A New Method of Radiorenogram Analysis by Gamma Function

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[1] Introduction

The renogram has been seized upon as a simple, safe and valuable method in the evaluation of renal function, since it was first presented as a mean of renal blood flow measureemnt by Taplin et al.

Several methods of quantification of the renogram pattern have been proposed and recently, some theoretical formulation has been proposed to explain the renogram pattern.

To further increase knowledge of the renogram, more complicated models have been published.

But the clinical use of these theoretical models will be limited, because the required mathematical manipulations involve intricate and lengthy calculations.

In this report, the renogram R(t) has been handled as a black box physiologically and a mathematical model was constructed by using gamma functions as follows;

$$R(t)=R_1(t)+R_2(t)$$

$$R_1(t)=S_1t^{\alpha_1}e-\frac{t}{\beta_1},$$

$$R_2(t)=S_2t^{\alpha_2}e-\frac{t}{\beta_2}$$

These expression for R(t) have convenient properties for machine computation on small computers and can be applicable to a wide variety of renogram curve.

[2] Methods

The procedure of curve fitting by using gamma functions consists of three steps. After the down slope over the midway in amplitude was fitted by the first gamma function ($R_1(t)$); a subtraction the first gamma function from the original renogram was made.... ($R(t)$-$R_1(t)$)

Then the remainder was fitted by the second gamma function ($R_2(t)$).

But if the peak time (TR-max) and the half time in amplitude on the down slope (TR-half) were not observed within 10 minutes and 25 minutes, respectively, then the renogram was represented by only one gamma function ($R_2(t)$).

In the precedure of curve fitting, a weighted least square method was used.

Flow of diagnostic logic

After digitalyzed data of the renogram is read, TR-max and TR-half are tested against normal value.... Logic unit 1

If TR-max and TR-half being within above mentioned values, the renogram is regarded as abnormal and curve fitting is performed by one gamma function and the flow is transfered to operational unit.

If the answer to logic unit 1 is "yes", the renogram is represented as the sum of two gamma function and the values (αi,βi,Si) are compared with normal values.... Logic unit 2.

If these values being normal, the case was diagnosed as normal and if the answer to logic unit 2 is "no", the flow is transfered to the operational unit.

In operational unit, calculation of scores of each discriminant function is executed to get a differential diagnosis among the cases of renal artery stenosis, depletion of renal function and urinary tract dysfunction.

[3] Results and conclusion

Radiorenogram curves were almost exactly expressed by our methods, not only in the normal but also in the cases of decreased renal function, urinary tract dysfunction and renal artery stenosis.

Generally speaking about α, β and S, in the cases of renal artery stenosis and urinary tract dysfunction, reduction of the value of β_1 and elevation of α_2 were common characteristics and the latter as often accompanied by an abnormal value of α_1.

However, there is considerable overlap between these two groups, as expected by a simulation study.

The value of each parameter in the decreased renal function was similarly abnormal. But in mild cases, low value of scale factor S is often only one evidence.

From present study, we have observed the following;

(1) 3 or 6 essential parameters can be extracted from the renogram.
(2) Error of collimation could be corrected to some extent, by introducing scale factor S.
(3) Our method has convenient properties for machine computation on a small computer.

Quantitative Analysis of Radioisotope Renogram by Digital Simulation Method

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Our quantitative analysis of RI renogram by the analog simulation method has been recognized as clinically valuable in the evaluation of kidney function. As the analog method takes much time in data handling, we adopted digital simulation technique for more rapid data management.

Principles of digital simulation are the same that of analog method. The digital computer we use is a mini-computer of 8 K memory size. In programming we use "BASIC" language, which can call "ASSEMBLER". Renogram data are restored into the computer after converted from random to regular pulses by a custom-made converter. Using "BASIC" language program, renogram data are calculated repeatedly until the best agreement is found between observed and computed value. Then, total renal plasma flow rate (RPF), its right to left ratio and right and left mean transit time (MTT) are printed out automatically with computed renogram figures by the teleprinter. Accuracy of the calculated data are shown by square of difference between observed and computed data to square of one standard deviation of observed data ratio.

By the digital simulation method, it takes only few minutes in calculation and the computed data show as much clinically valuable data of kidney function as shown by the analog simulation.