Computation of Glomerular Filtration Rate with Tc-99m DTPA: An In-House Computer Program

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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.

J Nucl Med 25: 613–618, 1984

The glomerular filtration rate (GFR) can be computed following scintigraphic determination of Tc-99m DTPA (diethylenetriaminepentaacetic acid) uptake within the kidney(s) at the 2- to 3-min interval after tracer arrival. This count determination is subsequently corrected for background and depth, and finally expressed as a percentage of the net injected counts present in the administered 2–3 mCi dose (*1*). The GFR is computed by the use of the regression formula Y = a + bX, where X = the percent renal uptake of radiotracer, a = −6.82519, and b = 9.8127 (*2*). This formula was established by performing a linear regression analysis comparing the percent renal uptake of Tc-99m DTPA with the 24-hr creatinine clearance determinations in 51 adult studies. The correlation coefficient of this relationship was 0.97 and the standard error was 7 cc/min (*2*). The GFR can then be multiplied by each kidney's fractional uptake of tracer in order to estimate individual renal function.

Background correction involves semilunar regions of interest placed around the lower, outer renal margins, as initially outlined with a light pen. Renal depth correction is then achieved by use of $e^{-\mu x}$, where $\mu = 0.153$ (the linear attenuation coefficient for Tc-99m radiation in soft tissues (*3*)), and x = the mid-plane depth of each kidney, in cm, which can be measured or estimated by the formulae of Tønnesen et al. (*4*). The net injected "counts" are determined by subtracting postinjection from preinjection syringe counts, this determination being made by placing the syringe 30 cm from the surface of a gamma camera and obtaining a 1-min count.

Received Oct. 10, 1983; revision accepted Dec. 19, 1983.

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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 of Tønnesen 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 Tønnesen 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 response (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 and 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 not 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 m^2) to patient's body area (m^2) (*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 tests 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 unplanned 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 inulin 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

