The Relationship Between Elution Time and Eluate Volume Using the Ultra-TechneKow® DTE Technetium-99m Generator

Joseph C. Hung, Douglas W. Mahoney, Der-chen T. Huang, and Alice Wang

Nuclear Medicine, Department of Radiology and Section of Biostatistics, Department of Health Sciences Research, Mayo Clinic, Rochester, Minnesota

Objective: The new Ultra-TechneKow® Dry Ship Top Elute ^{99m}Tc generator (UTK®-DTE generator; Mallinckrodt Medical, Inc., St. Louis, MO) was devised to facilitate fractionated elution with an ergonomically designed elution shield. Fractionation is accomplished traditionally by visually observing the eluted volume through 2 layers of leaded glass windows located in a lighted elution shield and generator auxiliary shield. The goal of our study was to use elution time to determine the endpoint for obtaining the required volume of ^{99m}Tc-eluate from a UTK-DTE generator.

Methods: After triplicate elution at several predetermined elution times, the initial weight of the evacuated collecting vial was subtracted from the total weight after elution to determine the elution volume.

Results: A quadratic relationship was established between the eluate volume (v, mL) and elution time (t, s) ($v = 0.3594 + 0.1889\,t - 0.0009\,t^2$). This equation is suitable for use with the 10-mL elution vial. This formula may not be accurate for the first elution since the UTK-DTE generator is a dry-column generator when shipped. The following elution times were calculated for some commonly eluted volumes: 2 mL (9 s), 4 mL (22 s), 5 mL (28 s), 7 mL (45 s), and 10 mL (88 s).

Conclusion: Our calculated elution time method can be used to predict the eluate volume from a UTK-DTE generator.

Key Words: Ultra-TechneKow® Dry Ship Top Elute technetium-99m generator; fractionation; elution; elution time; eluate volume

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A new generation of ^{99m}Tc generator, the UTK®-DTE generator (Ultra-TechneKow® Dry Ship Top Elute generator; Mallinckrodt Medical, Inc., St. Louis, MO) was recently introduced (*1*). There are many new features and improvements designed to make this new type of generator more efficient and user friendly. One of the new features added to the UTK-DTE generator system is a special elution shield that houses the elution vial for drawing ^{99m}Tc eluate out of the generator. This relatively heavy (~ 5-lb) elution shield (primarily made of lead) helps minimize radiation exposure to the hands. The ergonomically designed elution shield also is fitted with a leaded glass window to allow visual inspection of the elution process. This device is useful especially when performing fractionated elution (or fractionation), allowing customized elution of a required volume and/or amount of ^{99m}Tc activity, as well as offering flexibility with regard to specific concentration. The new elution shield also is equipped with a light source, further enhancing the visual inspection of eluted volume, which should help to facilitate determining the required volume during the fractionation process.

There are some disadvantages, however, along with the advantages associated with this new elution shield. Although the lighted window is designed to allow visual inspection, some radiation can still penetrate the leaded glass, resulting in radiation exposure to the user (especially to the eyes). The double layers of leaded glass, one layer on the elution shield and the other on the window ring of the auxiliary lead shield for the generator, makes it difficult to see clearly through the glass. Another potential problem is the power source for the light bulb inside the elution shield. If the batteries were to expire during the elution process, the user would have no method for determining how much eluate was in the elution vial. Visual inspection is especially crucial in the fractionation process, in which only a small volume of eluate is collected and the elution process takes only a few seconds.

The evacuated collecting vial (elution vial) poses yet another problem in the fractionation process. The volume graduation label is simply a sticker affixed to the vial. The label could become displaced, resulting in an inaccurately measured eluate volume. The elution vial must be aligned exactly so that the volume indicator numbers are facing the leaded glass window to ensure easy readability. The starting volume number on the vial label, while it is in elution position (i.e., upside-down position), is set at 4. Any eluted volume under 4 mL is only an estimation.

The objective of this study was to minimize or eliminate the potential problems identified with using the new elution shield by employing elution time to determine the endpoint for

For correspondence or reprints contact: Joseph C. Hung, PhD, BCNP, Nuclear Medicine, Department of Radiology, Mayo Clinic, 200 First St. SW, Rochester, MN 55905; Phone: 507–284–4399; E-mail: jhung@mayo.edu.

obtaining the required ^{99m}Tc volume from the UTK-DTE ^{99m}Tc generator. By establishing a relationship between the elapsed elution time and eluate volume, it will no longer be necessary to observe the vial through the leaded glass windows during the fractionated elution process. Unnecessary radiation exposure to the generator operator's eyes will be reduced, while ensuring the correct eluate volume is obtained during the fractionation process.

