Bolus Injections of Measured Amounts of Radioactivity

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Many time-based radionuclide techniques, such as glomerular filtration rate measurement (GFR), require prompt intravenous delivery of an accurately measured tracer bolus with minimal residual tracer retention at the injection site. The quality assurance aspects of two antecubital vein, quantitative injection techniques were investigated. A flush bolus technique using a tuberculin syringe piggybacked onto a 10-ml saline flush was compared to a single blood pressure cuff injection technique. Scintillation camera data for each technique were compared for bolus duration in the abdominal aorta and for residual activity at the injection site at 5 min. Bolus times were measured as the FWHM of the gamma variate fit to the abdominal aortic regional time-activity curves. The mean FWHM was 8.3 ± 2.2 sec for the flush bolus (n = 19), and 11.4 ± 3.7 sec for the cuff technique (n = 23) (mean ± 1 s.d.). Relatively little focal activity was seen in the antecubital injection site following the flush bolus: marked residual activity was seen following the blood pressure cuff injections. The injection site/arm background ratios averaged 1.3 for the flush bolus and 30.1 for the cuff technique (n = 20). Although both methods allowed accurate in vitro determination of administered radioactivity, only the tuberculin syringe flush bolus technique was acceptable for time-based quantitation because of its superior in vivo characteristics.

Quantitative bolus injection techniques should permit accurate assay of the delivered dose of the radiopharmaceutical with rapid and clean delivery of the radioactivity to the circulation. Two quantitative bolus injection techniques—the first after Crucitti et al. (*1*) and the other as modified after Oldendorf (*2*)—were compared for residual tracer in the injection site at five minutes after injection and for bolus transit times measured from abdominal aortic regions-of-interest (ROIs). The injection sites were imaged in order to determine how cleanly or completely the bolus was administered to the circulation. The promptness or speed of bolus delivery was quantitated using a gamma variate to the data from each aortic ROI.

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MATERIALS AND METHODS

The first quantitative bolus injection method examined was adapted from Crucitti et al. (*1*). Figure 1 shows a completed apparatus consisting of a butterfly infusion set attached to a 1-ml tuberculin syringe shaft which has been piggybacked onto the male end of a one-way stopcock. The female end of this stopcock has an attached 12-ml (flush) syringe. Note that the stopcock must be seamless so as to form an airtight seal with the tuberculin syringe shaft.

Once the tuberculin syringe shaft had been connected to the stopcock with the stopcock in the closed position, the apparatus was loaded with the radiopharmaceutical. A dose of 1 ml volume was drawn up into a separate disposable syringe and was injected into the male end of the tuberculin syringe shaft. The tuberculin syringe portion was capped to maintain sterility and assayed intact in the dose calibrator to determine the pre-injection dose. The butterfly infusion set was then inserted into a suitable arm vein, flushed with 1 or 2 ml of saline and attached to the tuberculin syringe shaft. With the stopcock in the open position, the entire contents of the apparatus were pushed into the vein using maximal manual power, typically within 4 sec. Finally, the residual radioactivity in the apparatus was assayed in order to determine the delivered dose.

The second quantitative bolus injection method examined employed the modified Oldendorf technique (*2*). The apparatus for the modified Oldendorf method shown in figure 2 consists of a 3-ml syringe with a 21-gauge or larger needle. The radiotracer to be injected was drawn to the appropriate volume. The syringe was then assayed in a dose calibrator. Prior to injection, a blood pressure cuff was placed high up on the arm and was inflated to just below systolic pressure. After injection, the blood pressure cuff was released by stripping open its velcro closure. The syringe was then removed and assayed for residual activity in order to determine the dose delivered to the patient.

The quality of the bolus injection technique was analyzed in two groups of patients. In Group 1 the injection site activity was evaluated and in Group 2 the compactness of the bolus was measured.

