# New Approach to the Quantification of Differential Renal Function: Technical Details


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***A computer program as well as technical details for implementing a new method for quantitating differential renal function is presented. By correlating the shapes of renal uptake curves and bladder uptake curves obtained in a standard [$^{99m}$Tc]DTPA renogram, percent contributions from left and right kidneys to the total bladder activity as well as approximate ureteral transit times may be determined.***


A new approach to the analysis of renal uptake and bladder curves obtained in standard $^{99m}$Tc-diethylenetriaminepentaacetic acid (DTPA) renograms has been presented previously (*1*). The method correlates the shapes of the left and right renal uptake curves with the bladder curve, allowing a determination of the percent of bladder activity attributable to each kidney. The method assumes that the rate of accumulation of activity in the bladder is directly proportional to the renal uptake of radiotracer as illustrated in the following equation:

$$A_B(t) = k_L \int_0^t A_L\,(t - t_L)\,dt + k_R \int_0^t A_R\,(t - t_R)\,dt, \quad \text{(Eq. 1)}$$

where $A_B$ is the activity in the bladder at time t, $A_L$ and $A_R$ are the left and right renal activities, $k_L$ and $k_R$ are constants relating renal uptake and the rate of accumulation of tracer in the bladder, and $t_L$ and $t_R$ are the left and right ureteral transit times. The curves $A_B(t)$, $A_L(t)$, and $A_R(t)$ are the renal and bladder uptake curves and are determined directly from the radionuclide procedure. The parameters $k_L$, $k_R$, $t_L$ and $t_R$ must be determined by applying a least squares procedure with Eq. 1. The contribution of each kidney to the final bladder activity is determined as follows:

$$\%\ \text{Left} = k_L \frac{\tilde{A}_L}{A_B(30)} \times 100\%$$

$$\%\ \text{Right} = k_R \frac{\tilde{A}_R}{A_B(30)} \times 100\%, \quad \text{(Eq. 2)}$$

where $A_B(30)$ is the bladder activity at 30 min postinjection.

The computer program listed in the Appendix will perform the least squares fit to the radionuclide uptake curves using Eq. 1 and will calculate the percent contribution to total bladder activities using Eq. 2.

## MATERIALS AND METHODS

The following steps are done to perform this new quantitative evaluation of differential renal function:

1. Perform a standard [$^{99m}$Tc]DTPA renogram with a large field-of-view scintillation camera. Make sure that at least a portion of the bladder will be seen by the camera as well as the two kidneys. Patients with urinary catheters should have the catheters clamped for the duration of the study. Acquire the dynamic scan at one frame per min for the standard number of views (N ~ 30).
2. Upon completion of the scan, produce background subtracted right and left renal and bladder curves. Renal regions of interest should include parenchyma and pelvis. Background regions for each kidney should be "C"-shaped regions lateral to each kidney.
3. Output the N values of right and left renal and bladder activities.
4. Load the program listed in the Appendix into the personal computer and run the program to analyze the renal data.
5. In response to the request "input number of observations," type in the value of the number of frames in the dynamic scan (N < 32) and press return.
6. In response to the request "input right kidney data," type the value of the right renal uptake at 1 min, then press return. Repeat this step for the 2-min uptake and continue on to the *n'th* value of right renal uptake.
7. In response to the request "input left kidney data," enter left kidney data as shown in Step 6.
8. In response to the request "input bladder data," enter bladder data as shown in Step 6.
9. In response to the request "input maximum value of transit time (min)," enter an integer less than the number of observations (N). The larger the entered value, the longer the computer will run. Experience has shown that a value of 10 is usually adequate. Depending on your computer, running time may exceed 5 min.
10. The computer will output the percent contribution of left and right kidney to total bladder activity as well as the approximate ureteral transit times. A sample run is shown in the Appendix.


