The glomerular filtration rate (GFR) can be computed from the scintigraphic determination of Tc-99m DTPA (diethylenetriaminepentaacetic acid) uptake within the kidneys. The required computations are straightforward and can easily be included in the software of various computers, including a hospital’s existing data-processing system. This report presents a complete operational program based on extensive experience with this method. The program is easy to use, allows for adjustments to be made for unusual clinical conditions, and produces a permanent record that can be issued as part of the final report.

The purpose of this communication is to present a computer program for making these computations. The program was written in BASIC for a small computer* and also operates on our (Digital Equipment Corporation) VAX-11/780 main-frame computer† with only minor modifications. The program asks a series of questions, allows for correction of erroneous responses, and prints the results, including the entered data, in a form acceptable as a final report.

THE GFR PROGRAM (LINES 1, 3180)

The program is shown in Appendix 1. Data input and output sections are separated by a computational section. Line 2410 is a printer activation command used by the small computer*, whereas line 3170 returns “control” to the video terminal. These two commands may have to be modified for other systems. A listing of the string and numerical variables encountered in the program is shown in Appendix 2. Following are specific comments regarding the input and output displays and the computational section.

INPUT SECTION (LINES 1, 360; SUBROUTINES 900, 1400)

Basic patient and test information (Lines 1, 340). Answers to the first five questions establish the patient’s name (and/or hospital’s or department’s identification number), age, sex, date of examination, and dose of radionuclide injected. The next four questions deal with the patient’s weight and height, and whether these numerical responses are in the English or metric systems. Subsequent processing converts all values into the metric, from which estimations of the mid-plane depth of normally positioned kidneys, as well as body surface area, are derived according to the formulae

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of Tjønnesen et al. (4) and Gehan and George (5), respectively. Patient position (upright or supine) is then recorded. Next the question asks whether a kidney transplant is being studied, and if so, it requires that the value of the measured mid-plane kidney depth be entered (this usually having been determined by ultrasonography). If the patient does not have a renal transplant, the next question requires the operator to decide whether the renal depth will be estimated (from patient's height and weight according to the formula of Tjønnesen et al. (4)) or will be measured (as by TCT or ultrasound). The depth is usually estimated, but under special situations, such as with polycystic kidneys, which may be giant and whose depth cannot be satisfactorily estimated, an actual measured value can be entered and is used in the subsequent calculations. If only one functional kidney is present and the "measured" option is selected, any number, including zero, can be entered for the nonfunctional side: only the value relating to the functional kidney will be used in the calculations. The final question allows for changes to be made in the data entry for this entire section. This question will automatically follow a measured depth response if a renal transplant is being studied, or completion of the questions and responses dealing with the option of using either estimated or measured renal depth in nontransplant patients. An affirmative response to "Any changes?" repeats the entire section. Any question in this section specifying an exact answer (e.g., "I" or "C" for inches or centimeters) will not proceed beyond that point if any other response is entered: in such circumstances, the incorrect answer is rejected, and the question is repeated.

Preinjection postinjection syringe counts (Line 350, subroutine 900). Entry of these data is the first instruction encountered and is followed by the time in seconds required to accumulate the counts. The GFR computation uses 1-min, preinjection syringe counts, but the "time" question allows for "adjustment" of the syringe counts in case the computer-camera combination results in some other counting time. The next question deals with "excess time" from the measurement of the preinjection syringe count until actual tracer injection into the patient. Usually the syringe is counted and the patient promptly positioned before the gamma camera so that the injection is made within 1-3 min. If a delay occurs, however, this "excess time" can be entered, and the subsequently computed decay factor will adjust the counts "downward.

The next questions deal with postinjection syringe count, the time required for such a determination, and whether excessive delay was encountered before making these determinations. A decay factor is not used if the postinjection syringe count is made promptly after the usual 6-min study. However, sometimes delays may unavoidably occur, and this option allows for count correction, which is adjusted "upward" by the computed decay factor. (I usually subtract 5 min from any "excess time" thus encountered, in order to maintain consistency with the uncorrected information obtained promptly after the usually short examination.) The next question encountered is "Any more postinjection counts?". Up to three postinjection counts may be entered, allowing for not only the usual postinjection syringe count but also correcting for any minor local infiltration at an injection site or other mishap. Following a negative response to the question (or completion of three such entries), the program queries the operator whether any changes are desired. If a positive response is indicated, then the entire syringe-count section will be repeated.

