Safe and Accurate Determination of Generator Eluate Volume

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A method is described which permits reduction of radiation exposure of personnel while determining generator eluate volume. The method involves weighing the eluate and converting to volume by dividing the density of the eluate into the mass. This technique is simple and can be performed in less than 2 min. Greater accuracy in measuring the eluate volume is concomitantly achieved.

The routine use of a radiopharmaceutical generator is based on assurances given by the user to federal and state regulatory agencies that accurate and safe assay procedures will be established and practiced. Commercially available dose calibrators fulfill the requirement for accurate determination of total activity in an elution vial, but determination of eluate volume for specific activity calculations is left to a visual estimate using the elution vial markings. Accurate localization of the eluate meniscus through the lead glass window of a vial shield is difficult at best, and impossible when the vial is in a windowless shield. The result is often removal of the vial from the shield for better meniscus visualization, which results in extremely high exposure rates to the hands and eyes.

We recently noted that doses drawn on the basis of specific activity calculations were consistently low and required additional volume to be added to achieve the desired total activity. A study was undertaken to evaluate the cause of these discrepancies and to develop a safer method of determining eluate specific activity.

Experimental Method

The accuracy of the "approximate" volume markings of elution vials was tested for a group of 20- and 6-ml elution vials selected at random from various lots of on-hand stock. Volumetric pipets, which had been calibrated by weighing serial additions of physiologic saline (9 mg NaCl/1 gm H_20) on a Mettler type H16 balance and comparing the observed weight change to the calculated expected weight change, were used to add known volumes of physiologic saline to the elution vials; the volume indicated by the vial markings was recorded. Further tests were limited to the 20-ml vial since the 6-ml vial is only infrequently used.

An empty 20-ml elution vial inside a lead shield was placed on both the right and left pans of a double-pan balance and the balance was tared. The balance had been previously calibrated by adding calibrated 1–20-gm weights to the left pan shield–vial combination and observing the balance reading. Known volumes of physiologic saline were added to the vial on the left pan using the calibrated volumetric pipets and the incremental mass of the added volume recorded. The incremental mass was then divided by the density of physiologic saline (1.009 gm/ml) to obtain the calculated incremental volume.

Results

The volume markings on the 20-ml elution vials were consistently 0.5–1.0 ml low (Table 1), while the markings on the 6-ml vials were generally accurate at the higher volumes but as much as 50% high at small volumes (Table 2).

The hypothesis that eluate volume could be obtained by dividing eluate density into eluate mass was shown to be valid (Table 3). An unpaired t-test showed that there were no statistically significant differences between the actual and calculated added volumes.

TABLE 1. Visual Estimate of Volume in 20-ml Vials

Actual volume of physiologic saline added (ml)	Visual-estimated volume				
	Vial 1 (ml)	Vial 2 (ml)	Vial 3 (ml)	Vial 4 (ml)	Vial 5 (ml)
2	2	2	2	2	2
3	2.0	2.5	2.0	2.0	2.5
4	3.0	3.5	3.0	3.0	3.5
5	4.0	4.5	4.0	4.0	4.5
6	5.0	5.5	5.0	5.0	5.5
7	6.0	6.5	6.0	6.0	6.5
8	7.0	7.5	7.0	7.0	7.5
9	8.0	8.5	8.0	8.0	8.5
10	9.0	9.5	9.0	9.0	9.5
11	10.0	10.5	10.0	10.0	10.5
12	11.0	11.5	11.0	11.0	11.5
13	12.0	12.5	12.0	12.0	12.5
14	13.0	13.5	13.0	13.0	13.5
15	14.0	14.5	14.0	14.0	14.5
16	15.0	15.5	15.0	15.0	15.5
17	16.0	16.5	16.0	16.0	16.5
18	17.0	17.5	17.0	17.0	17.5
19	18.0	18.5	18.0	18.0	18.5
20	19.5	19.5	19.0	19.0	19.5

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TABLE 2. Visual Estimate of Volume in 6-ml Vials.

Actual volume of physiologic saline added (ml)	Visual-estimated volume				
	Vial 1 (ml)	Vial 2 (ml)	Vial 3 (ml)	Vial 4 (ml)	Vial 5 (ml)
1	1.2	1.5	1.3	1.5	1.3
2	2.1	2.5	2.2	2.4	2.2
3	3.0	3.4	3.2	3.3	3.2
4	4.0	4.3	4.0	4.2	4.1
5	4.9	5.1	5.0	5.1	5.0
6	5.8	6.1	5.9	6.0	6.0

TABLE 3. Determination of Volume by Obtaining Mass and Correcting for Density.

Volume of physiologic saline added (ml)	Gross weight (gm)	Added weight (gm)	Calculated added volume (ml)
0	35.3	–	–
1	36.3	1.0	0.99
2	37.3	2.0	1.98
3	38.3	3.0	2.97
4	39.3	4.0	3.96
5	40.35	5.05	5.00
6	41.35	6.05	5.99
7	42.35	7.05	6.98
8	43.35	8.05	7.97
9	44.35	9.05	8.96
10	45.4	10.1	10.00
11	46.4	11.1	10.99
12	47.4	12.1	11.98
13	48.4	13.1	12.97
14	49.45	14.15	14.01
15	50.45	15.15	15.00
16	51.5	16.2	16.04
17	52.5	17.2	17.03
18	53.5	18.2	18.02
19	54.5	19.2	19.01
20	55.5	20.2	20.00

Note: Calculated added volume = added weight (gm) ÷ 1.009 gm/ml.

Discussion

The molybdenum–technetium generator has become not only one of the most important tools of the busy nuclear medicine clinic but also the most important single source of radiation exposure to the nuclear medicine technologist. The technologist who must handle generators daily should be made acutely aware of the radiation hazard of handling unshielded generators and unshielded generator eluates (*1–3*), and should strive to reduce radiation dose to a level as low as practicable. Mayes, et al have reported that a commercially available lead syringe shield provides a factor of 300 reduction in dose rate at the surface of the shield (*3*). When taken in light of the BEIR report's comments regarding demonstrable lens changes in mice at absorbed doses of less than 5 rads (*4*), the demonstration by Lombardi, et al of an average exposure rate to the eyes of nuclear medicine personnel of more than 1.2 rad/year (*5*) suggests that careful attention be paid to emphasizing and minimizing this potentially significant hazard. With the current availability of vial and syringe shields there is no longer any justification for handling unshielded generator eluates except during the period of dose calibrator assay.

The removal of an elution vial from its shield for the purpose of visually estimating the eluate volume was shown to be unacceptable due to the inaccurate volume markings on the vial and due to the high radiation doses to the hands and eyes. Filling of an elution vial with a volume exceeding the range of the vial markings is an obvious further shortcoming of the visual-estimate method. Calculation of eluate volume by dividing eluate density into eluate mass was shown to be superior in terms of greater accuracy and much reduced radiation exposure. For example, in the normally used range of 15–20 ml, the maximum error in the visual estimate method was 6.25% at 16 ml, while the maximum error using the balance method was only 0.25% at 16 ml. Why worry about achieving such accuracy when dose calibrators are only calibrated within 10–15 per cent? Although the reduced radiation exposure alone should be sufficient reason, it must be kept in mind that uncertainties are neither linearly additive nor governed by the "weakest link in the chain" concept. Overall system uncertainty is a vector sum of all the individual component uncertainties, which means that smaller uncertainties in any component of the system (e.g., more accurate syringes) will improve overall system uncertainty.

The reduction in radiation dose to technologists and the improved accuracy achieved by this method are significant and strongly commend adoption of the method as routine practice.

References

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