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## DISCUSSION

The program listed in the Appendix is a simplification of the one used in the original investigation (*1*), which required nonlinear regression software. The current program determines $k_R$ and $k_L$ using standard linear regression techniques (lines 230–480 and 860–970) for combinations of $t_R$ and $t_L$ which are varied in integer steps (lines 490–650) to achieve the lowest value of the residual sum of square errors between $A_B(t)$ determined from Eq. 1 in the observed bladder curve (lines 870–880). The percent contributions to bladder activity are calculated (lines 660–700) and, along with $t_R$ and $t_L$, are outputted (lines 710–840). Because $t_R$ and $t_L$ are varied in 1-min steps, the ureteral transit times determined by the program are approximated. The determination of ureteral transit times with greater accuracy would have required a considerably larger program with a much longer running time. Furthermore, since data are acquired in 1-min steps, there is a built-in uncertainty in time measurements on the order of 1 min.

This new method for determining the differential renal function differs from the usual 2-min uptake method (*2,3*) in that the shapes of the renal curves are correlated with the shape of the bladder curve. The absolute value of activities are not important. Thus, the method does not require renal count rates to be corrected for attenuation. There is, however, a potential pitfall: If right and left renal curves are exactly similar (i.e., differing by a multiplicative constant), the regression analysis will consider them as equivalent, and a unique least squares solution to Eq. 1 will not exist. A deliberate inspection of the right and left renal curves should preceed any interpretation of results with this new procedure.

The technologist with computer expertise may wish to modify the presented program to fit his or her particular needs. Data input, for example, could be accomplished with a menu driver, files could be created to store patient data, additional print statements could be included to output the parameters $k_R$ and $k_L$ (A and B, respectively, in the program), or the goodness of the least squares fit could be evaluated by outputting the residual sum of square error (R9 in the program).

## APPENDIX
## Program Listing

```
10 Dim U(30), V(30), W(30), X(30), Y(30, 30)
20 Dim K(30), L(30), B(30)
30 Print "Input Number of Observations (<32)"
40 Input N
50 Print "Input Right Kidney Data"
60 For I=0 to N-1
70 Print "RK(";I;")=";
80 Input K(I)
90 Next I
100 Print "Input Left Kidney Data"
110 For I=0 to N-1
120 Print "LK(";I;")=";
130 Input L(I)
140 Next I
150 Print "Input Bladder Data"
160 For I=0 to N-1
170 Print "B(";I;")=";
180 Input B(I)
190 Next I
200 Print "Enter Max Value of Ureteral Transit Time (min) <";N
210 Input T
220 If T > N-1 then 200
230 A1=B(0)Λ2
240 For T1=1 to N-1
250 K(T1)=K(T1)+K(T1-1)
260 L(T1)=L(T1)+L(T1-1)
270 A1=A1+B(T1)Λ2
280 Next T1
290 For T1=0 to T
300 U(T1)=0
310 V(T1)=0
320 W(T1)=0
330 X(T1)=0
340 For T3=T1 to N-1
350 U(T1)=U(T1)+K(T3-T1)Λ2
360 V(T1)=V(T1)+L(T3-T1)Λ2
370 W(T1)=W(T1)+B(T3)*K(T3-T1)
380 X(T1)=X(T1)+B(T3)*L(T3-T1)
390 Next T3
400 For T2=0 to T
410 Y(T1, T2)=0
420 For T3=0 to N-1
430 If T3<T1 then 460
440 If T3<T2 then 460
450 Y(T1, T2)=Y(T1, T2)+K(T3-T1)*L(T3-T2)
460 Next T3
470 Next T2
480 Next T1
490 T8=0
500 T9=0
510 T1=0
520 T2=0
530 Gosub 860
540 R9=R1
550 For T1=0 to T
560 For T2=0 to T
570 Gosub 860
580 If R1>R9 then 620
590 R9=R1
600 T8=T1
610 T9=T2
620 Next T2
630 Next T1
640 T1=T8
650 T2=T9
660 Gosub 860
670 K1=A*K(N-1-T1)
680 K2=B*L(N-1-T2)
690 K1=INT (K1/(K1+K2)*1000)/10
700 K2=100-K1
710 Print
720 Print
730 Print
740 Print
750 Print"                                   Right        Left"
760 Print
770 Print "Kidney Contribution"
780 Print "To Bladder (%)         ", K1, K2
790 Print
800 Print "Approximate Ureteral"
810 Print "Transit Time (min)", T1, T2
820 Print
830 Print
840 Print
850 Stop
860 Gosub 890
```

```
870 R1 = A1 + AΛ2 * U(T1) + BΛ2 * V(T2) – A * 2 * W(T1) –
    B * 2 * X(T2) + 2 * A * B * Y(T1, T2)
880 Return
890 A = (Y(T1, T2) * X(T2) – V(T2) * W(T1))/(Y(T1, T2)Λ2 – U(T1) * V(T2))
900 B = (Y(T1, T2) * W(T1) – U(T1) * X(T2))/(Y(T1, T2)Λ2 – U(T1) * V(T2))
910 If A>0 then 940
920 A = 0
930 B = X(T2)/V(T2)
940 If B>0 then 970
950 B = 0
960 A = W(T1)/U(T2)
970 Return
980 End
```