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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 ";PN$
20  INPUT "PATIENT AGE IN YEARS ?: ";PA
30  INPUT "SEX ? M OR F: ";PS$
40  IF PS$ = "M" THEN 70
50  IF PS$ = "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 KGM ? P OR K: ";W$
100  IF W$ = "P" THEN 130
110  IF W$ = "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 H$ = "I" THEN 180
160  IF H$ = "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: ";
AC$
320  IF AC$ = "Y" THEN 10
330  IF AC$ = "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 DF$ = "Y" THEN INPUT "EXCESS TIME (MIN-
UTES): ";A(0,3): GOTO 990
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970  IF DF$ = "N" THEN 1000
980  GOTO 950
990 A(0,1) = INT (A(0,1) * ( INT (( EXP ( - .693 * A(0,3) /
360) * 1000) + .5) / 1000) + .5)
1000  FOR N = 1 TO 3
1010  PRINT
1020  INPUT "DTPA POST-INJECTION COUNTS: ";
A(N,0)
1030  INPUT "TIME FOR COUNTS IN SECONDS: ";
A(N,2)
1040 A(N,1) = INT (((A(N,0) / A(N,2)) * 60) + .5)
1050  INPUT "99M-TC DECAY FACTOR ? Y OR N: ";
DF$
1060  IF DF$ = "Y" THEN INPUT "EXCESS TIME
(MINS): ";A(N,3): GOTO 1090
1070  IF DF$ = "N" THEN 1100
1080  GOTO 1050
1090 A(N,1) = INT (A(N,1) / ( INT (( EXP ( - .693 * A(N,3)
/ 360) * 1000) + .5) / 1000) + .5)
1100  IF N = 3 THEN 1260
1210  PRINT : INPUT "ANYMORE POST-INJECTION
CTS ? Y OR N: ";PC$
1220  IF PC$ = "Y" THEN 1250
1230  IF PC$ = "N" THEN 1260
1240  GOTO 1210
1250  NEXT N
1260  PRINT : INPUT "ANY CHANGES ? Y OR N: ";
AC$
1270  IF AC$ = "Y" THEN GOSUB 1320: GOTO 910
1280  IF AC$ = "N" THEN 1300
1290  GOTO 1260
1300 A(4,1) = A(0,1) - (A(1,1) + A(2,1) + A(3,1))
1310  RETURN
1320  FOR X = 0 TO 4
1330  FOR Y = 0 TO 3
1340 A(X,Y) = 0
1350  NEXT Y
1360  NEXT X
1370  RETURN
1400  REM KIDNEY COUNTS
1420  PRINT
1430  INPUT "WHAT IS COMPUTER FRAMING RATE,
IN SECONDS, FOR RENOGRAM? ENTERED VALUE
MUST RESULT IN WHOLE NUMBER WHEN DIVIDED
INTO 60 SECONDS. ";NS
1440 NI = 60 / NS
1450  IF NI > INT (NI) THEN PRINT : PRINT "FRAME
TIMING INCORRECT. MUST EQUAL WHOLE NUMBER
WHEN DIVIDED INTO 60 SECONDS. TRY AGAIN !":
GOTO 1420
1460  PRINT : INPUT "ANY CHANGES ? Y OR N: ";
AC$
1470  IF AC$ = "Y" THEN 1420
1480  IF AC$ = "N" THEN 1500
1490  GOTO 1460
1500  DIM B(NI,1)
1510  PRINT : PRINT "ENTER BACKGROUND COR-
RECTED COUNTS FOR 2-3 MIN INTERVAL AFTER
TRACER ARRIVAL IN KIDNEY(S)"
1520  PRINT : IF TP$ = "Y" THEN PRINT "KIDNEY
COUNTS": GOTO 1610
1530  INPUT "IS THERE A RIGHT KIDNEY ? Y OR N:
";RK$
1540  IF RK$ = "Y" THEN C = 0: GOSUB 1800: GOTO
1570
1550  IF RK$ = "N" THEN 1570
1560  GOTO 1530
1570  PRINT : INPUT "IS THERE A LEFT KIDNEY ? Y
OR N: ";LK$
1580  IF LK$ = "Y" THEN C = 1: GOSUB 1800: GOTO
1620
1590  IF LK$ = "N" THEN 1620
1600  GOTO 1570
1610 C = 0: GOSUB 1800
1620  PRINT : INPUT "ANY CHANGES ? Y OR N: ";
AC$
1630  IF AC$ = "Y" THEN GOSUB 1700: GOTO 1510
1640  IF AC$ = "N" THEN 1660
1650  GOTO 1620
1660  RETURN
1700  FOR X = 1 TO NI
1710  FOR Y = 0 TO 1