MATERIALS AND METHODS

Materials and Equipment

We used a 10-mL evacuated collecting vial (Mallinckrodt Medical, Inc., St. Louis, MO) to collect the ^{99m}Tc eluate to gather data for evaluating the relationship between commonly collected eluate fractionation volumes and the required elution times. A special plastic insert, supplied by the manufacturer, was placed inside the elution shield to push the rubber stopper of the 10-mL elution vial against the opening of the shield, since the elution shield was designed to hold a 20-mL evacuated collecting vial. An analog stopwatch (Fisherbrand; accuracy up to 1/5 s; Fisher Scientific, Pittsburgh, PA) was used to record specific time intervals of 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 85, 100, and 120 s. An electronic weight balance (Model AE 260, DeltaRange; Mettler-Toledo International, Inc., Greifensee, Switzerland) was used to determine the initial mass (g) of each evacuated collecting vial, as well as the final mass (g) of each elution vial containing eluate. To reduce radiation exposure, we used UTK-DTE ^{99m}Tc generators that were 1–3 mo after the original calibration time, and all of the elution vials containing radioactive ^{99m}Tc eluate were decayed to background inside the elution shield before performing the weight measurements.

Experimental Process

The elution process began by placing the evacuated collecting vial into the elution shield after removing the auxiliary shield plug along with the TechneStat™ vial (i.e., a 5-mL vial containing 0.5 mL of 70% (v/v) isopropyl alcohol) (*1*). Then the elution shield was placed on the UTK-DTE ^{99m}Tc generator with the rubber stopper pointing down until it was penetrated by the elution needle. The stopwatch was started at the same time that the elution shield was lowered onto the elution needle. One individual operated both the stopwatch and the elution shield to ensure that no time lapsed due to response time differences. When the desired time interval was reached, the elution shield was rotated 90° clockwise to terminate the elution process. At this time, the elution shield was pressed down immediately for 8–10 s to remove the rest of the vacuum from the elution vial with the addition of sterile air (*1*). The elapsed time was marked by pressing the stopwatch at the same time that the 90° clockwise rotation of the elution shield was initiated to stop the elution process. On completion of the elution process, the rest of the vacuum inside the elution vial was filled with air by directly attaching a vent needle onto the rubber septum.

The radioactive vials then were placed in a lead container and allowed to decay to background levels. The vials then were weighed, and the weight of each of the collected eluates was calculated (i.e., final weight of vial – initial weight of vial = weight of eluate). The eluate volume was calculated by assuming the density of the eluate (i.e., almost identical to physiological saline) to be 1 g/mL

Fourteen preselected elution time intervals (i.e., 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 85, 100, and 120 s) were investigated. For each of the 14 time intervals, 3 replications of the experiment were performed to obtain an estimate of experimental error. A total of 42 elution samples was obtained (i.e., 3 samples/time interval $\times$ 14 time intervals = 42 samples) for this study.

Data Analyses

The initial step in the data analysis consisted of plotting the measured eluate weight (volume) against elution time. A quadratic relationship was evident, and the calibration curve was obtained by fitting a second-degree polynomial to the data using the method of least squares. For prediction purposes the estimated 95% prediction interval of the fitted calibration curve is included in our data analysis.

Verification Processes

After obtaining the estimated calibration curve for the elution time and eluate volume, 2 additional validations of the experiments were conducted to determine the accuracy of the initial model and the polynomial equation. The first validation consisted of duplicating the initial sampling times of 5, 10, 15, 25, 30, 35, 40, and 50 s to determine the relationship between elution time and eluate volume. The second validation consisted of the calculated time points of 22, 28, 45, and 88 s (i.e., using the derived equation to calculate several elution time intervals for some of the commonly used eluate volumes, 4, 5, 7, and 10 mL). Both validations were performed in triplicate to rule out the possibility of any shift in results due to experimental error. The degree of agreement was summarized as the mean difference$\pm$1 SD from that predicted by the calibration curve.

