核醫電腦應用
Clinical NM Image Analysis and processing

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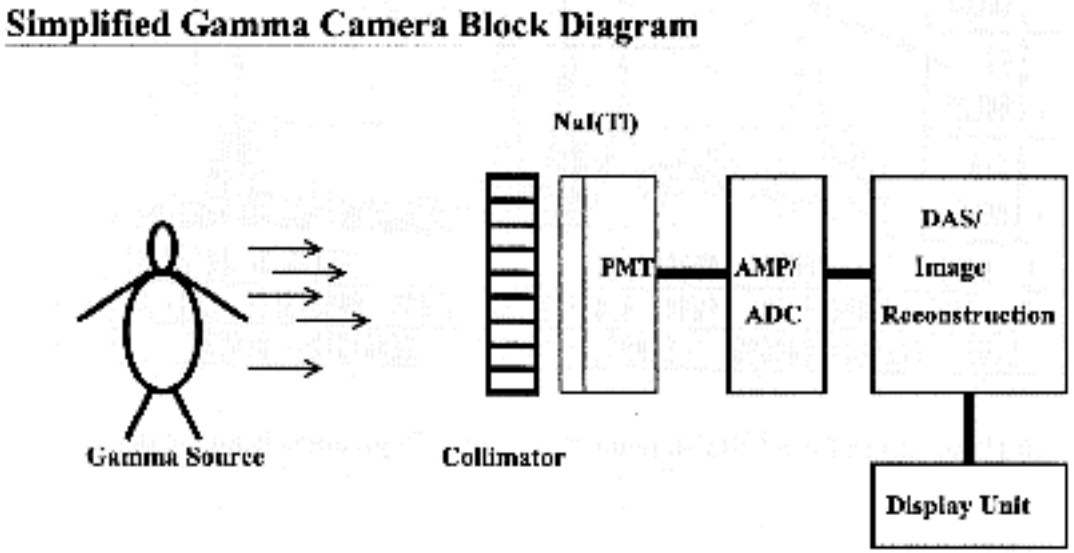
OUTLINE

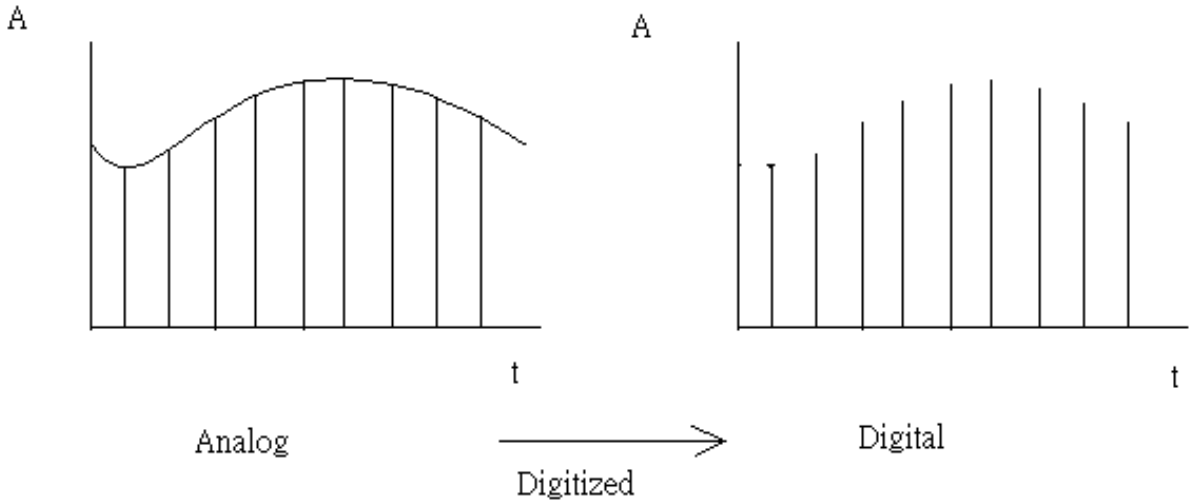
- Nuclear Medicine Image Acquisition method
- Methods of Qualitative Image Analysis
- Clinical method with Nuclear medicine