Renal count data (Line 360, subroutine 1400). The final section of information entry deals with the renal count data. This information is background-corrected (but net depth-corrected, since this requires knowledge of kidney depth, and is performed later in the GFR program) and is determined by inspecting a print-out of renal counts from the renogram. Following normalization of each renal background area to its respective kidney size, and subsequent subtraction of this information from gross renal counts, the net renal activity is printed out and the operator enters it into the GFR program. This information should represent the renal activity at 2-3 min following tracer arrival within the kidneys. The camera-computer system is activated at the instant of tracer injection, and the study is usually framed in 15-sec intervals. However, the program will ask for the framing time, thus allowing for use of other intervals. The operator is warned that the framing time must divide integrally into 60 sec. Improper intervals will be rejected, and the question repeated. Following a satisfactory response, the operator is allowed to make any necessary changes. The "Any changes?" option is located at this important point since the size of the subsequent array depends upon the answer.

Ordinarily, there is a 15-sec delay from the moment of injection until renal arrival of tracer owing to transit through the central cardiopulmonary circulation. This delay may be increased in cases of cardiopulmonary disease, however, and it is vital to inspect the listing of net renal counts in order to determine the correct data to enter into the program. The sudden increase in renal count activity makes this a straightforward determination. Merely entering the 2-3 min renal activity present after injection of radiotracer rather than following its renal arrival may produce erroneous results.

If a transplanted kidney is present, the operator will be asked to enter the 2-3 min sequential renal count determinations. If a transplant is not present, the operator will be asked whether there is a right kidney, and following an affirmative response will be directed to enter the sequential count determinations. After this, or if the right kidney is denied, the same routine is followed for the left kidney. Following this (or data entry for a transplant), the operator will be asked "Any changes?", and if so, the section for renal count data will be repeated.

COMPUTATION SECTION (LINE 370, SUBROUTINE 2000)

The patient's weight and height, if entered as pounds or inches, are converted to kilograms and centimeters, with rounding off to the nearest 0.1 kg and centimeter. The patient's body surface area is then computed according to the formula of Gehan and George (5).

Renal depth can be estimated from the patient’s height and weight, if desired, and will be rounded off to the nearest 0.1 cm. If kidney depth is measured and entered into the program, similar rounding off will occur. Depth-corrected renal counts are then computed as discussed earlier.

The depth-corrected, total renal counts are then divided by the net administered syringe counts in order to determine the percent of injected tracer residing in the kidneys at the 2- to 3-min time interval. GFR is then computed as previously discussed. The GFR value is then normalized by multiplying it by the ratio of the "standard" body surface area (1.73 m²) to patient's body area (m²) (6).

OUTPUT SECTION (LINE 380, SUBROUTINE 2400)

Patient data and test information (Lines 2400-2660). The first nine lines of the initial section of the printout reproduce the input responses regarding patient's name (and/or identification number), age, sex, date of examination, dose of tracer injected, height, weight, position during the examination, presence of a renal transplant (and if so, the measured depth), and estimated or measured kidney depth (this being omitted if a transplant is present). If only one functioning kidney is present, the estimated or measured depth of the nonfunctional kidney will not be printed. The last information printed in this section is the calculated body surface area.
Syringe and kidney count information (Lines 2700–2910). The second section lists the syringe counts, with the various time intervals, along with any "excess time" encountered. When appropriate, decay factors are printed. Following this, the printout shows the renal counts entered earlier.

Glomerular filtration rate (Lines 2920–3180). The total GFR is printed along with the percent and absolute contribution of each kidney (if two are present). The total as well as absolute GFR for each kidney will be rounded off to the nearest whole number as well as the percent contribution of each kidney to total GFR. The total GFR is multiplied by each kidney's fractional contribution to overall function in order to compute individual GFR. On rare occasions (0.4% of the time in this author's experience) when these fractional contributions "round off" to 50% but are used as multipliers of an odd-numbered GFR, the sum of the resulting rounded off individual GFRs will exceed the total value by 1 ml/min. The normalized total GFR is then printed, which in turn is compared with a similarly normalized, age-adjusted, mean "normal" value along with a lower limit value (standard error of the 5th percentile). This latter information is based on age-corrected insulin clearances for individuals ranging from 20 to 60 yr, and is independent of sex (7). This step requires the patient’s age (between 20 to 60 yr) to be rounded off to the nearest value that is evenly divisible by 5. This range of age-adjusted normals will not be printed for individuals who do not fall within the inclusive age range.

DISCUSSION

Most nuclear medicine computers use FORTRAN as their programming language, although at least one major vendor uses BASIC. On the other hand, most personal computers (some with considerable computing capability) and many hospital-based data-processing systems use BASIC as their language. Newer personal and hospital computers give the nuclear medicine physician a degree of independence previously not available. The BASIC language is more than capable of computing many of our tasks and, when coupled with an inexpensive printer, can produce a document suitable as a final product. Now department personnel can design and execute programs suited to their own needs and can easily modify them as conditions require. Cost is always a factor in actual practice, yet this can be minimal when a hospital’s existing data-processing system is used.

