Deconvolution Analysis of the Dynamic Renal Scan

Deconvolution analysis of the renogram has become a topic of current interest and could become useful in the determination of functional nephron mass. Recently Diffey et al. (*1*) proposed a matrix algorithm for performing this deconvolution, where the result is thought to represent the impulse response function of the renal system. Their procedure followed from the assumption that the renogram represents the convolution of the renal impulse response with the renal input function. The authors identified this input function with the cardiac time–activity curve, which represents the activity contained in the blood. This was a poor assumption.

The activity contained in the blood decreases with time, and the change in this activity represents the negative of the amount of activity entering the renal system. Thus, the renal input function depends on how the blood activity changes and is given by the negative time derivative of the blood–activity curve. This can also be shown mathematically since the distribution of a renally excreted radiopharmaceutical can be compartmentally modeled and described by differential equations (*2,3*).

During my attempts to reproduce previous work (*4*) in this area, I too was frustrated by the tendency for the resultant impulse response function to take negative excursions. When the deconvolutions were repeated using the correct renal input function, the problem did not recur. In addition, only minimal low-pass filtering was required, as opposed to the data-bounding methods employed by the authors.

C. ROBERT APPLEDORN
University of New Mexico School of Medicine
Albuquerque, New Mexico

REFERENCES

1. DIFFEY BL, HALL FM, CORFIELD JR: The ^{99m}Tc-DTPA dynamic renal scan with deconvolution analysis. *J Nucl Med* 17: 352–355, 1976

2. APPLEDORN CR: A letter to the editor. *Br J Radiol*: to be published

3. DEGRAZIA JA, SCHEIBE PO, JACKSON PE, et al.: Clinical applications of a kinetic model of hippurate distribution and renal clearance. *J Nucl Med* 15: 102–114, 1974

4. KENNY RW, ACKERY DM, FLEMING JS, et al.: Deconvolution analysis of the scintillation camera renogram. *Br J Radiol* 48: 481–486, 1975

Reply

We thank Dr. Appledorn for his interest in renal deconvolution and his comments on our work (*1*). We feel, however, that he is mistaken in his premise that the input function is the negative time derivative of the blood activity. It appears that he is confusing the principles of compartmental analysis, where the activity removed by the kidney is indeed given by the negative time derivative of the blood activity curve, with the technique of deconvolution applied to linear time-invariant systems.

The basis of deconvolution lies in the assumption that the kidney must be regarded as a linear system. This means that the amplitude of the renogram is taken to be directly proportional to the administered dose, or the activity contained in the blood. The class of linear systems is defined by the principle of superposition (*2*). If $y_1(t)$ and $y_2(t)$ are the responses when $x_1(t)$ and $x_2(t)$ are the respective inputs, then the system is linear if and only if

$$T[x_1(t) + x_2(t)] = T[x_1(t)] + T[x_2(t)] = y_1(t) + y_2(t), \quad (1)$$

where $T[x(t)]$ is defined as the operator that maps an input sequence $x(t)$ into an output sequence $y(t)$.

This principle will hold if the input sequence is taken as the blood activity curve and the output sequence is taken as the observed renogram, as described in our paper. If, however, the input sequence is taken as the negative time derivative of the blood activity curve, Eq. 1 will, in general, not hold and deconvolution may no longer be applied.

We suggest that the reason why Dr. Appledorn appears to perform satisfactory deconvolution, with reduced occurrence of negative excursions in the calculated retention function, arises from the observation that in practical renography the blood activity curve is closely approximated by the sum of two exponentials (*3*). The negative derivative of this function will yield a double exponential with a more rapid reduction in relative amplitude than the blood activity curve. The retention function exhibits negative excursions since the rate of removal of tracer from the kidney exceeds the rate of input from the blood. However, if the input function which is used decays more rapidly than the blood activity curve, the resultant negative excursions in the retention function will be diminished, but by operations that we regard as invalid assuming the present linear model of the kidney.

B. L. DIFFEY
J. R. CORFIELD
F. M. HALL
Kent and Canterbury Hospital
Canterbury, Kent, United Kingdom

REFERENCES

1. DIFFEY BL, HALL FM, CORFIELD JR: The ^{99m}Tc-DTPA renal scan with deconvolution analysis. *J Nucl Med* 17: 352–355, 1976

2. OPPENHEIM AV, SCHAFER RW: *Digital Signal Processing.* Englewood Cliffs, N.J., Prentice-Hall, 1975, p 11

3. FLEMING JS, GODDARD BA: A technique for the deconvolution of the renogram. *Phys Med Biol* 19: 546–549, 1974

Gallium-67 Scanning of Tuberculous Peritonitis

Dr. Steinbach's report of tuberculous peritonitis shown on ^{67}Ga-citrate scan (*1*) prompted us to review a similar case in our files. The essentially identical distribution of ^{67}Ga in our patient has led us to submit the following case report as additional data supporting Steinbach's finding that ^{67}Ga is concentrated in the lesion of tuberculous peritonitis.

