

A Precaution for Minimizing Radiation Exposure from Iodine Vaporization

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Therapeutic sodium iodide solutions have recently been reformulated by manufacturers to reduce iodine vaporization. Even so, chlorine in tap water can oxidize iodide to iodine and therefore contribute to the technologist's exposure to airborne iodine. Use of distilled water instead of tap water for preparation of doses can greatly reduce this radiation hazard.

Oral administration of therapeutic doses of iodine-131 has been described as one of the most hazardous procedures facing the hospital health physicist (1). Airborne I-131 activity in excess of the maximum permissible concentration has been reported in nuclear medicine laboratories (2) after handling of therapeutic amounts of I-131 or in patients' room after administration of doses (1,3). Loss of as much as 4 mCi of iodine as vapor from a 200-mCi dose has been observed, as well as iodine accumulation in the thyroid gland of a technologist handling doses (4,5). This vaporization problem is obviously a matter of concern in radiation protection.

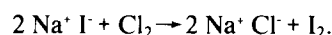
As originally noted by Howard (6), dissolved oxygen can in an acid solution oxidize iodide to the more volatile iodine. Vapor accumulation in a vial containing an I-131 solution will be released when the vial is opened. Oxygen generated by the radiolysis of water, because of the intense radiation flux within the small volume of liquid in a vial, no doubt also contributes to this effect.

In response to this problem, one manufacturer (Mallinckrodt Inc.) has issued a bulletin on safety precautions to be observed when vials are opened (7). This company has also reformulated its therapeutic solutions to contain sodium bisulfite as an antioxidizing agent and sodium diphosphate buffer, pH 7.5-9 (8). These measures reportedly cause a significant reduction in the release of iodine vapor from opened vials.

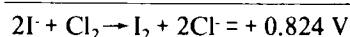
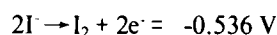
On one occasion our nuclear medicine department found an accumulation of approximately 50 nCi in a technologist's thyroid the day after he had prepared a therapeutic dose. Tap water was used to dilute this particular dose. We switched to the use of distilled deionized water for dose preparation and have not had a recurrence of this incident; subsequent thyroid monitoring has revealed only background counts. Much attention has been focused on vapor emanating from opened vials. We have

found, however, that the chlorine in tap water can be an additional cause of iodine vaporization. Fortunately, it is a cause that is quite easily controlled.

When an I-131 solution is diluted with tap water, the chlorine present can oxidize the iodine (9) by this reaction:



The net oxidation potential of the reaction:



is positive (10), and it will therefore occur spontaneously. The elemental iodine that is formed will quickly vaporize and be an additional source of unnecessary exposure to the technologist.

Materials and Methods

To test this hypothesis, an experiment was devised to compare relative rates of vaporization from tap water and distilled water. A large glass jar was used to contain any iodine vapor emanating from a dilute solution containing sodium iodide. A thyroid uptake probe with a flat field

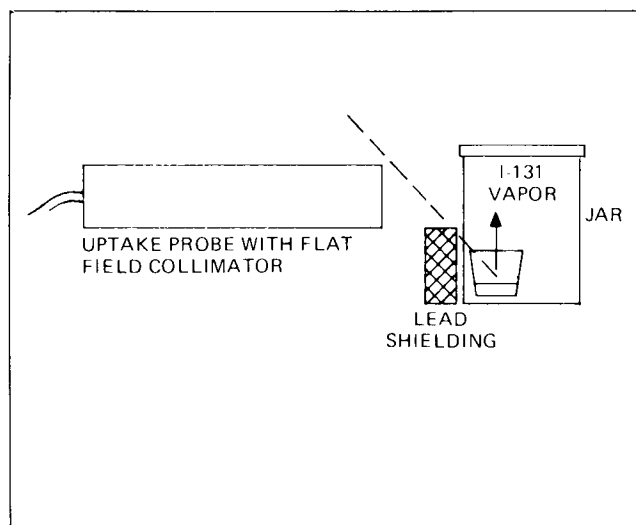


FIG. 1. Cup contains iodide in solution in 50 ml of either tap water, distilled water, or distilled water plus 1-ppm Cl_2 sealed inside large jar. Uptake probe was used to detect any I-131 vapor that might accumulate in airspace above cup. Activity in cup itself was shielded from counter.