Methods of Data Acquisition



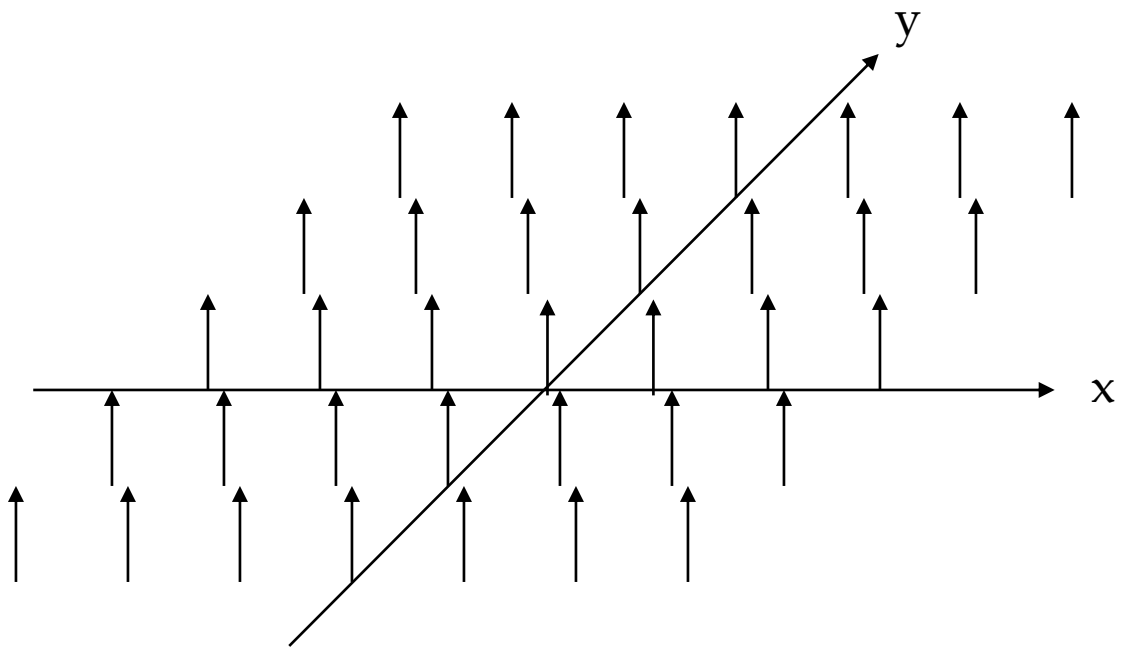
Digitized Image

- Digital Sampling
- Analog convert to Digital

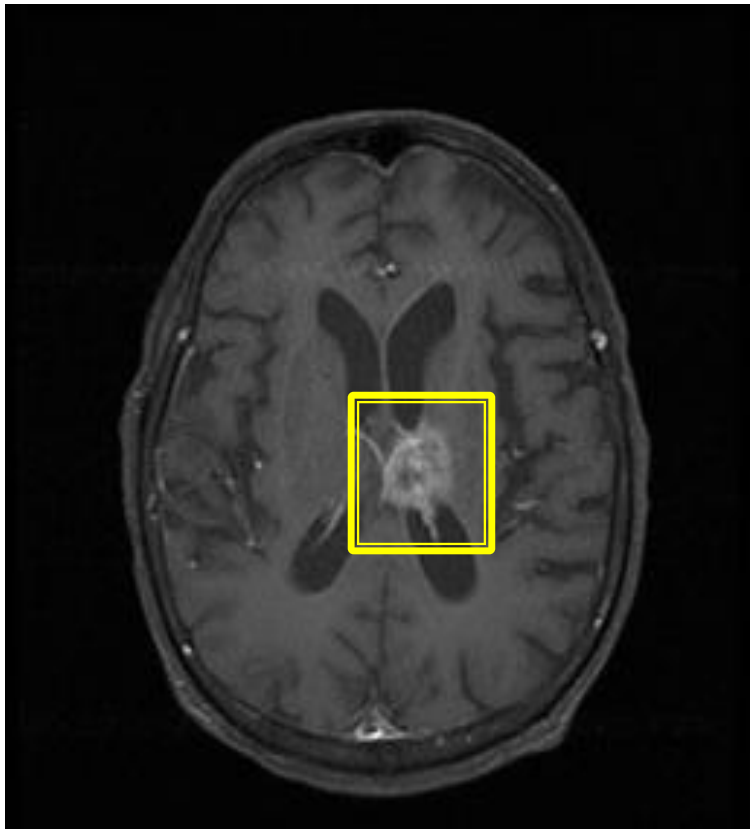


Digitized Image

- Two dimensional Sampling
  - Ideal sampling function



Example of a digitized image

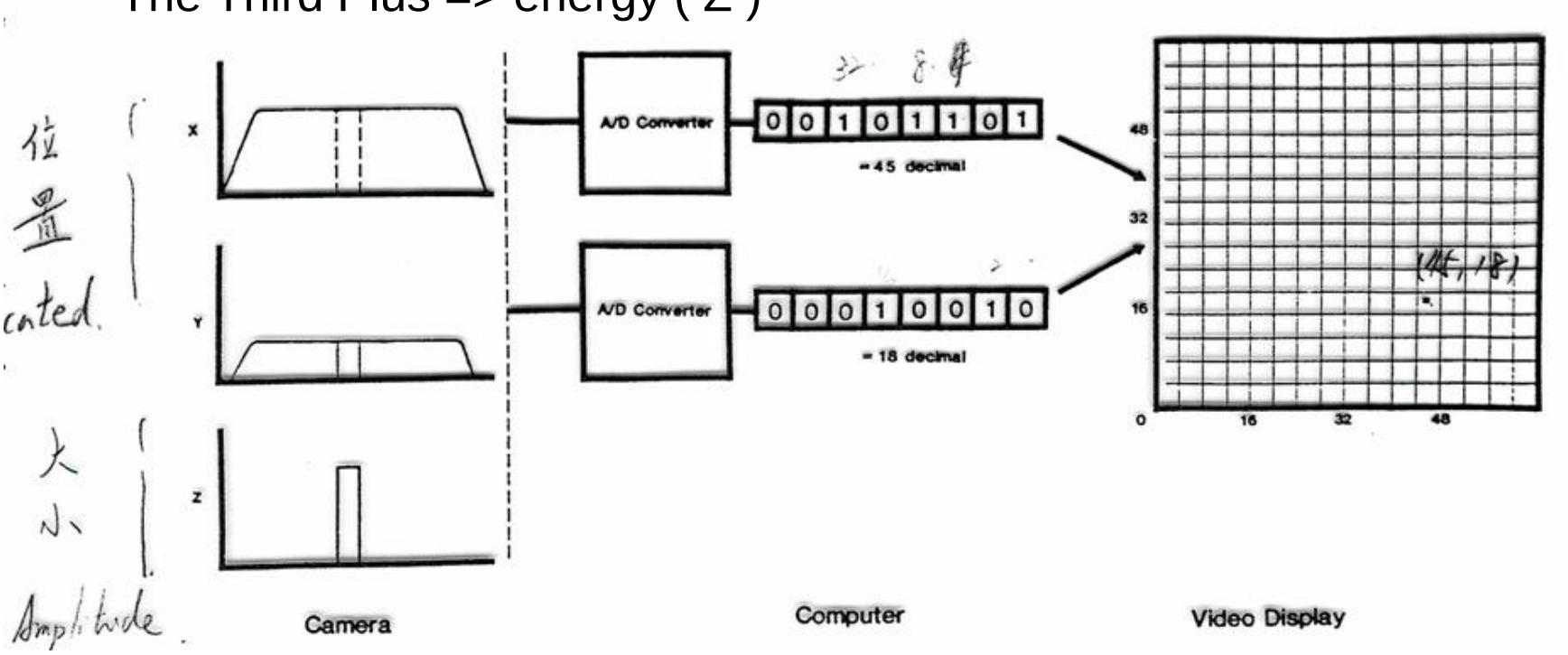


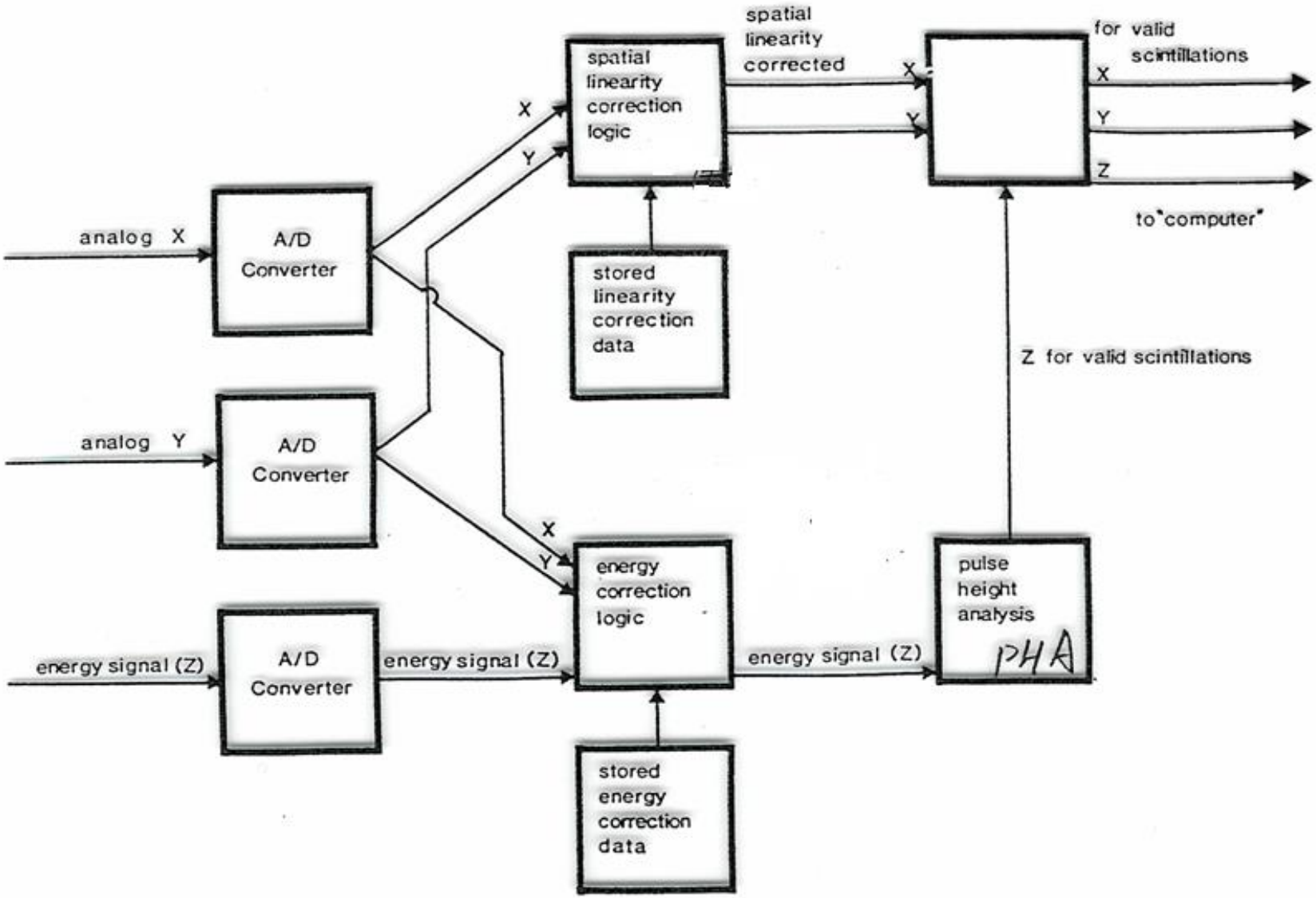
	117	118	119	120	121	122	123	124
122	178	195	214	210	206	212	212	207
123	176	189	212	213	207	209	210	210
124	174	184	208	215	210	211	211	211
125	170	178	202	211	206	208	213	211
126	169	177	199	213	208	206	210	210
127	171	172	188	207	211	207	206	207
128	167	165	180	200	210	214	213	204
129	171	155	166	194	206	213	214	196
130	176	159	163	190	203	203	200	190
131	181	169	148	158	184	194	190	189
132	172	145	107	110	138	154	169	192
133	170	157	153	163	154	125	123	154
134	168	167	177	192	187	167	154	141
135	174	174	174	176	172	169	180	175
136	178	176	172	175	171	163	174	188
137	173	171	172	175	171	168	177	182
138	170	171	174	179	176	171	178	177
139	173	168	168	172	175	171	174	180
140	175	169	171	174	176	174	170	176
141	174	169	167	167	171	177	174	173
142	174	172	166	165	171	176	173	170
143	175	173	168	169	174	177	175	172
144	171	171	169	170	173	172	173	174
145	168	171	168	166	167	165	168	173
146	173	177	173	169	171	173	178	181

Methods of Data Acquisition

Two Plus => 座標位置 (X, Y)

The Third Plus => energy (Z)




analog X
A/D Converter
analog Y
A/D Converter
energy signal (Z)
A/D Converter
X
Y
spatial linearity correction logic
stored linearity correction data
spatial linearity corrected
X
Y
X
Y
energy correction logic
stored energy correction data
energy signal (Z)
energy signal (Z)
pulse height analysis
PHA
Z for valid scintillations
for valid scintillations
X
Y
Z
to "computer"

- Most nuclear medicine imaging systems present their information as digital images.
- A digital image is stored in the computer as an array or matrix of count values and is displayed by assigning a gray or color scale that depends on the number of counts in each element.

Digital Image

- The Image arrays are square matrices that have dimensions range from 32*32 up to 1024*1024
- In nuclear medicine :
  32*32,64*64,128*128,256*256,
  512*512,1024*1024
- Byte mode & word mode

Image formation

- Frame Mode
- List Mode
- Dual Isotope Imaging

Frame mode

- X-Y coordinate
- Byte mode:
  - 256 gray scale
  - 1 byte = 8 bits
- Word mode:
  - 65535 gray scale
  - 2 byte =1 word

List mode

- 2 byte data series
  - Event addresses
  - Time flag
- List mode can be formatted any frame size
- List mode need more memory

Sampling

Sampling size:

pixel size(mm) = field of view (mm) / # of pixels

What should the pixel size be?

1. The spatial resolution of imaging system
2. The smallest object of interest in the image
3. The time it takes to perform any processing steps.
4. The amount of storage and archival space available.

Information Density

- What information can we expect to perceive at a given count density?

☆ this depends on the size of the smallest region in the image you are trying to perceive and its apparent contrast to the surrounding background.

※ How to define the image information density?

$$n > k^2/C^2d^2$$

n : estimate the count density

k : the signal – to – noise ratio (3~5)

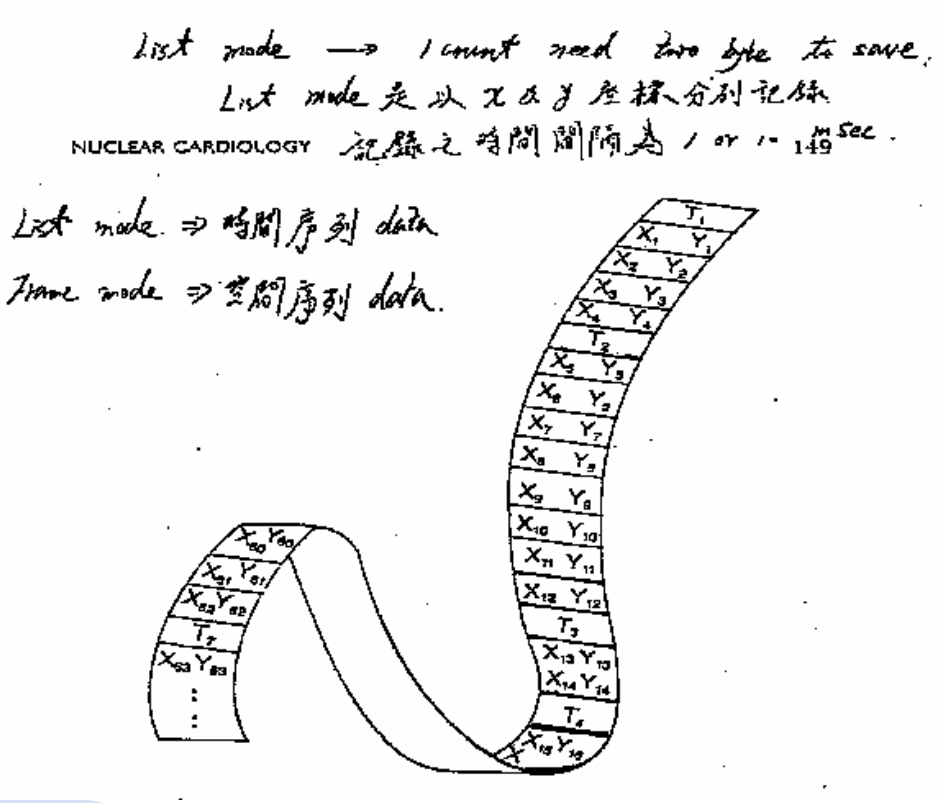
C : image constrast

d : image diameter

◎ Image constrast = (object count density – background count density)/ background count density