The patient, a 40-year-old black man, was admitted to an outlying hospital where a workup for a 2-day history of nausea, vomiting, and right upper quadrant abdominal pain led to a diagnosis of right lower lobe pneumonia with pleural effusion. Despite antibiotic therapy, the abdominal pain and temperature elevations to 104°F persisted. Upon transfer to our hospital, the patient was found to be febrile but in no acute distress. Signs of right pleural fluid were

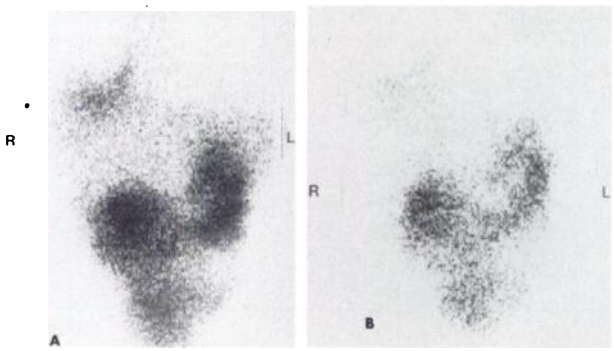

FIG. 1. (A) Anterior ^{67}Ga scan at 72 hr shows uptakes in right lower chest and throughout abdomen, separated by hepatic region that is essentially devoid of radioactivity. (B) Anterior ^{67}Ga scan at 96 hr, following further bowel cleansing, shows no change in distribution of ^{67}Ga uptake.

noted. Abdominal examination elicited generalized tenderness with nonlocalizing diffuse rebound. The remainder of the physical examination was unremarkable.

Routine blood tests and cultures were normal or negative. Chest roentgenogram showed right pleural effusion. Thoracentesis provided insufficient fluid for culture, and pleural biopsy yielded inadequate tissue for diagnosis. Fiber-optic bronchoscopy and bronchial washing were not helpful. Upper gastrointestinal series, barium enema, and intravenous cholangiogram were normal. A bone marrow aspirate was consistent with chronic infection, and a tuberculin skin test was positive (14 mm induration).

The patient's fever continued and remained undiagnosed. Prior to performing an exploratory laparotomy, a ^{67}Ga scan was requested. The initial scan at 72 hr (Fig. 1A) showed activity throughout the abdomen and in the area of the right pleural effusion and absence of activity in the hepatic area. A repeat scan at 96 hr (Fig. 1B), following cleansing enemas, showed identical tracer distribution. At surgery, biopsy of the peritoneum showed caseating granulomas, and culture eventually grew acid-fast bacilli. The patient responded to antituberculous medications and was discharged 10 days after surgery.

Our patient's distribution of ^{67}Ga within the abdomen is remarkably similar to that of Steinbach's patient. In addition, our patient had ^{67}Ga uptake in the area of his pleural effusion, most likely representing tuberculous involvement. This second case of ^{67}Ga accumulation in tuberculous peritonitis, together with the increasing evidence of positive scans in a variety of infections and inflammatory disorders, suggests that the ^{67}Ga scan may routinely diagnose tuberculous peritonitis. Confusion between diffuse peritoneal uptake and bowel radioactivity can be resolved by repeated scanning and by abdominal activity in excess of hepatic uptake.

ROBERT J. BARAN
MELVIN J. FRATKIN
Medical College of Virginia
Virginia Commonwealth University
Richmond, Virginia

REFERENCE

1. STEINBACH JJ: Abnormal ^{67}Ga-citrate scan of the abdomen in tuberculous peritonitis: Case report. *J Nucl Med* 17: 272–273, 1976

Comparison of ^{99m}Tc and ^{123}I for Thyroid Imaging

I was dismayed to read the article by Arnold and Pinsky (*1*), comparing ^{99m}Tc-pertechnetate images obtained 20–30 min after administration with ^{123}I images, obtained at 16–19 hr, in which they conclude that not only was pertechnetate better than the iodide, but "in a few cases ^{99m}Tc-pertechnetate showed abnormalities more readily."

Over three decades ago, Hamilton et al. established that the time course of radioiodide concentration by the thyroid was a function of many parameters dependent on blood flow, extraction efficiency ("trapping"), fixation ("organification"), storage, and release. It is generally appreciated that the rapid initial accumulation of tracer in the thyroid is primarily related to perfusion and extraction efficiency, whereas at later time intervals the fixation, storage, release, etc., components become more important. Thus, attempts to compare one tracer's uptake in the thyroid at 20–30 min with another tracer's uptake at 16–19 hr are absurd.

If one wishes to compare the relative efficacy of pertechnetate with iodide in evaluating thyroid function, it is necessary to perform studies on both at comparable time intervals and with comparable routes of administration. This was not done by Arnold and Pinsky.

If it was the intent of the authors to compare the results they obtained using two different techniques and types of study, which also happen to use different radionuclides, they should clearly state that the disparate techniques and nature of the two studies would be expected to influence the nature of the results.

If their intent was to show that thyroid images obtained shortly after administration of a tracer may provide useful information in addition to that which might be obtained from later studies, then they may wish to study whether such early studies are best done using pertechnetate or the iodide.

H. S. WINCHELL
Medi-Physics, Inc.
Emeryville, California

REFERENCE

1. ARNOLD JE, PINSKY S: Comparison of ^{99m}Tc and ^{123}I for thyroid imaging. *J Nucl Med* 17: 268–271, 1976

Reply

No one doubts that ^{99m}Tc-pertechnetate, ^{123}I, or both are currently used to image the thyroid in many nuclear medicine departments. On theoretical grounds, because of the different ways pertechnetate and radioiodine are handled by the thyroid (discussed in the opening paragraph of our paper), one would expect ^{123}I images to be superior. However, as ^{123}I is more expensive and less readily available than ^{99m}Tc, it seems very important to ask, "Is the theoretical superiority of ^{123}I over ^{99m}Tc for thyroid imaging significant in practice?" This is the question that our paper attempts to answer, and our results indicate that the answer is "No," with several important exceptions.

To answer the above question, it is essential that each radionuclide be used in the manner currently regarded as optimal. That this requires the use of one technique for