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collimator was used to detect iodine vapor in the jar. Prior to use, the probe was calibrated with a Cs-137 source, and an appropriate window setting for I-131 was used. A plastic cup containing 50 ml of either tap water, distilled water, or distilled water plus 1 parts per million (ppm) chlorine was used; 900 μ Ci of NaI solution (pH 8.0, specific activity 25 mCi/ml), containing sodium bisulfate as an anti-oxidant, was added. A 2-in. thick lead brick was used to shield the iodine solution itself, so that only counts caused by iodine vapor in the airspace of the jar over the solution would be recorded (Fig. 1). A plot of counting rate versus time represented the relative rates of vaporization.

Prior to each test, a background count was taken and subtracted from all subsequent counts. The sodium radioiodide was placed in the solution to begin each test. The jar was sealed immediately and counts were taken at 5-min intervals. Care was taken to insure that the geometry was identical for each trial.

Results are shown in Fig. 2; each point represents the average of duplicate tests.

To obtain quantitative rather than qualitative results, another study was done using activated charcoal to trap any iodine vapor. As shown in Fig. 3, a sodium iodide solution was placed in a jar containing activated charcoal. The solution was momentarily removed at regular intervals so the charcoal could be counted. As before, identical geometry was used for each test, appropriate corrections were made for background counts, and tests were done in duplicate. Counts recovered in the charcoal were converted to activity by comparison with a known standard. Results are shown in Fig. 4.

Results and Discussion

Figures 2 and 4 both show a significant difference between the vaporization rates from tap water and distilled water. In Fig. 2, the difference is evident within the first few minutes of the study. Even when doses are prepared and immediately administered to the patient, use of distilled water can reduce the technologist's exposure to airborne iodine.

This difference is attributed predominantly, although not necessarily entirely, to the effect of chlorine. In Fig. 2, the distilled water with added chlorine was included as a control for any possible chemical pollutants in tap water that might act as oxidizing agents (peroxides, quinones, etc.). This solution contained a chlorine concentration equal to that of the tap water but with none of the possible chemical contaminants. The measured vaporization rate turned out to be almost identical to tap water, showing that the difference between tap and distilled water is due to the presence of 1-ppm chlorine—not to the polluting chemicals in tap water.

Some of the oxidation can be attributed to dissolved oxygen; however, this would be equally present in the distilled water and in the distilled water plus chlorine—