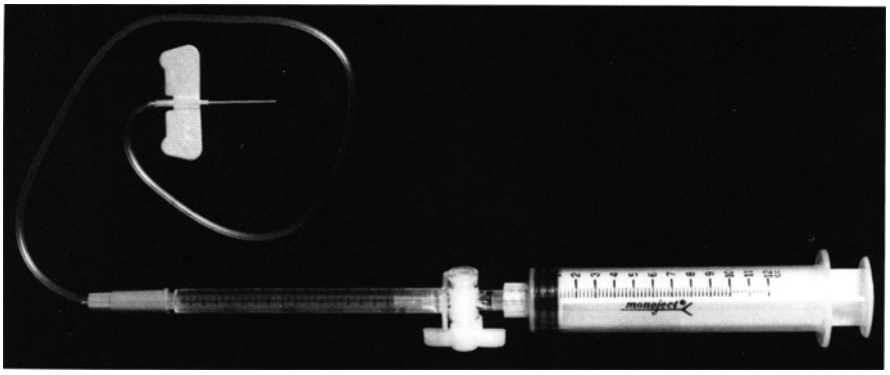

FIG. 1. Apparatus for assayed flush bolus injection = butterfly + tuberculin syringe shaft + one-way stopcock + 12-ml syringe. Modified after Ref. *1*.

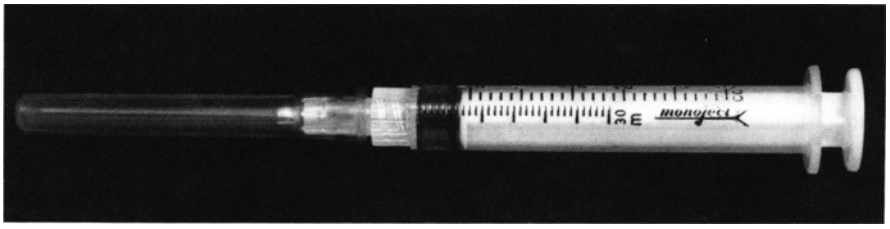

FIG. 2. Syringe for assay and injection by Oldendorf method. Modified after Ref. *2*.

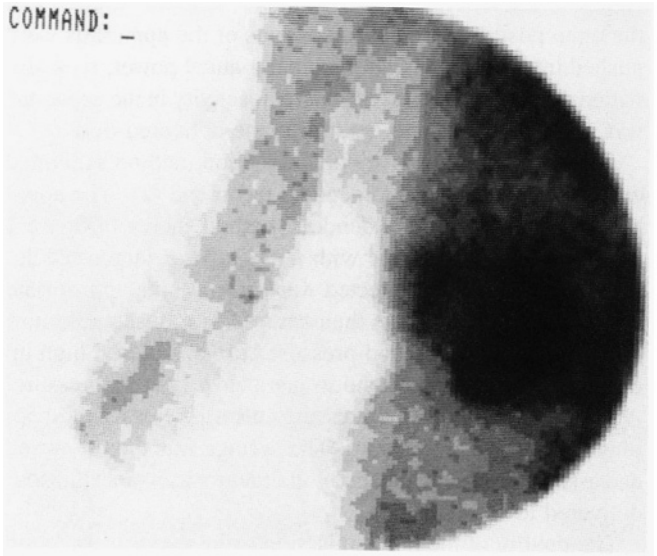

FIG. 3. Typical (median) result at 5 min after antecubital bolus with flush. Note relative uniformity of radiotracer distribution in the arm.

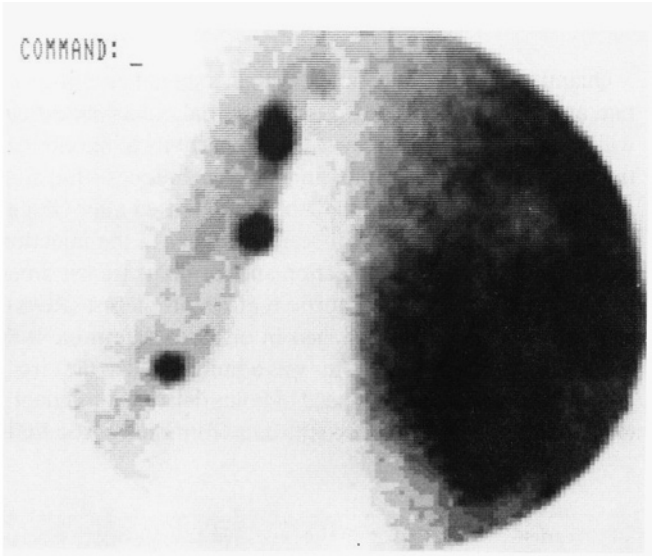

FIG. 4. Typical (median) result at 5 min after Oldendorf type injection. Note injection site and residual tracer in draining vein.

