The Transition from Technegas to Pertechnegas

Ernest M. Scalzetti and George M. Gagne

Department of Radiology, SUNY Health Science Center at Syracuse, Syracuse, New York

We set out to determine the oxygen concentration of the argon-oxygen mixture in the technegas generator where technegas-like behavior changes to pertechnegas-like behavior which allows [^{99m}Tc]pertechnetate to enter the solution. **Methods:** We prepared radioaerosols analogous to technegas and pertechnegas, with oxygen concentrations between 0% and 5%. They then were examined by thin-layer chromatography using saline as a solvent to measure the amount of [^{99m}Tc]pertechnetate moving with the solvent front as a function of oxygen concentration. **Results:** The amount of mobile pertechnetate markedly increased when the radioaerosols were created in an atmosphere containing between 0.1% and 0.2% oxygen. The transition from technegas-like to pertechnegas-like behavior occurs when the oxygen-argon gas mixture contains lower concentrations of oxygen than those used in the preparation of pertechnegas. **Conclusion:** Argon intended for the preparation of technegas should contain no more than 0.1% oxygen.

Key Words: technegas; pertechnegas; technetium-99m-pertechnetate; argon; radioaerosol

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Technegas is a fine, dry aerosol of ^{99m}Tc-labeled carbon articles (*1*). It is created in a proprietary generator (Technegas Generator, Tetley Technologies, Sydney, Australia) by the electrostatic heating of a graphite crucible in which a saline solution of [^{99m}Tc]pertechnetate has been placed. The crucible is heated in an inert atmosphere of pure argon. After generation of the aerosol, it is dispersed in a lead-lined chamber from which it can be administered to a patient by inhalation. Technegas has proved to be a valuable agent for lung ventilation imaging, primarily because its radioactive component remains in the lungs, presumably on the epithelial surface of the airways and alveoli. This characteristic permits ventilation images to be obtained from an arbitrary number of views.

Pertechnegas, a close relative of technegas, is created under the same conditions as is technegas, except that the atmosphere in which the crucible is heated contains a mixture of 3%–5% oxygen in argon (*2*). The resulting radioaerosol distributes itself in the lungs just as technegas does, but its radioactive component crosses the alveolar-capillary membrane and appears in the circulation as [^{99m}Tc]pertechnetate (*2,3*).

We used an in vitro model to determine the oxygen concentration of the argon-oxygen mixture where technegas-like behavior changes to pertechnegas-like behavior, which allows [^{99m}Tc]pertechnetate to enter the solution.

MATERIALS AND METHODS

Aerosol Generation

A standard graphite crucible was placed between the electrodes of the technegas generator. The well in the crucible was washed with ethanol and then loaded with approximately 500 MBq of [^{99m}Tc]pertechnetate. A single simmering cycle was performed, followed by a burn cycle which generates technegas.

Argon sources containing oxygen concentrations of 0.0%, 0.02%, 0.05%, 0.1%, 0.2%, 0.5%, 1.0%, 2.0%, 3.0% and 5.0% (Ultra-Spec Gases, Evans City, PA; Haun Welding and Specialty Gases, Syracuse, NY) were used to provide the atmosphere for the burn cycle. The oxygen contents of the gas mixtures were assayed by the suppliers; particularly the oxygen contained in the 0.1% mixture was found to be 0.103%, and the oxygen in the 0.2% mixture was 0.210%. The pure argon source (0.0% oxygen) is ordinarily used to generate technegas, and the argon source that contains 3.0% oxygen is ordinarily used to generate pertechnegas.

The generator was reset after the burn cycle and the purge cycle was initiated which drives the aerosol through the exhaust port of the generator. The crucible was then discarded.

Aerosol Collection

The exhaust port of the generator is fitted with a plastic housing that contains a merino wool filter. We inserted a thin plastic envelope in the exhaust stream, just prior to the wool filter. The envelope is designed to protect a silica gel strip from exposure to the particles of the radioaerosol, except for a small aperature that serves as the origin for subsequent chromatography. A fresh envelope was used for each strip to prevent cross-contamination.

Chromatography

Each silica gel strip (ITLC Strips, Gelman Sciences, Ann Arbor, MI) was developed in isotonic saline. The strips were then divided into four equal parts: one containing the origin, one containing the solvent front and two intervening segments. Each segment was assessed for radioactivity in an automated gamma scintillation counter (LKB 1280 Ultragamma). As a control, chromatography was performed as described above after placing [^{99m}Tc]pertechnetate at the origin of silica gel strips.

RESULTS

When pertechnegas was prepared by standard methods, the behavior of its radioactive component was similar to the [^{99m}Tc]pertechnetate that was used as a control. When

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For correspondence or reprints contact: Dr. Ernest M. Scalzetti, MD, Dept. of Radiology, SUNY Health Science Center at Syracuse, 750 East Adams St., Syracuse, NY 13210.