The GFR program presented here is based on extensive clinical experience. It includes options that allow the user to compensate for unlinked or unusual circumstances. At several junctions, the user can correct the entered data without aborting the entire program, and the final printout serves as: (a) a permanent record of the technical factors of the test, (b) a double check on the accuracy of the data entry, and (c) a final report that can be sent out with an interpretation to the referring physician. The age-adjusted, normal values were included since the GFR decreases linearly with age, independent of sex, at a rate of 4 ml/min per decade between ages 20 and 60 yr. This information serves as a guide for comparison with an individual patient’s results. However, these data (7) were determined from insulin clearances and not creatinine clearances, the latter being the basis for the GFR formula used in this program. On the other hand, creatinine clearances also decrease with age, (8) and the current listing of “normal” values was chosen since both sexes were extensively studied with the published tables including age-adjusted means as well as lower limit values.

FOOTNOTES
* Apple II.
† Digital Equipment Corporation VAX-11/780.

APPENDIX 1

1 REM PROGRAM TO COMPUTE GFR FROM SINGLE INJECTION OF 99M-TC DTPA
5 DIM A(4,3)
10 PRINT : INPUT "PATIENT NAME AND/OR I.D. NUMBER ?: C " ;PNS$ 20 INPUT "PATIENT AGE IN YEARS ?: " ;PA 30 INPUT "SEX ? M OR F : " ;PSS$ 40 IF PSS$ = "M" THEN 70 50 IF PSS$ = "F" THEN 70 60 GOTO 30 70 INPUT "DATE ?: " ;D$ 75 INPUT "DOSE OF 99M-TC DTPA INJECTED ? (MCI, NUMBERS ONLY): " ;MC$ 80 INPUT "WEIGHT ? (NUMBERS ONLY): " ;W : W1 = W 90 INPUT "POUNDS OR KGMS ? P OR K: " ;W$ 100 IF WS$ = "P" THEN 130 110 IF WS$ = "K" THEN 130 120 GOTO 90 130 INPUT "HEIGHT ? (NUMBERS ONLY): " ;H : H1 = H 140 INPUT "INCHES OR CMS ? I OR C: " ;H$ 150 IF HS$ = "I" THEN 180 160 IF HS$ = "C" THEN 180 170 GOTO 140 180 INPUT "PATIENT UPRIGHT OR SUPINE ? U OR S: " ;PP$ 190 IF PP$ = "U" THEN 220 200 IF PP$ = "S" THEN 220 210 GOTO 180 220 INPUT "TRANSPLANT ? Y OR N: " ;TP$ 230 IF TP$ = "Y" THEN INPUT "MEASURED DEPTH (CMS): " ;TP : GOTO 310 240 IF TP$ = "N" THEN 260 250 GOTO 220 260 INPUT "KIDNEY DEPTH ESTIMATED (FROM HEIGHT & WEIGHT) OR MEASURED ? E OR M: " ;DM$ 270 IF DM$ = "E" THEN 310 280 IF DM$ = "M" THEN 300 290 GOTO 260 300 INPUT "MEASURED RIGHT KIDNEY DEPTH (CMS): " ;RK : INPUT "MEASURED LEFT KIDNEY DEPTH (CMS): " ;LK 310 PRINT : INPUT "ANY CHANGES ? Y OR N: " ;ACS$ 320 IF ACS$ = "Y" THEN 10 330 IF ACS$ = "N" THEN 350 340 GOTO 310 350 GOSUB 900 360 GOSUB 1400 370 GOSUB 2000 380 GOSUB 2400 390 END 900 REM SYRINGE COUNT DATA 910 PRINT 920 INPUT "DTPA PRE-INJECTION COUNTS: " ;A(0,0) 930 INPUT "TIME FOR COUNTS IN SECONDS: " ;A(0,2) 940 A(0,1) = INT (((A(0,0) / A(0,2)) * 60) + .5) 950 INPUT "99M-TC DECAY FACTOR ? Y OR N: " ;DF$ 960 IF DFS$ = "Y" THEN INPUT "EXCESS TIME (MINUTES): " ;A(0,3); GOTO 990
IF DFS = "N" THEN 1000
GOTO 950