Data Acquisition Method

- Frame Mode
- List Mode

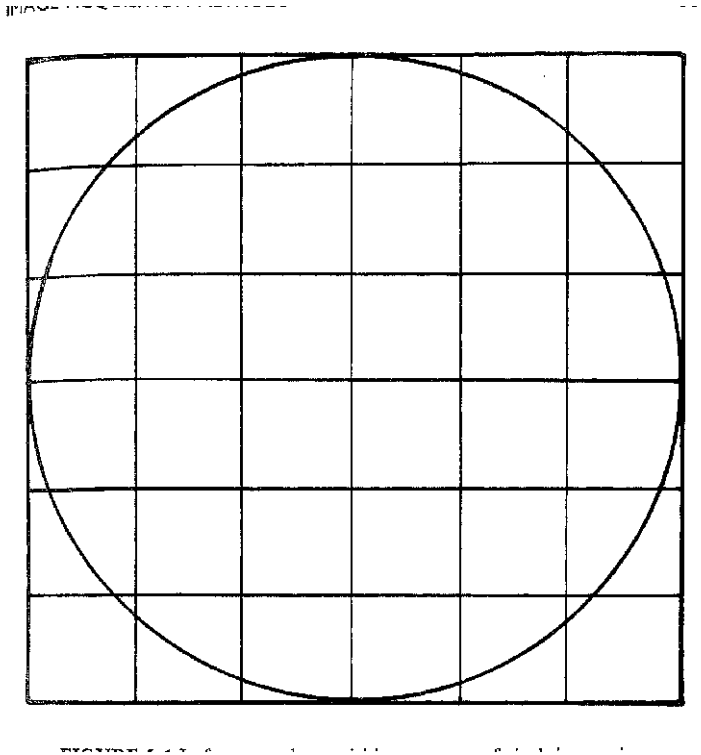


Nuclear Medicine Acquisition method

- Static acquisition
- Dynamic acquisition
- Whole body scan Acquisition
- ECT
- MUGA

Frame mode Acquisition

- Picture elements
  - 64*64
  - 128*128
  - 256*256
- Pixel : Picture element
- Square mosaic :
  - Image matrix,
  - Image array
  - pixel array



Resolution

- Spatial Resolution
- Temporal Resolution
- Energy Resolution

Spatial Resolution

- Each pixel in the image matrix has one-to-one correspondence with a given location in the plane of NaI crystal

$$\text{Spatial resolution} = 1/2 * FWHM * \frac{\text{diameter}}{\text{pixel No.}}$$

- Ex: Gamma camera FOV=55cm
  - For 64*64 FWHM = 10 pixels
  - pixel size=550/64=8.59mm
  - S.R =1/2*10*8.59=42.9 mm
  - For 128*128
  - pixel size=550/128=4.29mm
  - S.R =1/2*10*4.29=21.45mm

Statistical Noise

A

100	100	100	100
100	144	144	100
100	144	144	100
100	100	100	100

number of counts in each pixel

10	10	10	10
10	8.3	8.3	10
10	8.3	8.3	10
10	10	10	10

% noise in each pixel $\frac{100\%}{\sqrt{N}}$

B

444	444
444	444

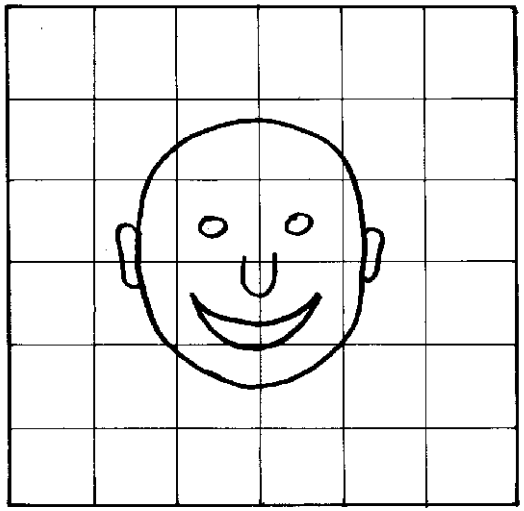
number of counts in each pixel

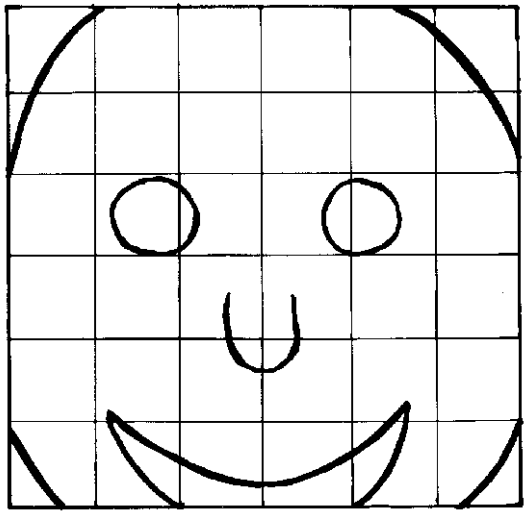
4.6	4.6
4.6	4.6

% noise in each pixel $\frac{100\%}{\sqrt{N}}$

Increase Spatial resolution

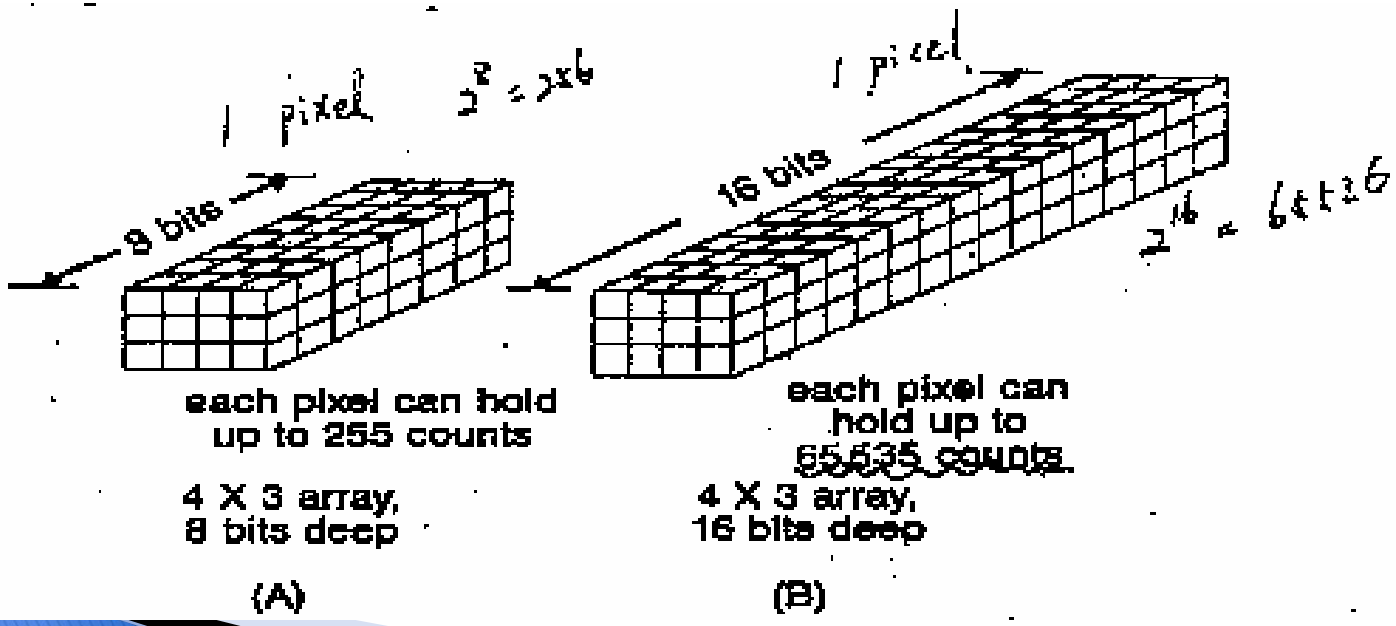
- Zooming
  - Hardware
  - Software
  - Zoom can
  - (1) decrease Background count
  - (2) increase resolution
- The spatial resolution of computer image is ultimately limit by resolution of gamma camera





Byte mode V.S. Word mode

- 1 Byte = 2^8 bits =256 (0-255)
- 1 Word = 2^{16} bits = 65536 (0-65535)
- 1 Word = 2 Bytes



Byte mode V.S. Word mode

- Byte mode Acquisition: a pixel deep is 1 byte
- Word mode Acquisition: a pixel deep is 2 byte
- What Kind of the acquisition mode we should used?
  - In low count studies => Byte mode
  - In High count studies => Word mode

Byte mode V.S. Word mode

- Byte mode
  - 優點: less memory
  - 缺點: 1. dead time
    2. truncation error
- Word mode
  - 優點: 1. No dead time
    2. No truncation
  - 缺點: more memory

Overflow:

Dead time:

Truncation:

臨床診斷上使用的應用軟體

- 影像增強(Image enhancement)
- 量化分析(Qualitative Image analysis)
- ECT影像重建 (ECT image reconstruction)

Image Enhancement

- Image smoothing filters
  - P7 $\text{Avg} = (P_2 + P_3 + P_4 + P_6 + P_7 + P_8 + P_{10} + P_{11} + P_{12})/9$

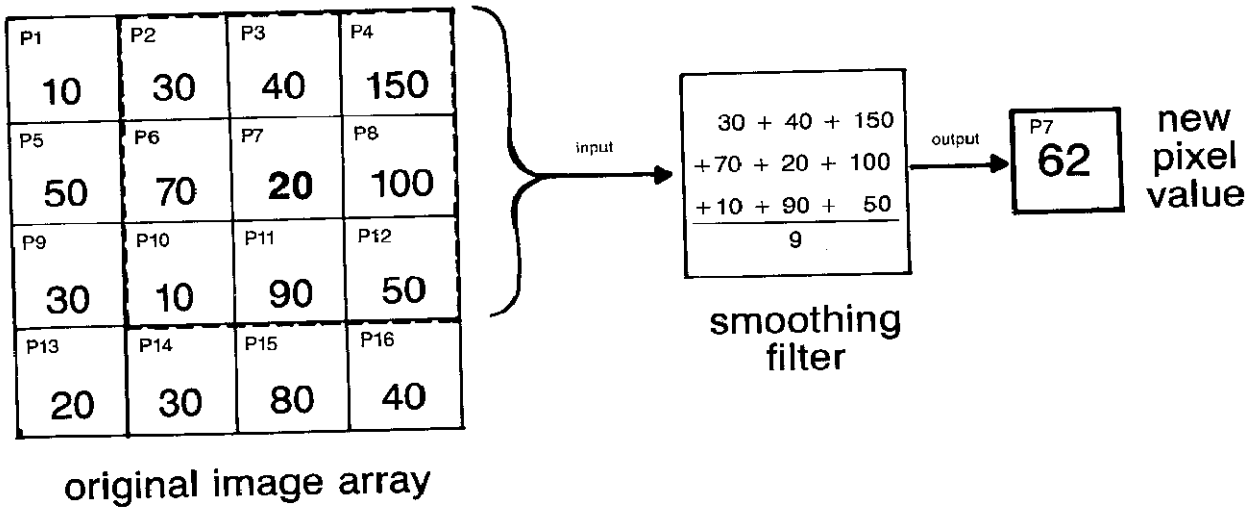


FIGURE 6-1 The simple average filter changes the counts in the center pixel (P7) to the average of the nine pixels within the mask.