RESULTS

Figure 1 depicts the calibration curve with the corresponding 95% prediction limits, along with observed data obtained during the experimental phase of the study. The estimated calibration curve may be obtained using the following equation:

$$v = 0.3594 + 0.1889\,t - 0.0009\,t^2$$

where v is the eluate volume (mL) and t is the elution time (s). For a given eluate volume, the corresponding required elution time can be estimated by the inverse relationship as follows:

$$t = 104.94 - \sqrt{11403.34 - v/0.0009}$$

where t is the elution time in seconds and v is the eluate volume in milliliters The initial fit of the calibration curve had an estimated $r^2 = 0.99$ and the variability between replicated trials was low at $\pm$ 0.096 mL. Table 1 lists the elution times that were calculated based on this formula for some commonly eluted volumes.

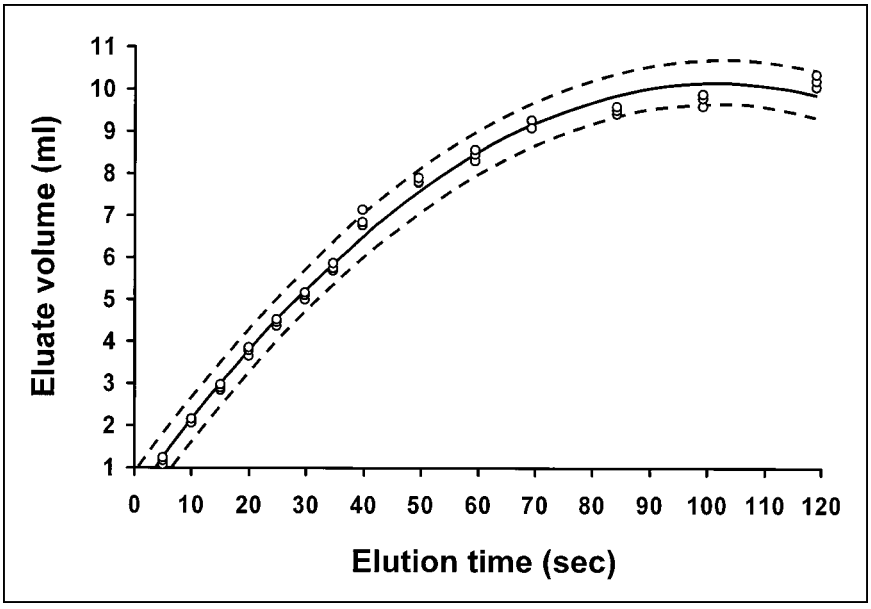

FIGURE 1. The calibration curve was generated using the preselected elution times to predict the desired eluate volumes. The dotted lines indicate the 95% limits of prediction. The calibration curve was constructed based on the formula of $v = 0.3594 + 0.1889\,t - 0.0009\,t^2$.

Figure 2 is the calibration curve with the corresponding 95% prediction limits, along with observed data during the validation phase of the study. The validation samples tended to drift higher than predicted, as seen on the graph. The majority of the samples were still within the 95% prediction limits of the calibration curve. For the first series of validation samples, 27 of 30 (90%) of the runs were within the 95% prediction curve, and the mean difference was 4.1% ± 5.2% of that predicted or 0.24 ± 0.22 mL, in absolute terms. For the second series, 9 of 15 (60%) of the runs were within the 95% prediction interval, and the mean difference was 7.1% ± 5.6% of that predicted or 0.39 ± 0.36 mL, in absolute terms.

DISCUSSION

The UTK-DTE ^{99m}Tc generator was introduced to the US market in 1997. Several key changes and new features have been implemented for use with the UTK-DTE ^{99m}Tc generator. One important feature is that the new generator is shipped dry, which eliminates the potential for any breakage of the internal physiological saline charge vial due to freezing when being transported at high, cold altitudes or when left in extremely cold temperature conditions. The dry condition of the generator column before the first elution (may be up to a few days after production) also greatly reduces the possibility of formation of H_2O_2 and free radicals (e.g., $HO_2^{\bullet}$) caused by radiolysis of water in a wet-column generator (*1–4*). The hydrogen peroxide and free radicals are strong oxidizing agents and can interfere with reduction of stannous chloride (*1–4*). Although the UTK-DTE ^{99m}Tc generator is shipped under dry-column conditions, it functions as a wet-column generator after the first elution. The wet-column generator has been known to give reliable performance and consistent yields. The UTK-DTE generator also eliminates the valve mechanism previously found on generators and replaces it with a shortened, more simplified elution path. Another feature found on this new generation of generators is that it does not require the changing or recapping of needles. This greatly reduces the risk for needle sticks and contamination during the elution process. A heavy-weight auxiliary shield (318 lb) for the UTK-DTE ^{99m}Tc generator has greatly reduced radiation exposure to the user. The window ring of the auxiliary shield has a leaded glass window that allows the user to observe the elution process, especially during fractionation, when the elution shield is used.