A(1) = INT (A(0,1) * (INT ((EXP (-.693 * A(0,3)) / 360) * (1000) + .5) / 1000) + .5)
FOR N = 1 TO 3
PRINT
PRINT "DTPA POST-INJECTION COUNTS: "; A(N,0)
PRINT "TIME FOR COUNTS IN SECONDS: "; A(N,2)
A(N,1) = INT (((A(N,0) / A(N,2)) + 60) + .5)
INPUT "99M-TC DECAY FACTOR? Y OR N: "; DFS
IF DFS = "Y" THEN INPUT "EXCESS TIME (MIN/S): "; A(N,3) GOTO 1090
IF DFS = "N" THEN 1100
GOTO 1050
A(N,1) = INT ((A(N,0) / (INT ((EXP (-.693 * A(N,3)) / 360) * (1000) + .5) / 1000) + .5)
1100 IF N = 3 THEN 1260
PRINT : INPUT "ANYMORE POST-INJECTION CTS? Y OR N: "; PCS
IF PCS = "Y" THEN 1250
IF PCS = "N" THEN 1260
GOTO 1210
NEXT N
PRINT : INPUT "ANY CHANGES? Y OR N: "; AC$1
IF AC$ = "Y" THEN GOSUB 1320: GOTO 910
IF AC$ = "N" THEN 1300
GOTO 1260
A(4,1) = A(0,1) - (A(1,1) + A(2,1) + A(3,1))
RETURN
FOR X = 0 TO 4
FOR Y = 0 TO 3
A(X,Y) = 0
NEXT X
NEXT Y
PRINT "REM KIDNEY COUNTS"
PRINT
INPUT "WHAT IS COMPUTER FRAMING RATE, IN SECONDS, FOR RENOGRAM? ENTERED VALUE MUST RESULT IN WHOLE NUMBER WHEN DIVIDED INTO 60 SECONDS. "; NS
440 NI = 60 / NS
450 IF NI > INT (NI) THEN PRINT : PRINT "FRAME TIMING INCORRECT. MUST EQUAL WHOLE NUMBER WHEN DIVIDED INTO 60 SECONDS. TRY AGAIN!"
GOTO 1420
PRINT : INPUT "ANY CHANGES? Y OR N: "; AC$2
IF AC$ = "Y" THEN 1420
IF AC$ = "N" THEN 1500
GOTO 1460
DIM B(N,1)
PRINT : PRINT "ENTER BACKGROUND CORRECTED COUNTS FOR 2-3 MIN INTERVAL AFTER TRACER ARRIVAL IN KIDNEY(S)"
PRINT : IF TP$ = "Y" THEN PRINT "KIDNEY COUNTS": GOTO 1610
PRINT : INPUT "IS THERE A LEFT KIDNEY? Y OR N: "; RKS
IF RKS = "Y" THEN C = 0: GOSUB 1800: GOTO 1570
IF RKS = "N" THEN 1570
GOTO 1530

PRINT : INPUT "IS THERE A LEFT KIDNEY? Y OR N: "; RKS
IF RKS = "Y" THEN C = 0: GOSUB 1800: GOTO 1570
IF RKS = "N" THEN 1570
GOTO 1530

PRINT "REM FINAL REPORT"
PR # 1
PRINT "PRINT "PATIENT NAME AND/OR I.D. NUMBER: "; PN
PRINT "PRINT "PATIENT AGE: "; PA: "YEARS"
PRINT "PRINT "PATIENT SEX: ";
IF FSS = "M" THEN PRINT "MALE"
IF FSS = "F" THEN PRINT "FEMALE"
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REFERENCES


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Education and Research Foundation Fundraiser
Third Annual Tennis Tournament

June 4, 6, 7, 1984

L.A. Racquet Club

Los Angeles, California

The Education and Research Foundation Fundraiser Third Annual Tennis Tournament will be held June 4, 6, 7, 1984 at the L.A. Racquet Club, Los Angeles, California.

Organizers: Ben Greenspan, M.D.
Robert O'Mara, M.D.
Justine J. Parker

Court Time: Monday, June 4th
Wednesday, June 6th
Thursday, June 7th

Fee: $15/person/day

Everyone is cordially invited to participate in this year's tennis activities. All proceeds from the tournament will be donated to the SNM Education and Research Foundation. To reserve your game, please write or call Jean Parker, P.O. Box 40279, San Francisco, CA 94140. Tel: (415)647-0722 or 647-1668. A check for $5 (per person) payable to Western Region, SNM, must accompany your reservation.

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Missouri Valley Chapter
Society of Nuclear Medicine
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October 12–14, 1984

Marriott Hotel

Des Moines, Iowa

The Missouri Valley Chapter of the Society of Nuclear Medicine will hold its Annual Meeting, "New Horizons in Nuclear Medicine," October 12–14 at the Marriott Hotel in Des Moines, Iowa. The program will include submitted papers, invited speakers, and commercial exhibits.

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The program will be approved for credit toward voice CEU and Category 1 of the AMA Physicians Recognition Award.

Two hundred word abstracts should be sent to:
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