Quantitative Evaluation of Differential Renal Function: A New Approach

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A simple method is presented for quantitating the relative contribution of left and right kidneys to the total bladder activity observed in a [^{99m}Tc]DTPA renogram. The method is shown to be useful in identifying ureteral obstruction.

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Technetium-99m-labeled diethylenetriaminepentaacetic acid (DTPA) is used clinically to assess renal blood flow and function (*1*,*2*). Routinely, 2-min renal uptakes of the radiotracer are used to determine differential renal performance (*3*,*4*). In the case of ureteral obstruction, however, activity taken up by the kidneys will not subsequently appear in the bladder. We present a technique for correlating the shapes of renal uptake curves and bladder curves to determine the percent of bladder activity attributable to each kidney. The method produces a useful addition to the other parameters currently reported in DTPA renograms, especially when compared to the percent 2-min renal uptake used to evaluate differential renal clearance by glomerular filtration.

MATERIALS AND METHODS

It is reasonable to assume that the rate of accumulation of activity in the bladder is directly proportional to the renal uptake of radio tracer, i.e.,

$$A_B(t) = k_L \int_0^t A_L(t - t_L)dt + k_R \int_0^t A_R(t - t_R)dt \quad (1)$$

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.

Patients were referred to the nuclear medicine department for evaluation of renal function. Dynamic scans consisting of 30 2-sec frames followed by 29 1-min frames of both kidneys were acquired following intravenous bolus injection of [^{99m}Tc]DTPA, 15 mCi. The large field-of-view camera was positioned posteriorly so that bladder activity could be observed concurrently. Following the radionuclide procedure background corrected renal and bladder time-activity curves were generated. Renal regions of interest included parenchyma and pelvis. The bladder curves were fitted to Eq. 1 with the observed renal curves (linearly interpolated between data points) as input function using a least square approach and the rate constants and transit times were determined.

The percent of bladder activity attributable to each kidney was calculated from the integrated renal uptake and final bladder activity by

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

$$\%\,\text{RIGHT} = k_R \frac{\tilde{A}_r}{A_B(30)} \times 100\% \quad (2)$$

where $\tilde{A}_L$ and $\tilde{A}_R$ are the areas under the left and right renal time activity curves and $A_B(30)$ is the activity of the bladder at the end of the 30-min study.

RESULTS

Table 1 summarizes the rate constants and transit time and percent function data for the nine patients considered. For purposes of comparison the table also shows the percent function determined by the 2-min uptake method.

Figure 1 shows time-activity curves for the left and right kidneys for Patient 1, a normal study. Figure 2 shows similar curves for Patient 2, an abnormal study. The raw bladder activity data and fitted bladder curve using Eq. 1 are also given. The model is seen to produce an excellent fit to the bladder data.

DISCUSSION

Patient 2 illustrates the utility of this new procedure. The 2-min uptake method implied roughly 39% function for the right kidney whereas the proposed method de-

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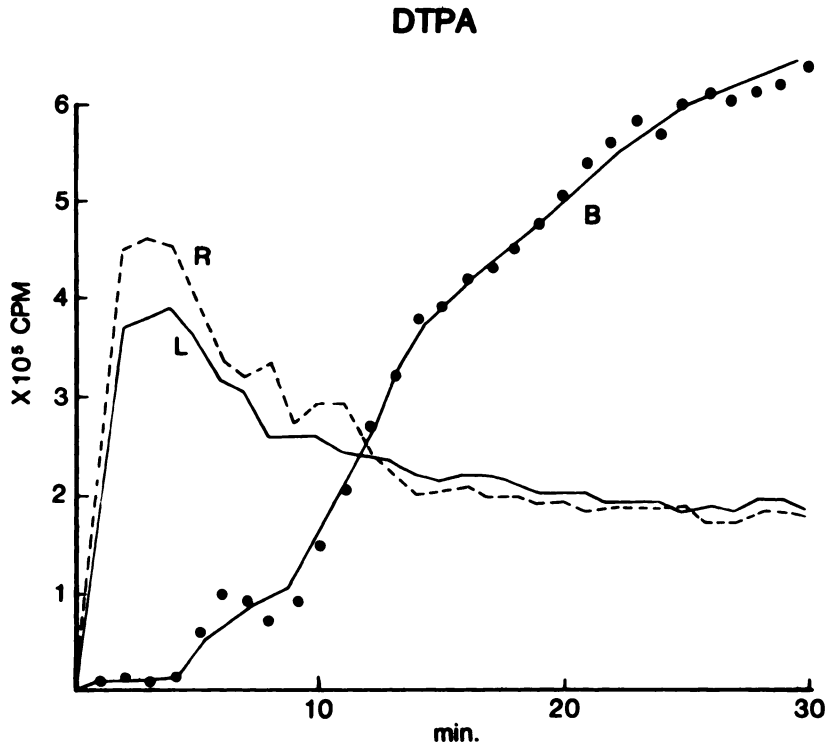