Image Enhancement

- Nine-point smooth (mask)

$\frac{1}{9}$

1	1	1
1	1	1
1	1	1

w1	w2	w3
w4	w5	w6
w7	w8	w9

Image Enhancement

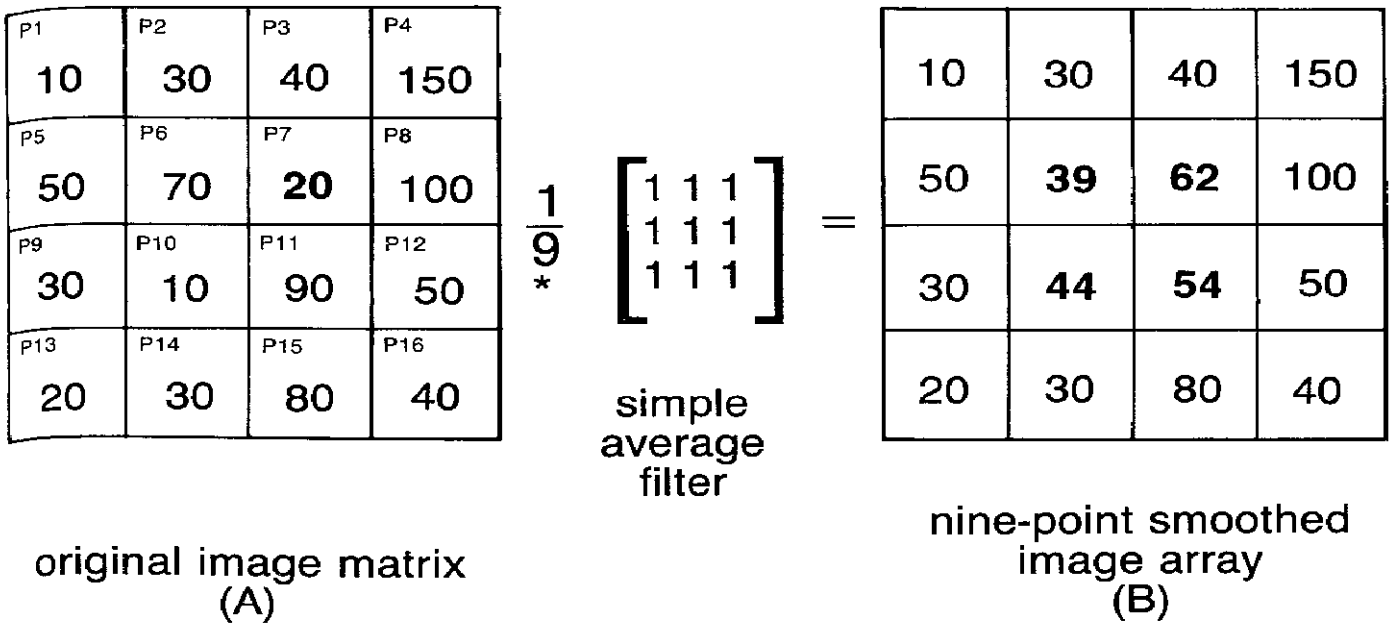


FIGURE 6-2 A simple nine-point smoothed image is obtained by moving the mask over the image matrix. At each stop, it replaces the value in the center pixel by the average of the nine pixel counts within the mask.

Image Enhancement

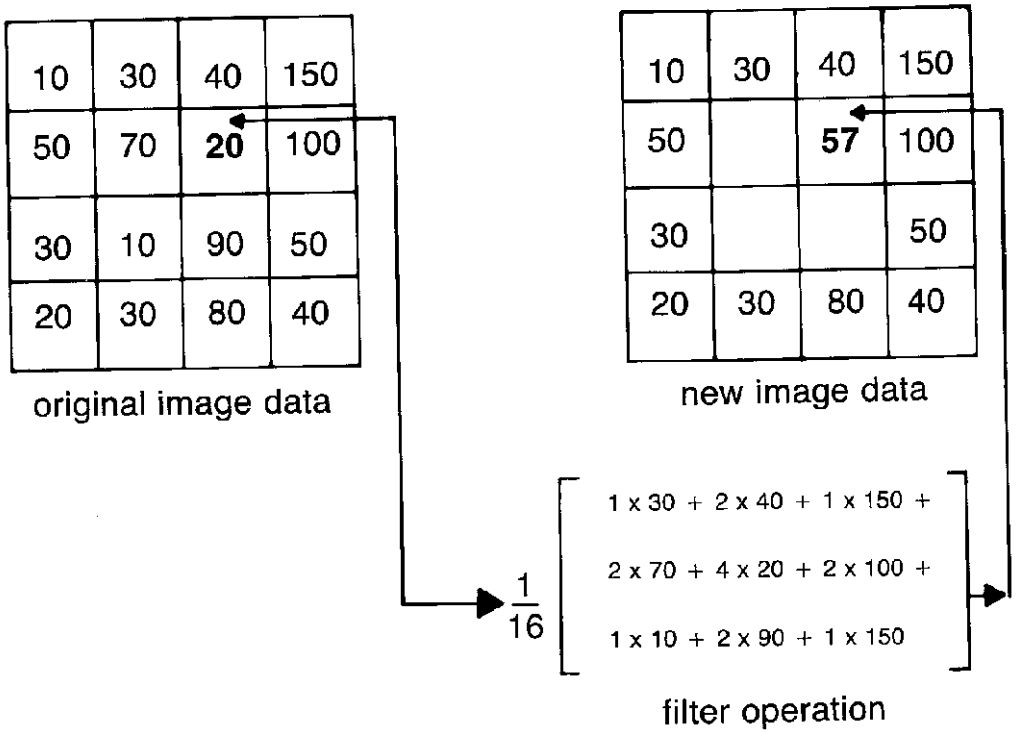


FIGURE 6-3 The number of counts in the center pixel is replaced by the weighted average of the nine pixels under the mask.

Image Enhancement

- Medium smooth

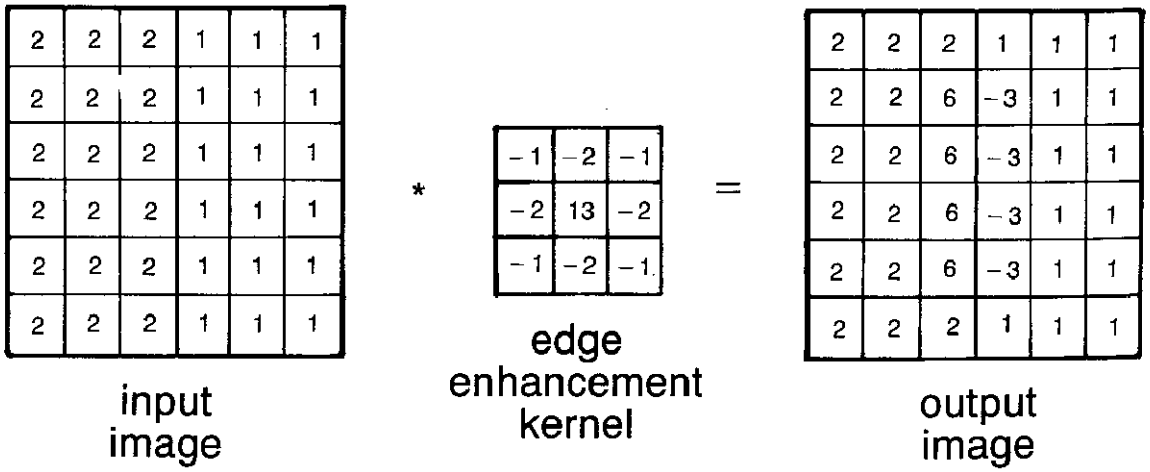
  Half way mask => replace average (weight)

  > 50% count value (mask)

  < 50% count value (Keep)

Image Enhancement

- Edge-enhancement filter (sharpen mask)
  - Mask: (2N+1)*(2N+1)