Group 1. Twenty patients were injected with 20 mCi (740 MBq) ^{99m}Tc-MDP by the Crucitti et al. (*1*) (n=10) or the modified Oldendorf technique (*2*) (n=10) in random sequence. At five minutes, the antecubital fossa and proximal arm activity were imaged as a 64× 64 pixel 60-sec image. The computer image data were processed by an observer who was without knowledge of the injection technique employed. Regions-of-interest were drawn over the injected arm to include the most focally increased activity and were compared to background regions of the same arm. After decoding the randomized series, comparison was made between the two groups of focal activity rations as shown in Results.

Group 2. Forty-two sequential patients referred for renal scintigraphy were injected with 10–19 mCi (370–700 MBq) ^{99m}Tc-DTPA using the modified Oldendorf (*2*) (n=23) or using the Crucitti et al. (*1*) technique (n=19). With the patient supine and the camera under the imaging table, computer acquisition of 120 images at one-half second per frame in a 64 × 64 format was started immediately at the time of injection. Abdominal aortic ROIs were chosen from a point just below the lungs to extend six centimeters (10 pixels) caudad (*3*). These ROIs were drawn over a 10-sec summed frame image formed by adding the 20 image frames subsequent to first visualization of the abdominal aortic activity (*3*). Subsequently, time-activity curves were generated. In addition, the bolus times were measured as the full width half maximum (FWHM) of a gamma variate fit to each abdominal aortic regional time-activity curve (*4*).

RESULTS

For the patients in Group 1, typical arm activity seen subsequent to injection by the technique of Crucitti, et al. is shown in figure 3. Similarly, the typical result five minutes after using the modified Oldendorf technique is shown in figure 4. Figure 5 shows a plot of the residual activity ratios from the injection sites and/or draining veins for both methods. Relatively little focal activity was seen in the arms sites following the blood pressure cuff type of injection. The injection site/arm background ratios averaged 1.3 for the Crucitti et al. technique and 30.1 for the modified Oldendorf technique. The class ratios of uncleared arm-to-arm background are shown in tabular form in Table 1. The average and median arm ratios from the modified Oldendorf technique are significantly different suggesting that this is a highly skewed distribution.

Bolus times were measured in patient Group 2 as the FWHM of a gamma variate fit to each abdominal aortic regional time activity curve. The mean FWHM bolus time was 8.3

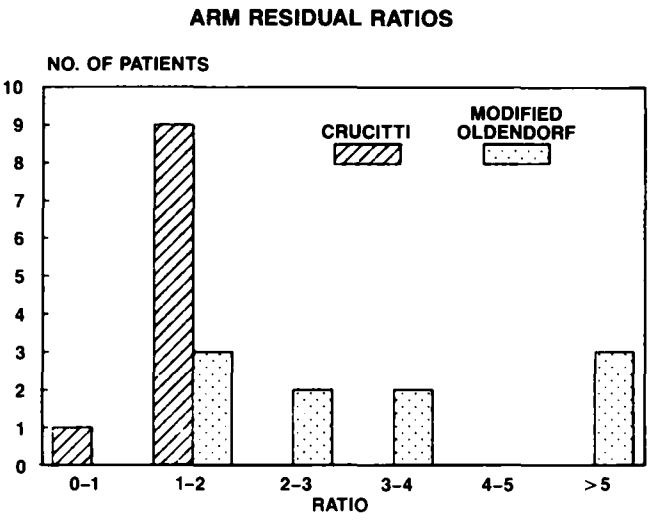

FIG. 5. Ratios of focal activity in the arm to more representative arm background at 5 min post injection, (Bq/pixel)/(Bq/pixel).

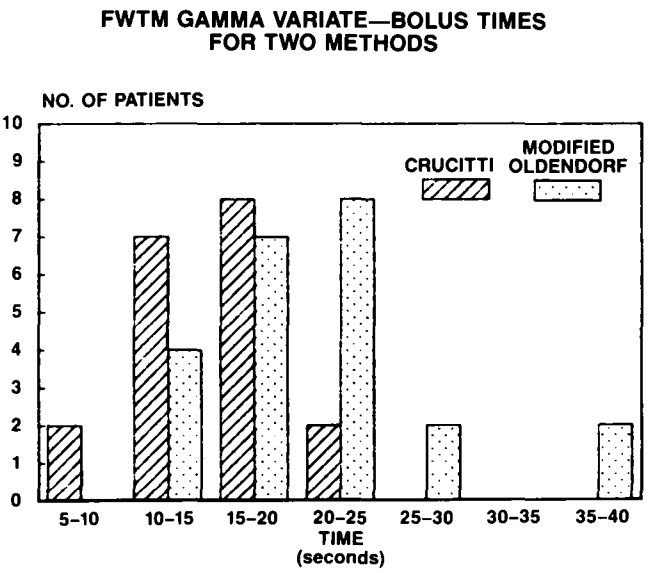

FIG. 6. Distribution of FWTM bolus times from gamma variates fit to the abdominal aortic ROI time-activity curves of 42 patients and two bolus methods.