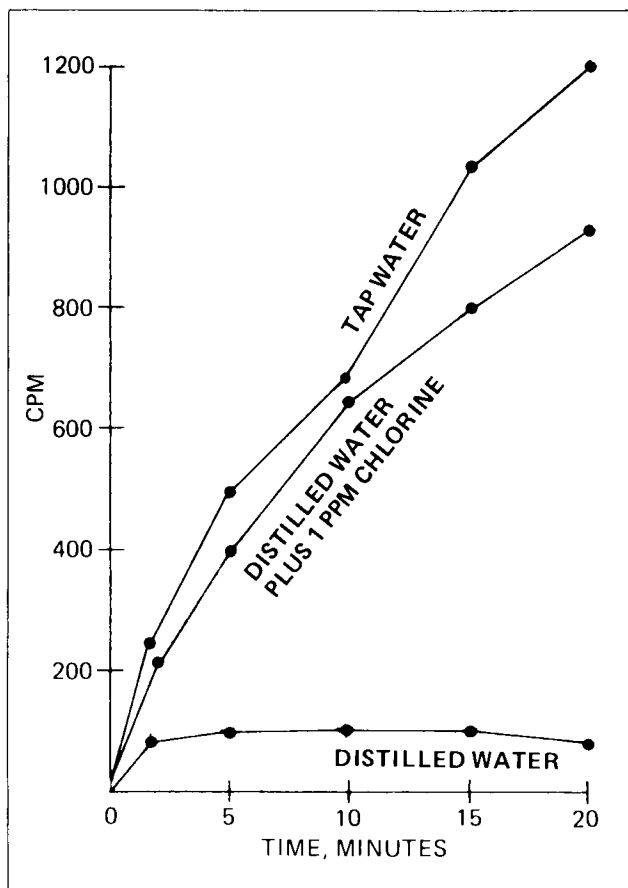


FIG. 2. Vaporization was faster from tap water than from distilled water. Chlorine added to distilled water gives almost identical vaporization rates from tap water.

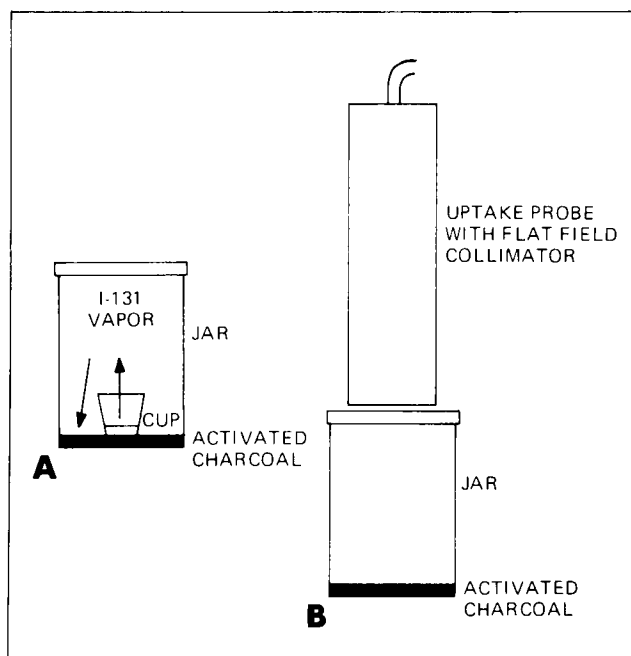


FIG. 3. (A) Cup contains sodium iodide solution sealed in jar containing activated charcoal; any vapor released was absorbed onto the charcoal. (B) Activity trapped by charcoal was counted at intervals.