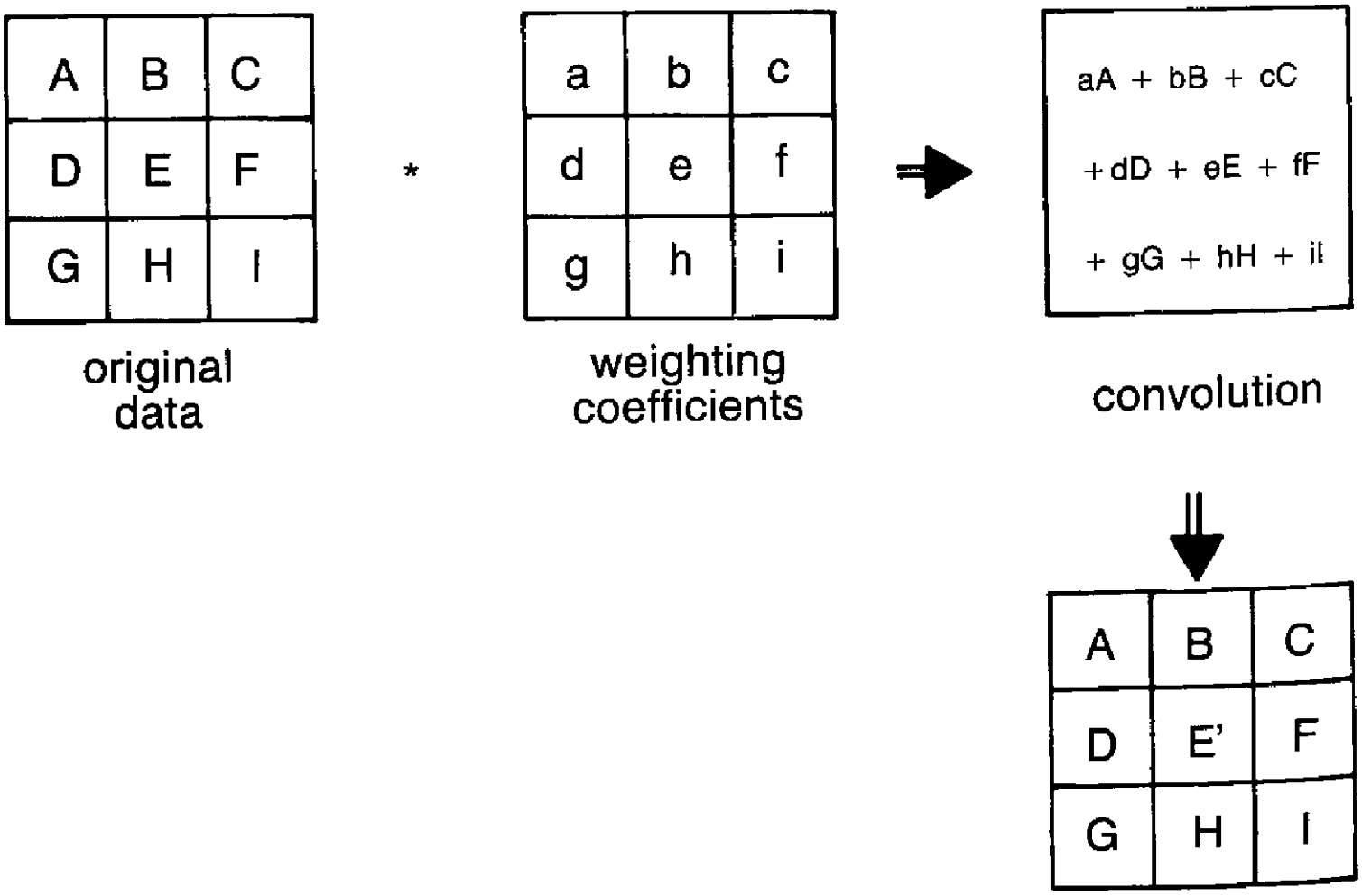


FIGURE 6-4 The procedure for convolution of the original image matrix with the filter kernel to produce the processed image matrix.

Image Enhancement

$\frac{1}{9}$

-1	-1	-1
-1	8	-1
-1	-1	-1

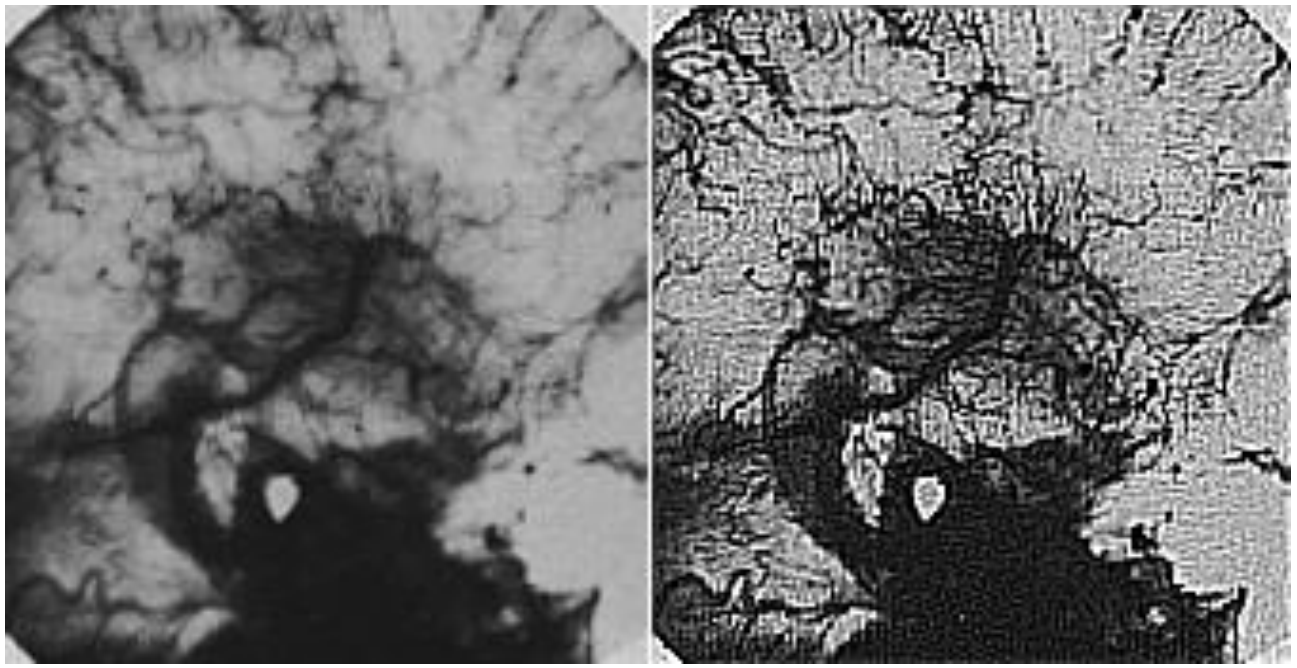


Image Enhancement

- Point processing operations
  - Background subtraction
  - Gray scales
  - Color translation table
- Frame processing operation

  ex: Parathyroid scan study

Point processing operation

- Background subtractior (pixel-by-pixel)

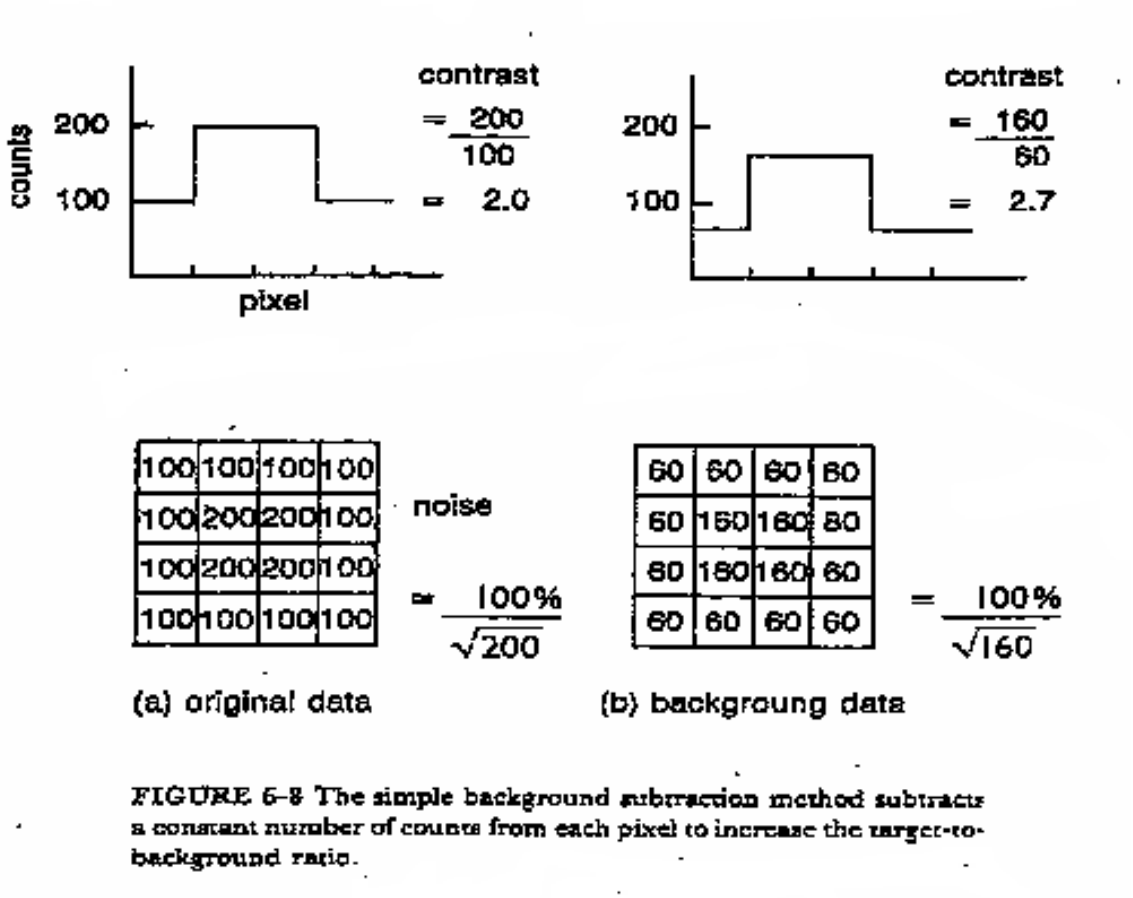


FIGURE 6-8 The simple background subtraction method subtracts a constant number of counts from each pixel to increase the target-to-background ratio.

Point processing operation

- Interpolated background subtraction (weight)

$$Bkg = \frac{W_a A + W_b B + W_c C + W_d D}{W_a + W_b + W_c + W_d}$$

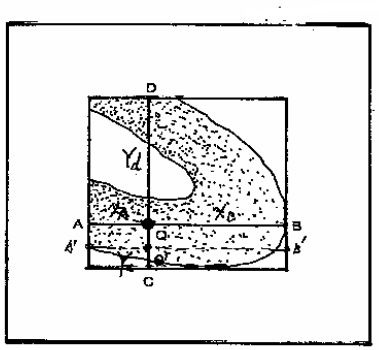


FIGURE 6-9 The interpolated background subtraction method subtracts from each pixel a number equal to the weighted average of the counts in four pixels at the edge of the ROI.