## Example Program Data and Results

```
Run Input Number of Observations (<32)
? 30

Input Right Kidney Data      Input Left Kidney Data

RK( 0) = ? 0                 LK( 0) = ? 0
RK( 1) = ? 16900             LK( 1) = ? 15000
RK( 2) = ? 33800             LK( 2) = ? 28100
RK( 3) = ? 34700             LK( 3) = ? 28500
RK( 4) = ? 33800             LK( 4) = ? 29100
RK( 5) = ? 30000             LK( 5) = ? 26300
RK( 6) = ? 25300             LK( 6) = ? 23400
RK( 7) = ? 24400             LK( 7) = ? 22500
RK( 8) = ? 25300             LK( 8) = ? 19700
RK( 9) = ? 20600             LK( 9) = ? 19200
RK(10) = ? 21900             LK(10) = ? 19100
RK(11) = ? 21900             LK(11) = ? 18000
RK(12) = ? 18400             LK(12) = ? 17800
RK(13) = ? 16500             LK(13) = ? 17300
RK(14) = ? 15100             LK(14) = ? 16500
RK(15) = ? 15000             LK(15) = ? 15900
RK(16) = ? 15400             LK(16) = ? 16100
RK(17) = ? 14800             LK(17) = ? 16300
RK(18) = ? 14600             LK(18) = ? 15400
RK(19) = ? 14300             LK(19) = ? 15000
RK(20) = ? 14100             LK(20) = ? 15000
RK(21) = ? 13300             LK(21) = ? 14800
RK(22) = ? 13900             LK(22) = ? 14100
RK(23) = ? 13900             LK(23) = ? 14300
RK(24) = ? 13900             LK(24) = ? 14300
RK(25) = ? 13700             LK(25) = ? 14100
RK(26) = ? 12800             LK(26) = ? 14000
RK(27) = ? 12900             LK(27) = ? 13700
RK(28) = ? 13500             LK(28) = ? 14100
RK(29) = ? 13900             LK(29) = ? 14000

Input Bladder Data

B( 0) = ? 0
B( 1) = ? 661
B( 2) = ? 2690
B( 3) = ? 5540
B( 4) = ? 8450
B( 5) = ? 11200
B( 6) = ? 13600
B( 7) = ? 15800
B( 8) = ? 17800
B( 9) = ? 19900
B(10) = ? 21700
B(11) = ? 23500
B(12) = ? 25400
B(13) = ? 27000
B(14) = ? 28500
B(15) = ? 29900
B(16) = ? 31300
B(17) = ? 32700
B(18) = ? 34100
B(19) = ? 35500
B(20) = ? 36800
B(21) = ? 38100
B(22) = ? 39400
B(23) = ? 40600
B(24) = ? 41900
B(25) = ? 43200
B(26) = ? 44500
B(27) = ? 45700
B(28) = ? 46900
B(29) = ? 48200

Enter Max Value of Ureteral Transit Time (min) < 30 ? 10
```

| | Right | Left |
|---|---|---|
| Kidney Contribution to Bladder (%) | 52.9 | 47.1 |
| Approximate Ureteral Transit Time (min) | 1.0 | 0 |

## REFERENCES


1. Harpen MD, Lecklitner ML. Quantitative evaluation of differential renal function: A new approach. *J Nucl Med* 1985;26:647–49.

2. Gates GF. Glomerular filtration rates: Estimation from fractional renal accumulation of $^{99m}$Tc-DTPA (stannous). *Am J Roentgenol* 1982;138:565–70.

3. Gates GF. Split renal function testing using Tc-99m DTPA: A rapid technique for determining differential glomerular filtration. *Clin Nucl Med* 1983;8:400–07.