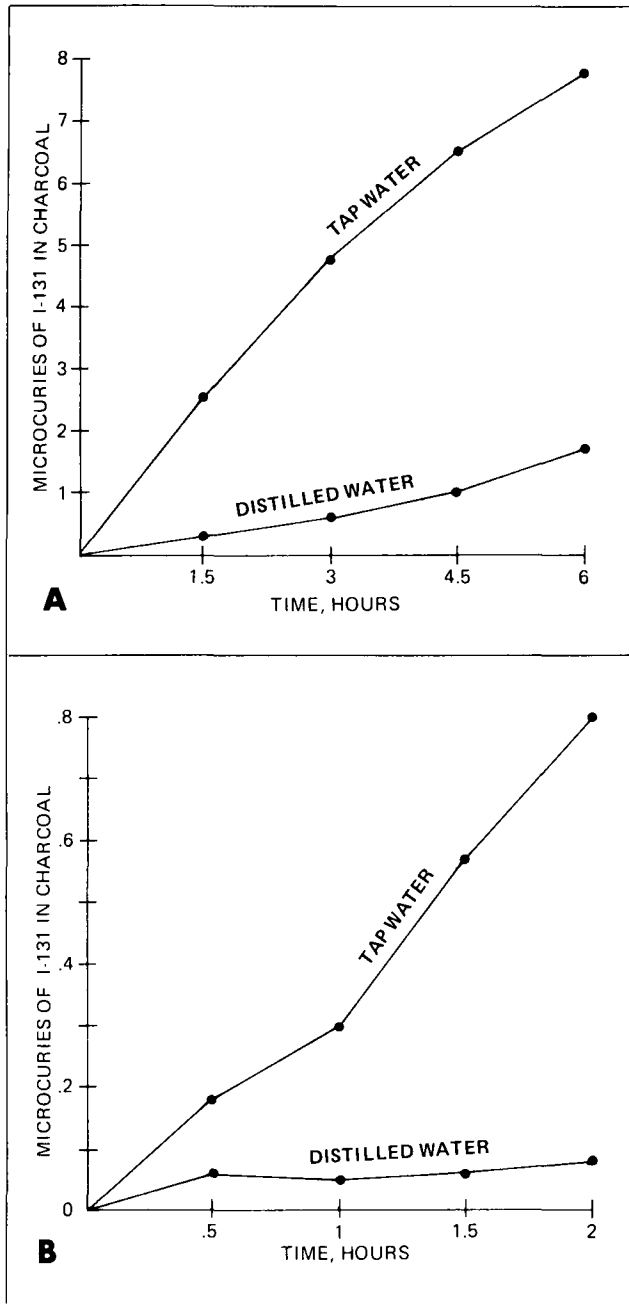


FIG. 4. (A) As in Fig. 2, vaporization was faster from tap than distilled water. (B) With reformulated sodium iodide solution containing buffer and antioxidizing agents, total vaporization was considerably reduced; however, chlorine in tap water caused tenfold difference in amount of vaporization.

making the difference between the two due entirely to the chlorine. The tap and distilled water solutions both had a pH of 6.75, so the difference in vaporization is not due to a difference in acidity.

The study shown in Figs. 3 and 4 was originally performed with the acidic Mallinckrodt sodium iodide and was then repeated after the reformulated product became available. Figure 4 (A and B) is a "before and after" comparison. The total amount of vaporization in B is less than

in A—from both tap and distilled water. The more basic pH and the sodium bisulfite to some extent reduce the total amount of oxidation. However (Fig. 4B), even with the buffer and antioxidant present, the chlorine effect has not been eliminated and an almost tenfold difference in vaporization rate still occurs. This is not a criticism of the manufacturer but an indication that use of distilled water is still a useful precaution, even with the new formulation.

The Environmental Protection Agency regulations require all communities to have at least 0.2-ppm chlorine in their drinking water (11). One ppm is added to the water in Memphis, since our water comes from artesian wells and is relatively pure to begin with; many communities add considerably more (12). Iodine vaporization caused by chlorine, therefore, can be a problem anywhere in the United States, and in communities with heavily chlorinated water it could be more extreme than described here.

Recommendations

Precautions for safe handling of iodine solutions have already been suggested (2,5,6,8). They include:

- storing at room temperature or cooler;
- minimizing frequency and duration of opening of vials;
- opening vials only in a fume hood;
- wearing rubber gloves while handling iodine containers and solutions;
- wipe testing of containers;
- bioassaying personnel by monitoring thyroid uptake; and
- minimizing contact with therapy patients.

Based on the results reported here, another precaution should be added to this list: using only distilled water to prepare therapeutic doses of I-131. All these recommendations are easily implemented.

The simple precaution described here will further reduce a technologist's exposure to iodine vapor. Consider that the breathing rate for the "standard man" for occupational exposure estimates is 2×10^4 ml of air/min (13), and absorption of iodine through the lungs is nearly 100% efficient (14). The technologist exposed to vapor can accumulate a significant amount of iodine in a short time. For example, exposure to the maximum permissible concentrations (MPC = 9×10^{-9} μ Ci/ml) of iodine vapor could result in accumulation of 9×10^{-9} μ Ci/ml $\times 2 \times 10^4$ ml/min $\times 60$ min $\times 100\%$ = 0.011 μ Ci/hr. Airborne concentrations greatly in excess of the MPC have been reported. Once absorbed, iodine follows its normal biorouting to the thyroid, where it delivers a radiation dose of 1.5 rads/ μ Ci (15). For the technologist, this is an unnecessary and easily avoided radiation dose. When one considers that, additionally, the technologist is being exposed to gamma radiation while handling radioiodine, simple and easily implemented radiation exposure reduction procedures should be readily practiced.

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