Wa=Xb/Xa

Wb=Xa/Xb

Wc=Yd/Yc

Wd=Yc/Yd

Xa: Q距A點距離

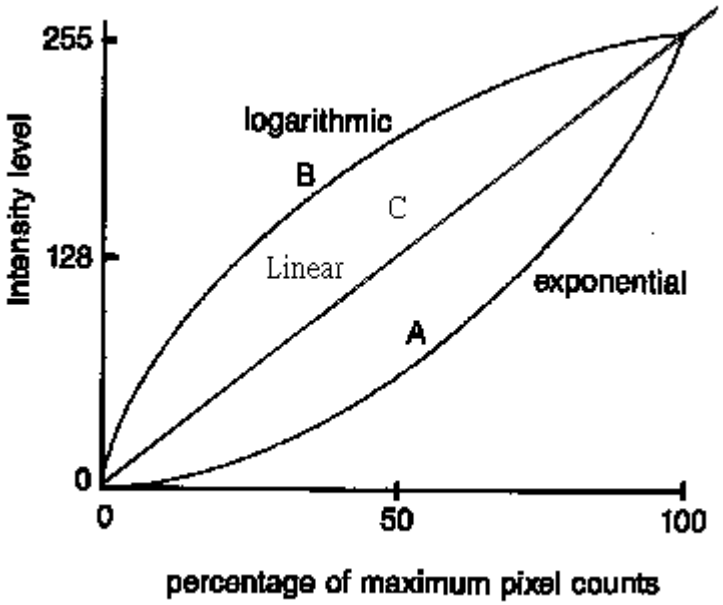
Xb: Q距B點距離

Yc: Q距C點距離

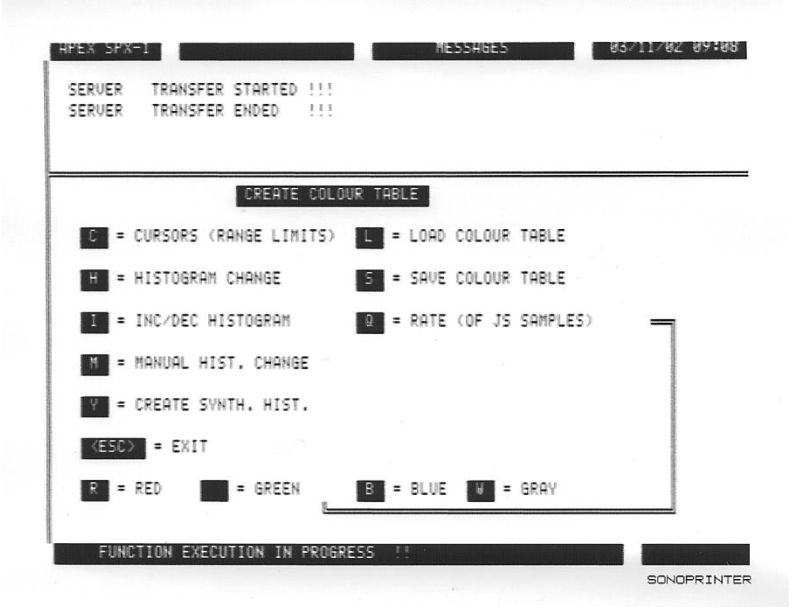
Yd: Q距D點距離

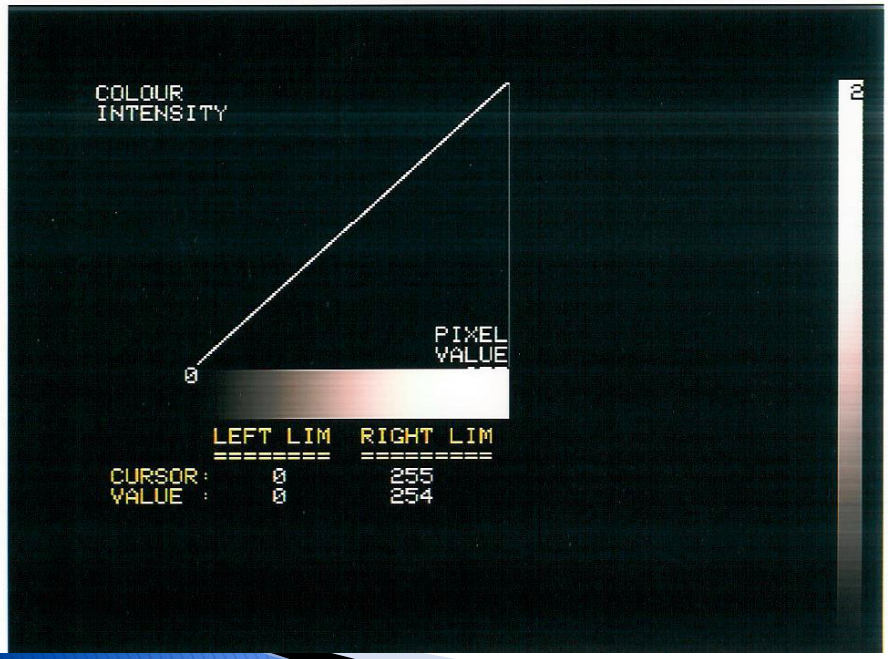
Gray scales and color table

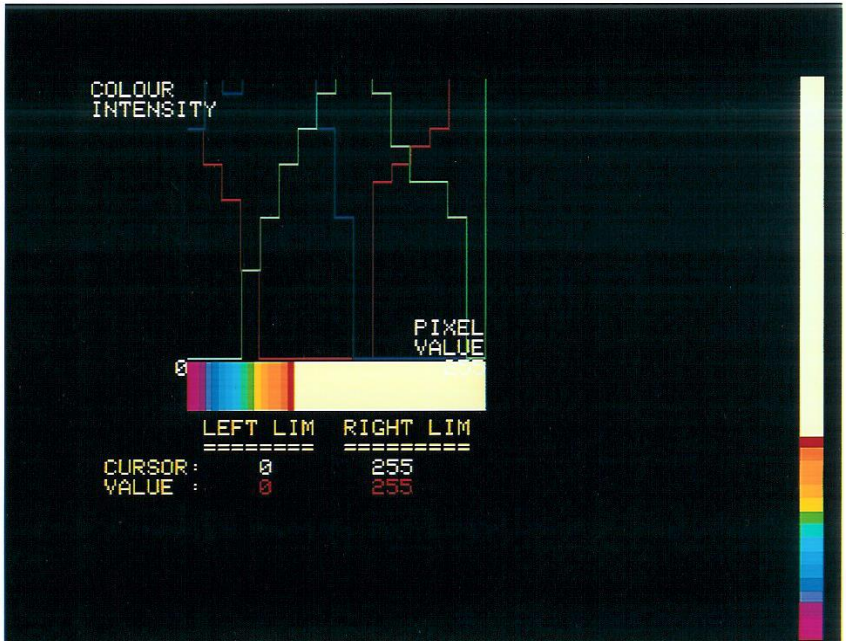
- Gray scale (dynamic range)
  the number of shades of gray between these two extremes
- Type:
  - Linear
  - exponential
  - logarithmic