TABLE 1. Arm Residual Ratios

Measure	Method: Crucitti (n=10)	Method: Modified Oldendorf (n=10)
Average (mean)	1.3	30.1
Median	1.2	3.2

TABLE 2. Results—Bolus Times

Measure	Method: Crucitti (n=19) Mean ± 1 s.d. (sec)	Method: Modified Oldendorf (n=23) Mean ± 1 s.d. (sec)	Student's t-test
FWHM	8.29 ± 2.2	11.4 ± 3.7	$p < 0.002$
FWTM	15.1 ± 4.1	21.0 ± 6.8	$p < 0.002$

± 2.2 sec (mean ± 1 s.d.) for the Crucitti et al. (n=19), and 11.4 ± 3.7 sec for the modified Oldendorf technique (n=23). Figure 6 shows the bolus times for both injection methods. The data were analyzed by the Student's t-test as shown in Table 2. Note that the method of Crucitti produces significantly more rapid transit of radiotracer as seen in the abdominal aorta.

DISCUSSION

The quality assurance of quantitative techniques is an important consideration for any nuclear medicine service using these techniques. Our results indicate a significant difference between two quantitative bolus injection techniques. Specifically, the modified Oldendorf technique frequently demonstrated focal spots of a variable amount of radiotracer in the arm at five minutes after injection. And, the abdominal aortic bolus transit times were prolonged as compared to the times from the Crucitti et al. method. These differences suggest that the modified Oldendorf technique is not suitable for quantitative and scintigraphic procedures.

The technique of Crucitti et al. is our choice as the superior quantitative bolus method. This method meets our criteria for delivery of a measured amount of radiotracer as quickly, completely, and consistently as possible. It is an easy technique to use and the cost of the materials is reasonable ($1.86 Canadian, or ~$1.38 U.S., per study). The authors recommend that each nuclear medicine service evaluate their bolus injection techniques for the purpose of quality assurance.

APPENDIX

The tuberculin syringe shafts*† can be connected to the following one-way stopcocks:

1. One-Way stopcock‡ 91001
   Cost $42.00 for case of 50 ($.84 each)
2. DK17A
   Clear One-Way stopcock§
   Cost $90.00 for a case of 50 ($1.80 each)
3. Namic 70015016
   One-Way slip¶
   Cost $55.00 for a case of 50 ($1.10 each)

Costs

Method 1*

Butterfly	$ .35
Tuberculin syringe	.17
12-ml syringe	.40
One-Way stopcock	.84
10 ml of saline	.10
	$1.86
	(~ $1.38 U.S.)

Note: Costs for both methods are listed in Canadian and U.S. dollars.

* Modified after Crucitti et al. (*1*).

Method 2†

3-ml syringe	$ .20
	$ .20
	(~ $.15 U.S.)

† Modified after Oldendorf (*2*).

NOTES

* Sterile disposable 5015-TB, Monoject, Division of Sherwood Medical, St. Louis, MO
† Syringe and Precision Needle, 5625, Becton Dickinson & Co., Rutherford, NJ
‡ Mallinckrodt, St. Louis, MO
§ American Pharmaseal, Valencia, CA
¶ Graphic Controls Ltd., Gananoque, Ontario, Canada

REFERENCES

1. Crucitti TW, Bigham KE, Herrew NE. A new bolus injection system for the performance of dynamic time-function studies. *J Nucl Med Technol* 1979;7:150-153.

2. Oldendorf WH. Temporary circulatory arrest in the extremities to restrict distribution of i.v. isotopes. *J Nucl Med* 1972;13:228.

3. Wesolowski CA, Hurwitz GA, Conrad GR, et al. The long aortic region of interest for renal vascular quantitative analysis. *Clin Invest Med (Suppl)* 1986;9:A118.

4. Thompson HK, Starmer F, Whalen RE, et al. Indicator transit time considered as a gamma variate. *Circ Res* 1964;14:502-512.