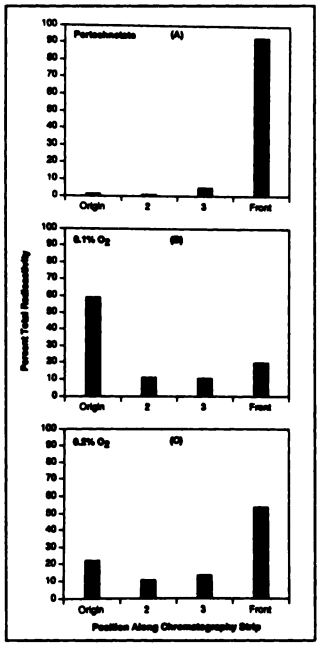

FIGURE 1. Average radioactivity in the segments of the silica gel strips, as a percentage of the total activity of each strip. Along the abscissa, origin indicates the chromatographic origin, front indicates the segment of the chromatography strip that contains the solvent front, and 2 and 3 indicate the two intervening segments of the strip. (A) The [^{99m}Tc]pertechnetate controls. (B) The aerosol prepared with an oxygen concentrations of 0.1%. (C) The aerosol prepared with an oxygen concentration of 0.2%.

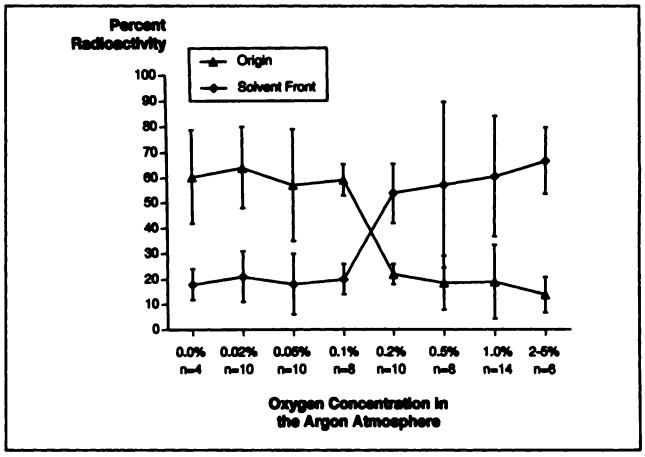

FIGURE 2. Percent radioactivity as a function of oxygen concentration for the first and last (origin and solvent front) segments of the chromatography strips. The error bars indicate 95% confidence intervals for each measurement. The number of experiments that contribute to each measurement are presented below each oxygen concentration label. The crossover occurs between the 0.1% and 0.2% oxygen concentrations.

technegas were prepared by standard methods, the great majority of the ^{99m}Tc label was confined to the origin, although approximately 20% of the ^{99m}Tc migrated with the solvent front.

An abrupt transition from technegas-like to pertechnegas-like behavior was observed between oxygen concentrations of 0.1% and 0.2%. The chromatographic behavior of the aerosols at the various oxygen concentrations is summarized in Figures 1 and 2.

DISCUSSION

We examined the behavior of technegas, pertechnegas and related radioaerosols as a function of the concentration of oxygen in the argon-oxygen mixture that was used in the technegas generator. We found an abrupt transition from technegas-like behavior to pertechnegas-like behavior between oxygen concentrations of 0.1% and 0.2%.

Although our results at the extremes of oxygen concentration (0% corresponding to technegas, and 2%–5% corresponding to pertechnegas) are qualitatively the same as those reported by Bellen et al. (*4*), we found that a small fraction of the technegas aerosol migrated with the solvent front. Conversely, we found that a small fraction of the pertechnegas aerosol did not migrate with the solvent front. The only difference between the two studies, with respect to thin-layer chromatography, was in the collection of the radioaerosols. Bellen et al. (*4*) bubbled their aerosols through saline to trap the particles, and agitated the suspension to maintain the radioactivity in the aqueous phase. Their purpose was to assess the radiochemical purity of the aerosols. We wished to simulate the behavior of our radioaerosols at the epithelial surface of the lung, and we believe that our purpose was better served by collecting samples directly from the aerosol phase.

The transition from technegas-like to pertechnegas-like behavior can be explained by considering the environment in which the radioaerosol is created. When [^{99m}Tc]pertechnetate ($^{99m}TcO_4^-$) is placed in the graphite crucible and heated in argon, it undergoes reduction. This most likely results in a mixture of insoluble ^{99m}Tc carbides and metallic technetium along with incompletely reduced $^{99m}TcO_4^-$, probably as $^{99m}TcO_2$ which reverts to water-soluble $^{99m}TcO_4^-$ in an aqueous environment. Small amounts of oxygen in the argon atmosphere combine with the vaporized graphite to form carbon monoxide and carbon dioxide. Greater amounts of oxygen interfere with the reduction of $^{99m}TcO_4^-$, biasing the mixture away from ^{99m}Tc carbides and metallic technetium and toward $^{99m}TcO_2$ and $^{99m}TcO_4^-$.

We employed thin-layer silica-gel chromatographs developed in isotonic saline, to simulate the mobility of free pertechnetate ions in an aqueous environment similar to what they encounter in the lungs. Although it is intended to be a qualitative model, the clear distinction between and the abrupt transition from technegas-like to pertechnegas-like behavior suggests that our results should apply in vivo as well.

CONCLUSION

Isotonic saline and thin-layer chromatography were used to model the behavior of technegas, pertechnegas and related aerosols in the aqueous environment of the lungs. Based on the mobility of the pertechnetate ion, the transition from technegas-like to pertechnegas-like behavior occurs when the oxygen-argon gas mixture in the generator contains between 0.1% and 0.2% oxygen. The oxygen concentration used to create pertechnegas in the clinical set-

ting, approximately 3%, is well above the transition point. Argon used to generate technegas should contain no more than 0.1% oxygen as a contaminant, and preferably less.

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