FIGURE 1
Left and right renal time-activity curves (L and R) used as input functions in Eq. 1, bladder time-activity data (●) and least square fit (curve B) for Patient 1

termined that essentially none of the bladder activity could be accounted for by right renal uptake. A follow-up ultrasound scan of this patient showed a dilated right collecting system, consistent with a diagnosis of right ureteral obstruction. For Patient 5 the 2-min uptake method estimated a 40–60% split in renal function whereas the proposal method determined that none of the activity taken up by the left kidney appeared in the bladder. A follow-up renal ultrasound examination was normal. Complete left ureteral obstruction was later confirmed by intravenous pyelogram. No obvious obstructions were observed in the analog images of these patients and ureters were not visualized. In Patient 6, however, the left ureter was visualized; the bladder

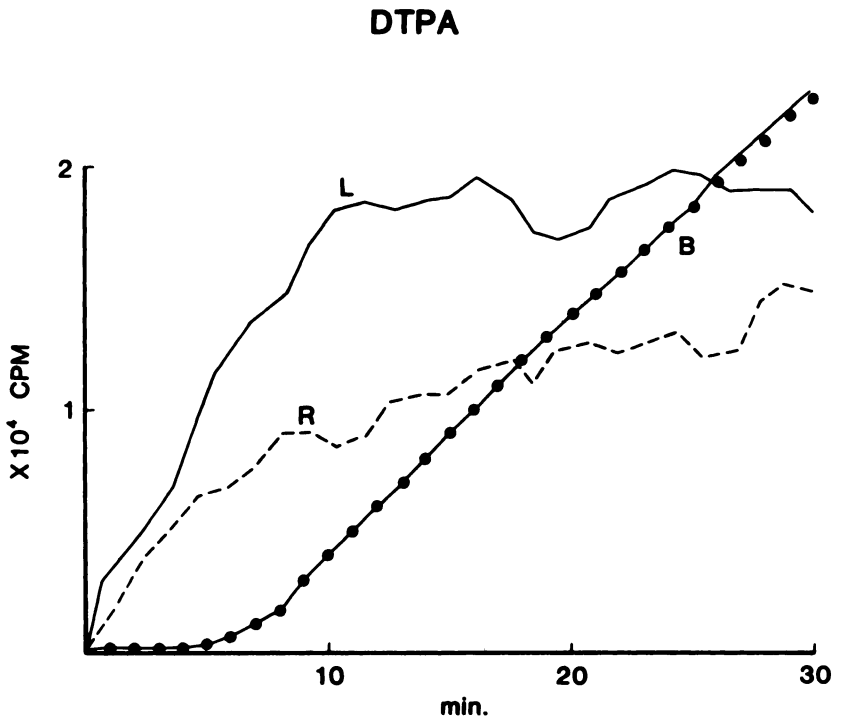

FIGURE 2
Left and right renal time-activity curves (L and R) used as input functions in Eq. 1, bladder time-activity data (●) and least square fit (curve B) for Patient 2

contribution from the left kidney for this patient was calculated at 20%. No evidence of ureteral obstruction was noted in the other patients.

TABLE 1
Summary of Fitting Parameters and Differential Renal Function

Patient no.	k(10^{-2} min)	t(min)	Bladder contribution (%)	2-min uptake (%)
1 L	2.37	1.18	47.8	42.2
R	2.59	2.04	52.2	57.8
2 L	7.84	2.07	>99.9	61.2
R	<0.01	—	<0.1	38.8
3 L	3.99	0.27	43.7	45.0
R	6.88	5.04	56.3	55.0
4 L	0.99	4.80	23.4	57.0
R	5.76	5.41	76.6	43.0
5 L	<0.01	—	<0.1	40.5
R	7.28	0.24	>99.9	59.5
6 L	0.57	4.33	20.8	54.1
R	3.64	5.15	79.2	45.9
7 L	3.46	17.4	41.1	54.6
R	3.86	0.76	58.9	45.4
8 L	1.87	1.23	49.1	46.2
R	3.01	2.92	50.9	53.8
9 L	6.55	3.53	51.2	38.4
R	5.08	2.39	48.8	61.6

Our method for determining differential renal function correlates the shapes of renal uptake curves with the shape of the bladder curve. Unlike the 2-min uptake method, actual values of renal uptake are not particularly important: e.g., if the activity from one kidney is attenuated to a greater extent than that of the other kidney its rate constant will be appropriately adjusted upward. This is so since attenuation affects the magnitude of an uptake curve but not its shape.

If the renal curves are exactly similar, i.e., differing from each other by a multiplicative constant, a unique least square solution for the rate constant and transit times will not be obtainable. Thus, a deliberated visual inspection of the uptake curves is recommended when interpreting these parameters and percent differential functions. In our limited experience with this procedure, we have yet to encounter a situation in which a good fit to the observe data could not be obtained. Because the method assumes that renal activity accumulates in the bladder it is essential that patients with catheters have them clamped during this 30-min procedure.

We have presented a simple technique for determining the contribution each kidney makes to the bladder activity observed in a renal uptake and flow study and have demonstrated its utility in the diagnosis of ureteral obstruction.

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