1720 B(X,Y) = 0
1730  NEXT Y
1740  NEXT X
1750 S(0) = 0
1760 S(1) = 0
1770  RETURN
1800 S(C) = 0
1810  FOR N = 1 TO NI
1820  PRINT NS;" SEC COUNTS FOR INTERVAL # ";
N;" ";
1830  INPUT B(N,C)
1840 S(C) = S(C) + B(N,C)
1850  NEXT N
1860  RETURN
2000  REM GFR CALCULATIONS
2005  IF W$ = "K" THEN W = INT (W * 10 + .5) / 10:
GOTO 2015
2010 W =  INT ((W / 2.2 * 10) + .5) / 10
2015  IF H$ = "C" THEN H = INT (H + .5): GOTO 2030
2020 H =  INT (H * 2.54 + .5)
2030 TP =  INT ((TP * 10) + .5) / 10
2040 BS = ( INT ((((.0235) * (H ∧ .42246) * (W ∧ .51456)) *
100) + .5)) / 100
2050  IF TP$ = "Y" THEN 2100
2054  IF DM$ = "E" THEN 2060
2056 RK =  INT ((RK * 10) + .5) / 10:LK = INT ((LK * 10)
+ .5) / 10: GOTO 2080
2060 RK =  INT (((13.3 * ( INT (((W / H) * 100) + .5) / 100)
+ .7) * 10) + .5) / 10
2070 LK =  INT (((13.2 * ( INT (((W / H) * 100) + .5) / 100)
+ .7) * 10) + .5) / 10
2080 R1 =  INT ((S(0) / EXP ( - .153 * RK)) + .5):L1 = INT
((S(1) / EXP ( - .153 * LK)) + .5):DT = INT (((R1 + L1) /
A(4,1) * 100000) + .5) / 1000
2090  GOTO 2110
2100 T1 =  INT ((S(0) / EXP ( - .153 * TP)) + .5):DT = INT
(((T1 / A(4,1 )) * 100000) + .5) / 1000
2110 GF =  INT ((DT * 9.8127 - 6.82519) + .5): IF GF < 0
THEN GF = 0
2120 NG =  INT (((( INT (((1.73 / BS) * 100) + .5)) / 100)
* GF) + .5)
2130  RETURN
2400  REM     FINAL REPORT
2410  PR# 1
2420  PRINT : PRINT "    *************** RENOGRAM
REPORT ***************"
2430  PRINT : PRINT "PATIENT NAME AND/OR I.D.
NUMBER: ";PN$
2440  PRINT "PATIENT AGE: ";PA;" YEARS"
2450  PRINT "PATIENT SEX: ";
2460  IF PS$ = "M" THEN PRINT "MALE"
2470  IF PS$ = "F" THEN PRINT "FEMALE"
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2480  PRINT “DATE: ”;D$
2490  PRINT “DOSE OF 99M-TC DTPA INJECTED = ”;
MC$;” MCI”
2500  PRINT “PATIENT WEIGHT = ”;W1;
2510  IF W$ = “P” THEN PRINT “ POUNDS”
2520  IF W$ = “K” THEN PRINT “ KGM”
2530  PRINT “PATIENT HEIGHT = “;H1;
2540  IF H$ = “I” THEN PRINT “ INCHES”
2550  IF H$ = “C” THEN PRINT “ CMS”
2560  PRINT “PATIENT POSITION: ”;
2570  IF PP$ = “U” THEN PRINT “UPRIGHT”
2580  IF PP$ = “S” THEN PRINT “SUPINE”
2590  PRINT “TRANSPLANT ? : ”;
2600  IF TP$ = “Y” THEN PRINT “YES”: PRINT
“  MEASURED DEPTH = “;TP;” CMS”: GOTO 2660
2610  IF TP$ = “N” THEN PRINT “NO”
2620  IF DM$ = “E” THEN PRINT “ESTIMATED KIDNEY
DEPTH: ”.
2630  IF DM$ = “M” THEN PRINT “MEASURED KID-
NEY DEPTH: ”
2640  IF RK$ = “Y” THEN PRINT “      RIGHT = “;RK;”
CMS”
2650  IF LK$ = “Y” THEN PRINT “      LEFT = “;LK;”
CMS”
2660  PRINT “BSA = “;BS;” SQUARE METERS”
2700  PRINT : PRINT “DTPA SYRINGE COUNTS”
2710  PRINT “   PRE-COUNT = “;A(0,0);” CTS PER “;
A(0,2);” SECS”
2720  IF A(0,3) > 0 THEN PRINT “      EXCESS TIME =
“;A(0,3);” MINS WITH DECAY FACTOR = ”; INT ( EXP
( − .693 * A(0,3) / 360) * 1000 + .5) / 1000
2730  FOR N = 1 TO 3
2740  IF A(N,0) > 0 THEN PRINT “   POST-COUNT =
“;A(N,0);” CTS PER “;A(N,2);” SECS”
2750  IF A(N,3) > 0 THEN PRINT “      EXCESS TIME
= “;A(N,3);” MINS WITH DECAY FACTOR = ”; INT (