TABLE 1
Calculated Elution Times for Some Commonly Used Eluate Volumes

Required eluate volume (mL)	Suggested elution time (s)
2	9
4	22
5	28
7	45
10	88

Fractionated elution is an important technique that can be effectively used to obtain a high specific concentration of ^{99m}Tc eluate even with an older generator (e.g., 2 wk postcalibration time). Although the window ring and lighted elution shield have been developed to facilitate the fractionation process, these features are not practical. The problems include radiation exposure through the leaded glass window, obscured view through 2 layers of leaded glass windows, and expired batteries.

Since approximately 98% of the total accumulated ^{99m}Tc eluate activity is obtained within the first few milliliters obtained from a generator (this usually occurs at about 4 mL with the UTK-DTE ^{99m}Tc generator) (*5–7*), we primarily focused our study on the 10-mL evacuated collecting vial, rather than the 20-mL vial size.

The proposed function of elution time will only work with second and subsequent elutions of the UTK-DTE generator, as the generator is shipped dry. During the first elution, the

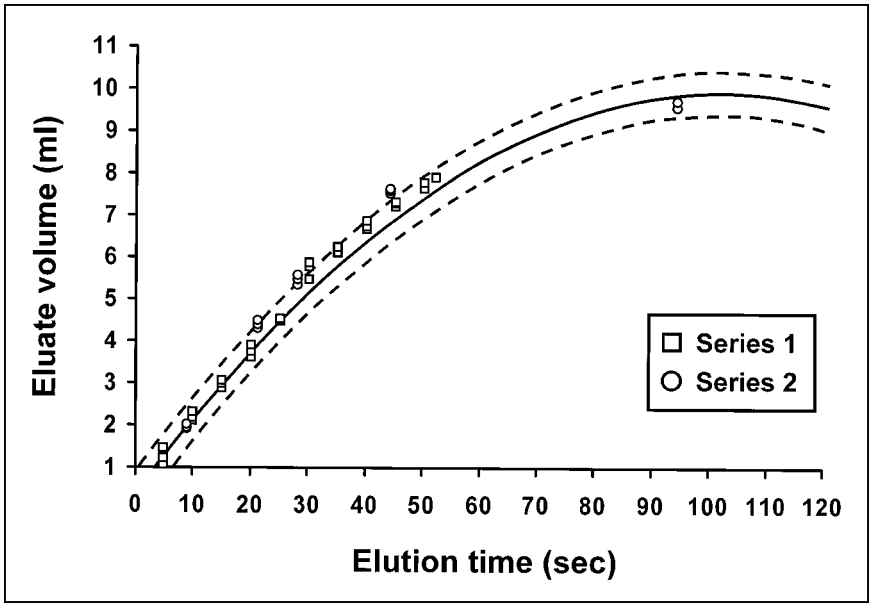

FIGURE 2. The calibration curve with corresponding 95% prediction limits (dotted lines), along with the observed data obtained during the 2 validations of the procedure.

physiological saline is drawn through the empty elution pathway (i.e., tubing and column), and all of the air contained within the elution path is pumped out. The derived equation does not apply to the air during the first elution and is, therefore, unsuitable for use with the first elution.

During the validation process, our results regarding anticipated volumes of eluate started to shift. The same elution time interval yielded a slightly higher eluate volume. However this higher volume deviated from the theoretical value by only about 0.2 mL. This small variation could be the result of reaction time differences between operators. Since the elution vials used to perform fractionation were rarely more than 2 m old and were well within their useful shelf life, we do not believe that our formula yields an elution time that generates eluates having a greater amount of eluate volume than that desired. As long as the equation does not yield an elution time that results in a smaller amount of volume than that expected, the user will obtain the desired volume and amount of ^{99m}Tc activity.

CONCLUSION

Our calculated elution time method can be used to predict the eluate volume from a UTK-DTE generator. Unnecessary radiation exposure to the eyes can be reduced by using this method.

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