt.snmjournals.org). Data averages for $^{99m}TcO_4$ against stainless steel and vinyl surfaces are in Table 1, with graphical representations available in Supplemental Figure 5, and data averages for ^{131}I against stainless steel and vinyl surfaces are in Table 2, with graphical representations available in Supplemental Figure 6.

TABLE 2
Effectiveness of Decontaminants Against ^{131}I

Decontaminant	Contact time (min)	%AR: Stainless steel surface	%AR: Vinyl surface
Negative control	5	1.2	0.7
	10	0.9	0.5
	15	0.9	0.4
Ionized water	5	96.9	93.5
	10	95.3	89.8
	15	96.1	89.5
10% bleach	5	95.9	90.8
	10	97.6	91.9
	15	96.3	91.8
Detergent solution	5	91.8	92.9
	10	97.4	93.1
	15	95.4	93.1
Positive control	5	93.5	92.5
	10	95.6	92.1
	15	93.1	92.7

The $^{99m}TcO_4$ and ^{131}I contaminants had %ARs greater than 80% after 5 min of contact with ionized water and all the other decontaminants. The %ARs for all agents at other contact times manifested effective decontamination of $^{99m}TcO_4$ on the stainless steel and vinyl surfaces (Table 1), since the values were higher than the %AR for the negative control. The %AR from the $^{99m}TcO_4$-contaminated stainless steel surfaces increased as the contact times increased from 5 to 10 to 15 min. However, the positive control showed no change in %AR with an increase in contact time.

The results for ionized water as a radiodecontaminant for ^{131}I on stainless steel surfaces were promising, because there was almost no change in %AR (from 95.3% to 96.1%) when the contact time was increased from 10 to 15 min, respectively. Moreover, ionized water was the fastest-acting decontaminant, removing 93.5% of the ^{131}I radioactivity in 5 min on a vinyl surface and 96.9% in 5 min on a stainless steel surface (Table 2).

Two-way ANOVA analyzed the effect of the decontaminants and the 3 contact times on the %AR for $^{99m}TcO_4$ on stainless steel and vinyl or on the %AR for ^{131}I on stainless steel. There was no significant interaction between the effect of the decontaminants and the contact times for $^{99m}TcO_4$ on stainless steel ($F_{8,30} = 1.177, P = 0.345$), for ^{131}I on stainless steel ($F_{8,30} = 1.685$, $P = 0.143$), or for $^{99m}TcO_4$ on vinyl ($F_{8,30} = 0.351$, $P = 0.938$). The statistical comparisons are available in Supplemental Table 1. Moreover, there was no statistically significant difference in the main effect of contact time. The main effect of decontaminants, however, was statistically significant, with a P value of less than 0.001. A Tukey post hoc test revealed significant pairwise differences between decontaminants and the negative control. No significant pairwise differences were found among the decontaminants. The effectiveness of ionized water was equal to that of the other agents on stainless steel and vinyl contaminated with ^{131}I and $^{99m}TcO_4$ for all 3 contact times.

For ^{131}I on vinyl, the P value for comparison of the %AR of the decontaminants was less than 0.001, which indicates a significant difference. The effect of contact time with the decontaminants was also significant, at a P value of 0.380 (Supplemental Table 2). Further, the interaction effect of the decontaminant and the contact time was also significant ($P = 0.015$), indicating that the relationship between decontaminant and %AR may be dependent on contact time.

A simple main-effect analysis was done to determine the mean difference in %AR between decontaminants at each contact time and the mean difference in %AR among contact times. For ionized water, the simple effect of contact time was statistically significant, with a P value of less than 0.001. A pairwise comparison among the estimated marginal means of the different contact times for ionized water showed significant differences in %AR between 5 and 10 min, 5 and 15 min, and 10 and 15 min. This finding implies that for different contact times, there is a significant difference in the effectiveness of ionized water in decontaminating ^{131}I on vinyl.

The mean %AR for ionized water against ^{131}I on vinyl indicates that effectiveness decreases as contact time increases. All decontaminants were effective in decontaminating ^{131}I on vinyl at both 5 min and 10 min, but at 15 min there were statistically significant differences (all $P < 0.001$) from 10% bleach, detergent, the positive control, and the negative control. Ionized water was not as effective as 10% bleach, detergent, or the positive control when exposed for at least 15 min but was still significantly more effective than the negative control.

DISCUSSION

Proper decontamination procedures effectively remove and reduce exposure from spills of common radioactive materials. It is essential to use a suitable, convenient, and fast-acting radiodecontaminant to immediately clear spills and avoid unnecessary radiation exposure of staff and patients.

The %AR results of our study revealed that all agents, including ionized water, effectively removed radioactivity from stainless steel surfaces contaminated with ^{131}I and $^{99m}TcO_4$. These results corroborate those of Ruhman et al. (*9*), who used water and soap, bleach, a commercial glass cleaner, and a commercial decontaminant on $^{99m}TcO_4$. Our results are also similar to those of Eroğlu and Aksakal (*7*), who used commercially available radiodecontaminants (e.g., Radiacwash; Biodex) and specially developed multipurpose cleaners on ^{131}I, finding almost no differences among them. Their study (*7*) showed that approximately 100% of the radioactivity was removed in the first 5 min from nonporous surfaces such as stainless steel. Other decontamination procedures for other radioactive materials from laboratory surfaces such as epoxy, acrylic resin, vinyl, and stainless steel showed that the procedures were most effective on stainless steel and vinyl (*9,10*).

A wet method of decontamination would remove dry ^{131}I contaminants within a few minutes, provided it is performed a few minutes after detection using nonspecific cleaners (*11*). However, use of a wet method for removal of liquid contaminants (i.e., ^{131}I solution) may result in a wash-in effect, by which the %AR during decontamination decreases over time (*12,13*). This effect may explain the decrease in the %AR of ^{131}I for ionized water when it reached a contact time of 15 min. To avoid a wash-in effect, the contact time should be kept within 10 min (*14*).

CONCLUSION

Compared with 10% bleach, a detergent solution, and a commercial radiodecontaminant, ionized water is an effective decontaminant for $^{99m}TcO_4$ and ^{131}I on stainless steel and vinyl surfaces for contact times of 5–15 min. Ionized water is also as effective as 10% bleach, a detergent solution, and a commercial radiodecontaminant against ^{131}I on vinyl surfaces for contact times of 5–10 min. We recommend that ionized water be applied for 5 min to decontaminate $^{99m}TcO_4$ and ^{131}I spills on common nuclear medicine laboratory surfaces. We also recommend studies of shorter contact times with ionized water to establish the speed of decontamination. Decontamination should be done immediately to prevent exposure of patients and staff, and decontamination guidelines should be added to radiation protection programs. The results of this and similar studies can serve as a basis for identifying a safe, suitable, sufficient, and fast-acting radiodecontaminant to clear contamination and preserve the integrity of surfaces.

DISCLOSURE

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

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KEY POINTS

QUESTION: How effective is ionized water as a radiodecontaminant for $^{99m}TcO_4$ and ^{131}I on vinyl and stainless steel surfaces when kept in contact with the contamination for 5, 10, and 15 min?

PERTINENT FINDINGS: Ionized water is an effective decontaminating agent for $^{99m}TcO_4$ and ^{131}I for vinyl and stainless steel surfaces at any given contact time of at 5, 10, and 15 min as indicated by a %AR higher than that for the negative control or no treatment.

IMPLICATIONS FOR PATIENT CARE: Ionized water may be used as an alternative nontoxic, noncorrosive decontaminant for minor $^{99m}TcO4$ and ^{131}I spills on vinyl and stainless steel surfaces.

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