EXP ( − .693 * A(N,3) / 360) * 1000 + .5) / 1000
2760  NEXT N
2770  PRINT “RENAL COUNTS PER “;NS;” SEC
ONDS”
2780  IF TP$ = “Y” THEN 2840
2790  IF RK$ = “Y” THEN 2820
2800  IF LK$ = “Y” THEN 2830
2810  IF LK$ = “N” THEN 2920
2820 C = 0: PRINT “   RIGHT KIDNEY COUNTS”: GOTO
2850
2830 C = 1: PRINT “   LEFT KIDNEY COUNTS”: GOTO
2850
2840 C = 0: PRINT “      TRANSPLANTED KIDNEY
COUNTS”: GOTO 2850
2850  FOR N = 1 TO NI
2860  PRINT “      ”;B(N,C)
2870  NEXT N
2880  IF TP$ = “Y” THEN 2920
2900  IF C = 0 THEN 2800
2910  IF C = 1 THEN 2920
2920  PRINT : PRINT “TOTAL GFR = “;GF;” ML/
MIN”
2930  IF TP$ = “Y” GOTO 3010
2940 RF = INT (R1 / (R1 + L1) * 100 + .5)/100
2950  IF RK$ = “N” THEN 2970
2960  PRINT “   RIGHT KIDNEY = “; INT (RF * GF +
.5);” ML/MIN (“;RF * 100;”%)”
2970  IF LK$ = “N” THEN 3010
2980  PRINT “    LEFT KIDNEY = “; INT ((1 − RF) * GF
+ .5);” ML/MIN (“;( 1 − RF) * 100;”%)”
3010  PRINT “  (NORMALIZED TOTAL GFR = “;NG;”
ML/MIN)”
3020  REM NORMAL VALUE TABLE BASED ON AGE
GROUPS
3030  IF PA < 20 THEN 3160
3040  IF PA > 60 THEN 3160
3050 AR = ( INT (PA / 5 + .5)) * 5
3060  IF AR = 20 THEN X = 118:Y = 90
3070  IF AR = 25 THEN X = 115:Y = 88
3080  IF AR = 30 THEN X = 112:Y = 86
3090  IF AR = 35 THEN X = 109:Y = 84
3100  IF AR = 40 THEN X = 106:Y = 82
3110  IF AR = 45 THEN X = 104:Y = 80
3120  IF AR = 50 THEN X = 101:Y = 78
3130  IF AR = 55 THEN X = 99:Y = 75
3140  IF AR = 60 THEN X = 96:Y = 73
3150  PRINT “    (MEAN NORMAL FOR AGE “;AR;” =
“;X;” ML/MIN, LOWER LIMIT = “;Y;” ML/MIN)”
3160  PRINT : PRINT : PRINT : PRINT
3170  PR# 0
3180  RETURN
```

APPENDIX 2

STRING VARIABLES (16)

PN$ = patient name
PA$ = patient age
PS$ = patient sex
D$ = date
MC$ = millicurie dose of tracer
W$ = pounds or kilograms (“P” or “K”)
H$ = inches or centimeters (“I” or “C”)
PP$ = patient position (“U” or “S”)
TP$ = transplant (“Y” or “N”)
DM$ = depth measurement (“E” or “M”)
AC$ = any changes (“Y” or “N”)
DF$ = decay factor (“Y” or “N”)
PC$ = any more postinjection counts (“Y” or “N”)
RK$ = right kidney present (“Y” or “N”)
LK$ = left kidney present (“Y” or “N”)
T$ = time interval

NUMERICAL VARIABLES AND ARRAYS (24)

A(4,3) = array for syringe counts and time data
W = patient weight
W1 = patient weight
H = patient height
H1 = patient height
TP = centimeter depth of transplant
RK = right kidney depth
LK = left kidney depth
NS = number of seconds/frame
NI = number of images/min
B(NI-1,1) = array for renal counts
C = counter
S(C) = summation array
BS = body surface area
R1 = depth-corrected right-kidney counts
L1 = depth-corrected left-kidney counts
DT = depth-corrected total kidney counts, expressed as % of injected counts
T1 = depth-corrected transplant counts
GF = glomerular filtration rate
NG = normalized GFR

RF = fractional renal function
AR = age range of patient
X = normal mean GFR for patient age, AR
Y = lower limit GFR for patient age, AR

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