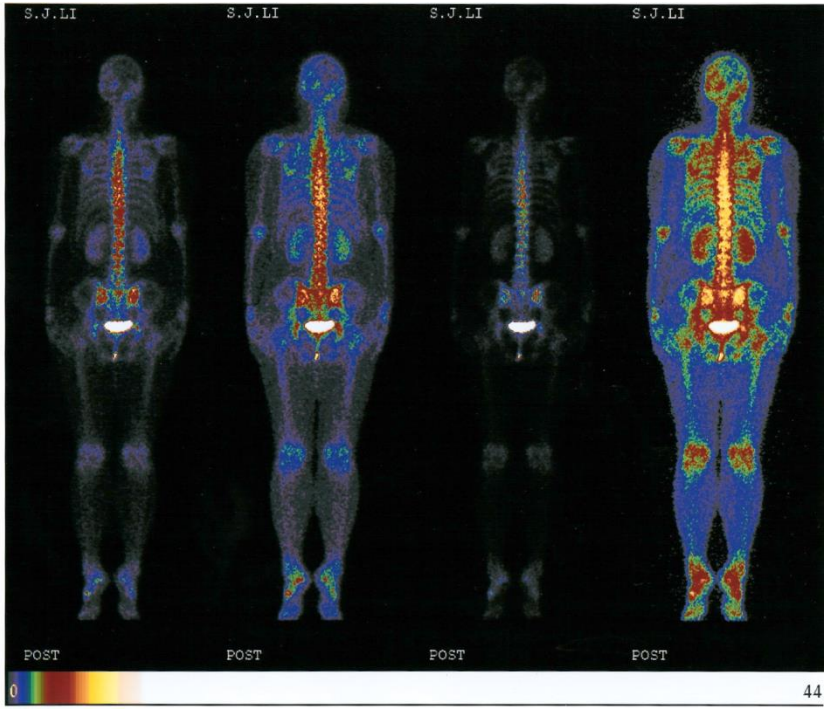
Gray and color table



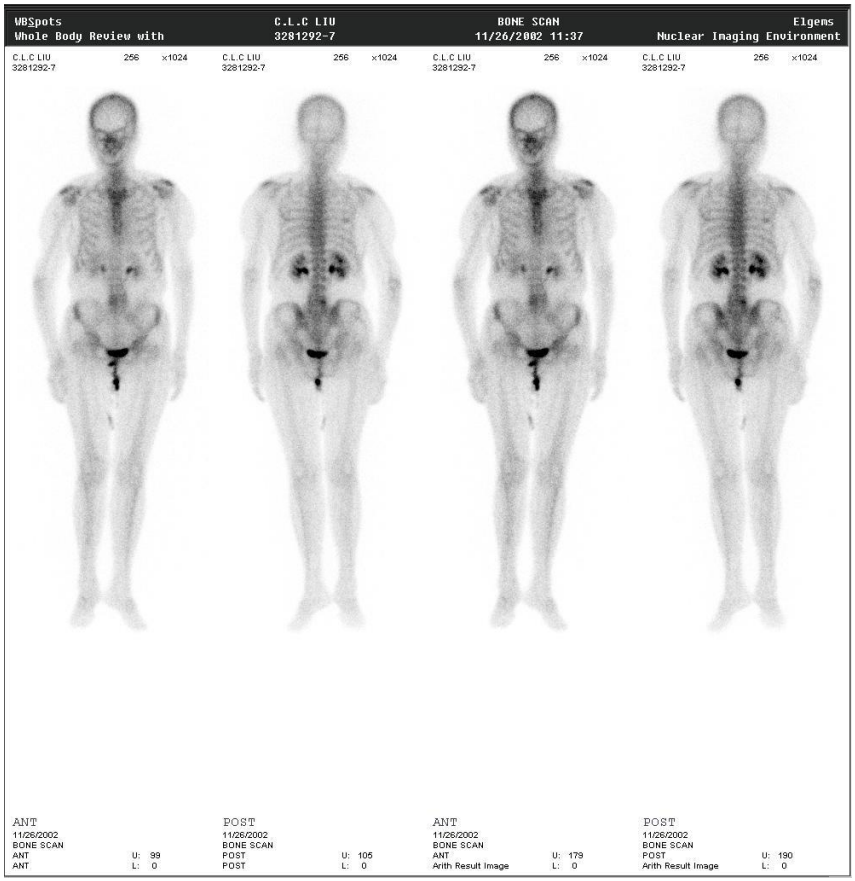


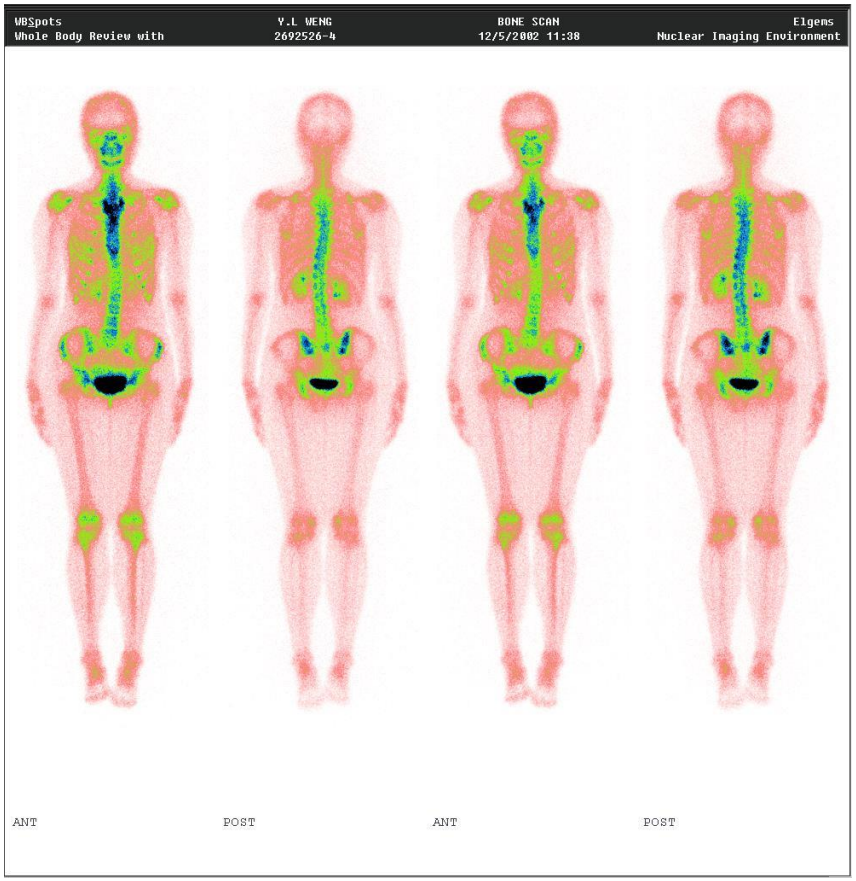


Gray scales and color display

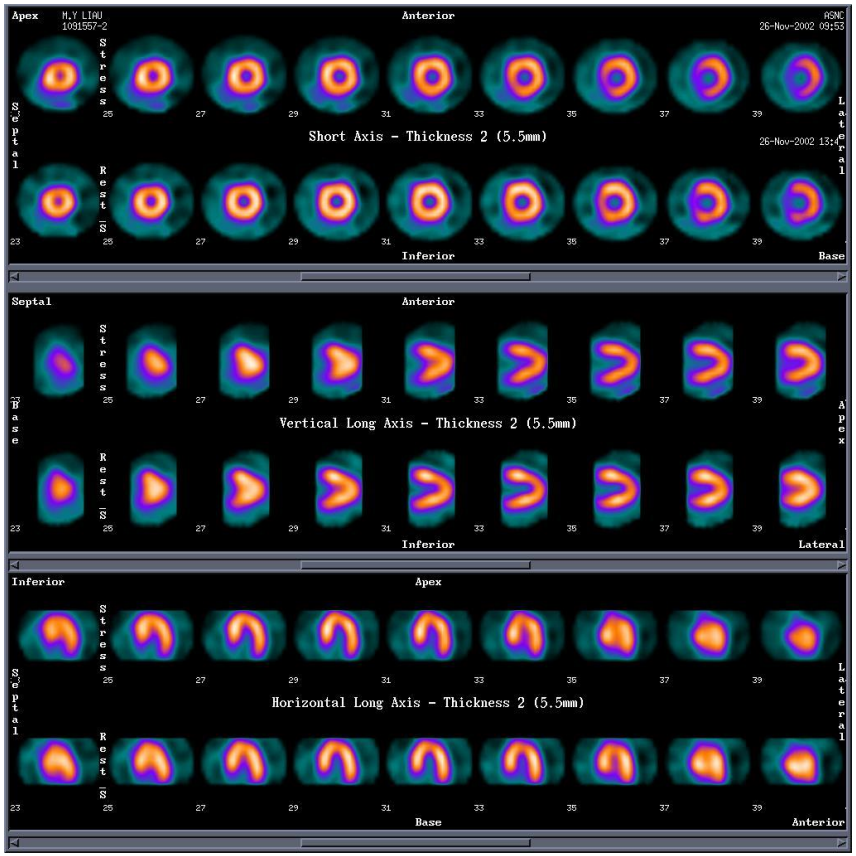


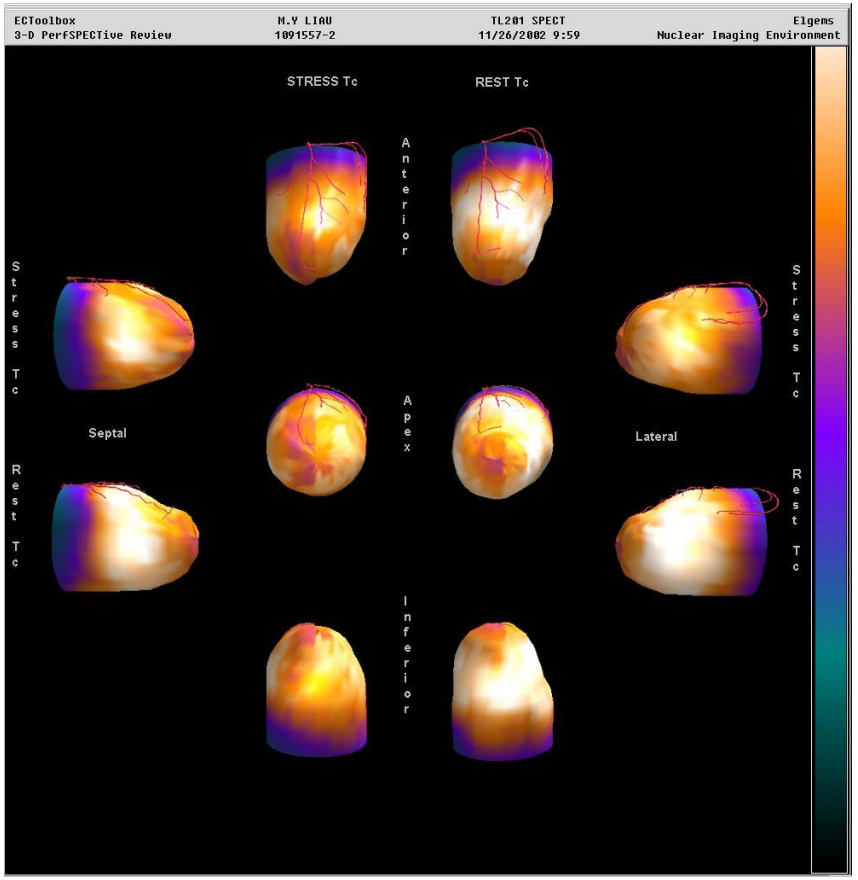
Gray scales and color display



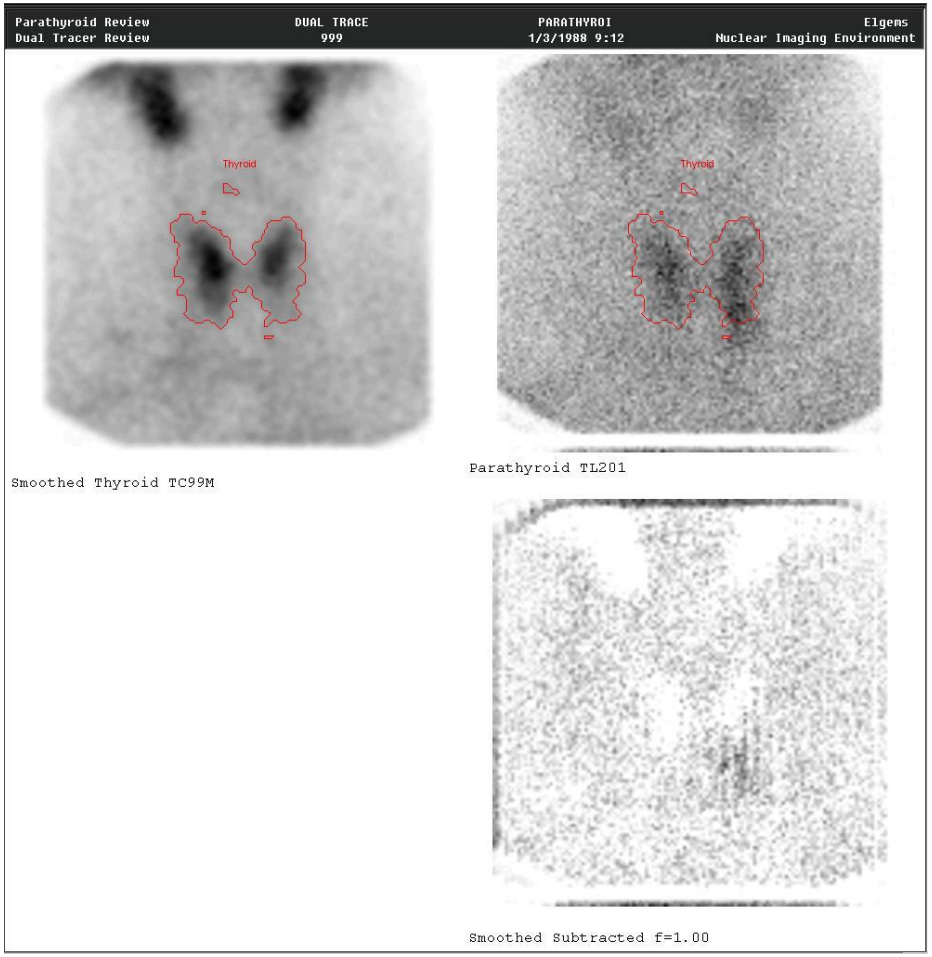


Tl201 myocardial perfusion study





Parathyroid subtractuin

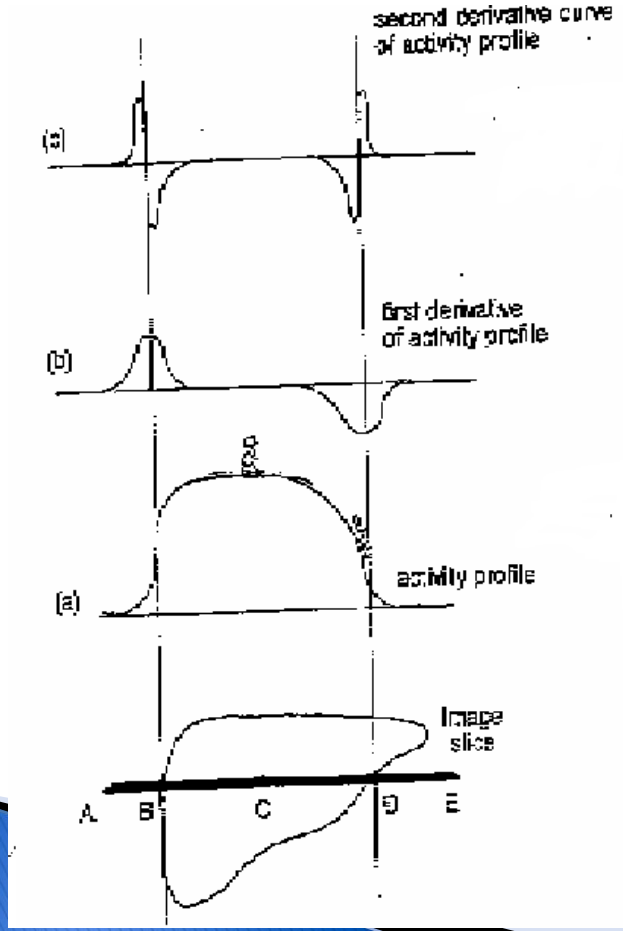


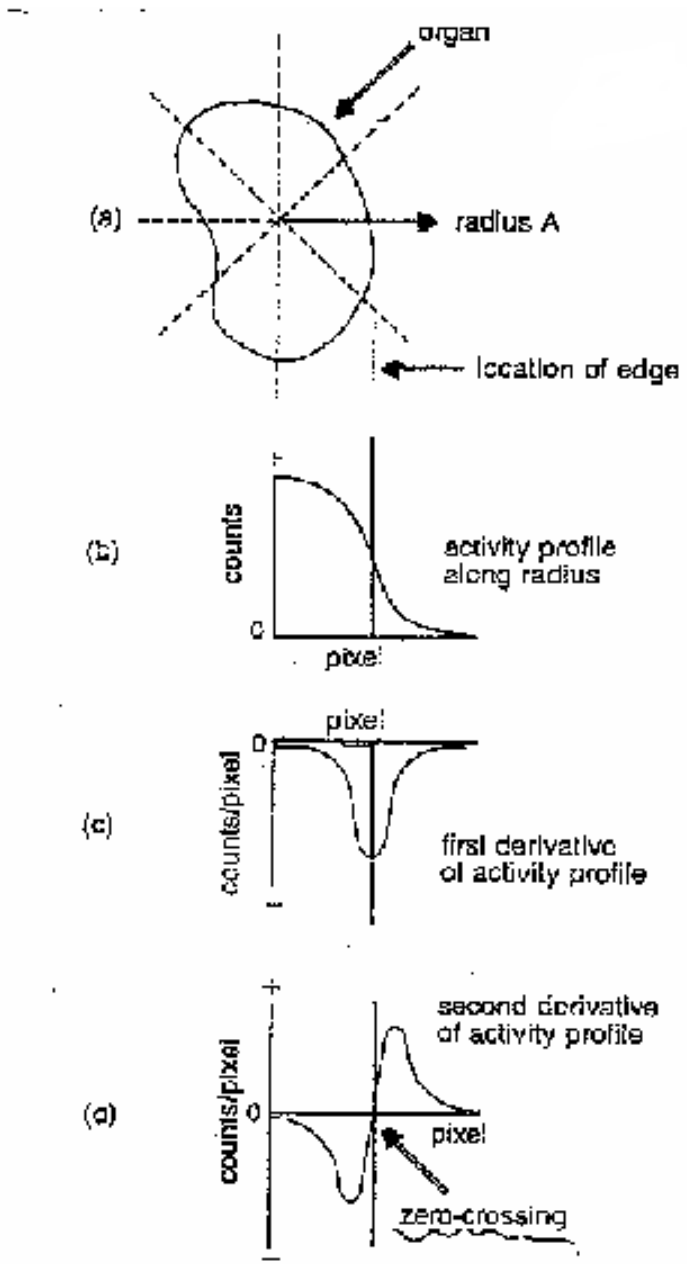
影像量化分析

- ROI(region of interesting) create
- Histogram create
- Analysis ROI and Histogram
- Clinical mathematic

Creating ROIs

- Automatic edge detection methods:

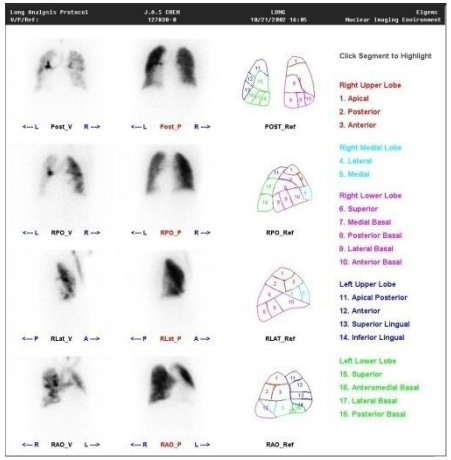


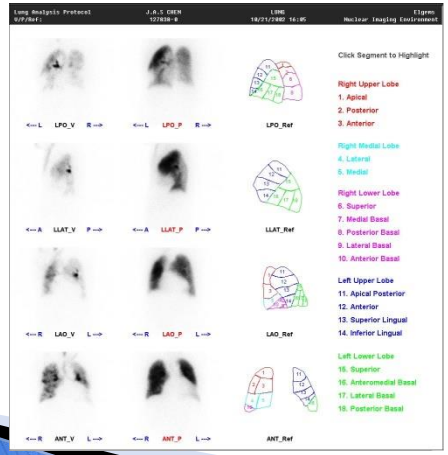


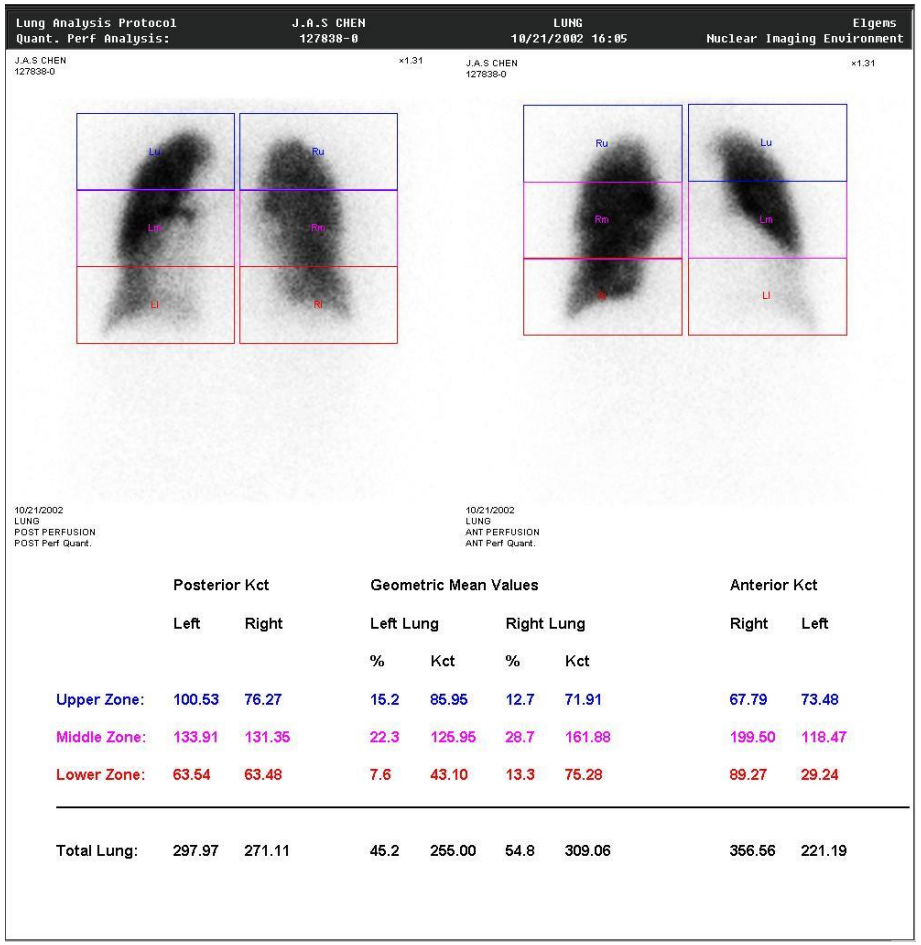
Create ROI

- Method:
  - Circular ROI
  - Rectangular ROI
  - Irregular ROI
  - Automatic ROI

Lung perfusion/ventilation ratio







	Posterior Kct		Geometric Mean Values				Anterior Kct	
	Left	Right	Left Lung		Right Lung		Right	Left
			%	Kct	%	Kct		
Upper Zone:	100.53	76.27	15.2	85.95	12.7	71.91	67.79	73.48
Middle Zone:	133.91	131.35	22.3	125.95	28.7	161.88	199.50	118.47
Lower Zone:	63.54	63.48	7.6	43.10	13.3	75.28	89.27	29.24
Total Lung:	297.97	271.11	45.2	255.00	54.8	309.06	356.56	221.19

Curve Generation and Analysis

- The starting point for analyzing the flow pattern quantitatively is the construction of an activity-versus-time curve.
- Method
  - Eye-balling
  - The move average method
  - The weighted moving-average method

The Moving Average method

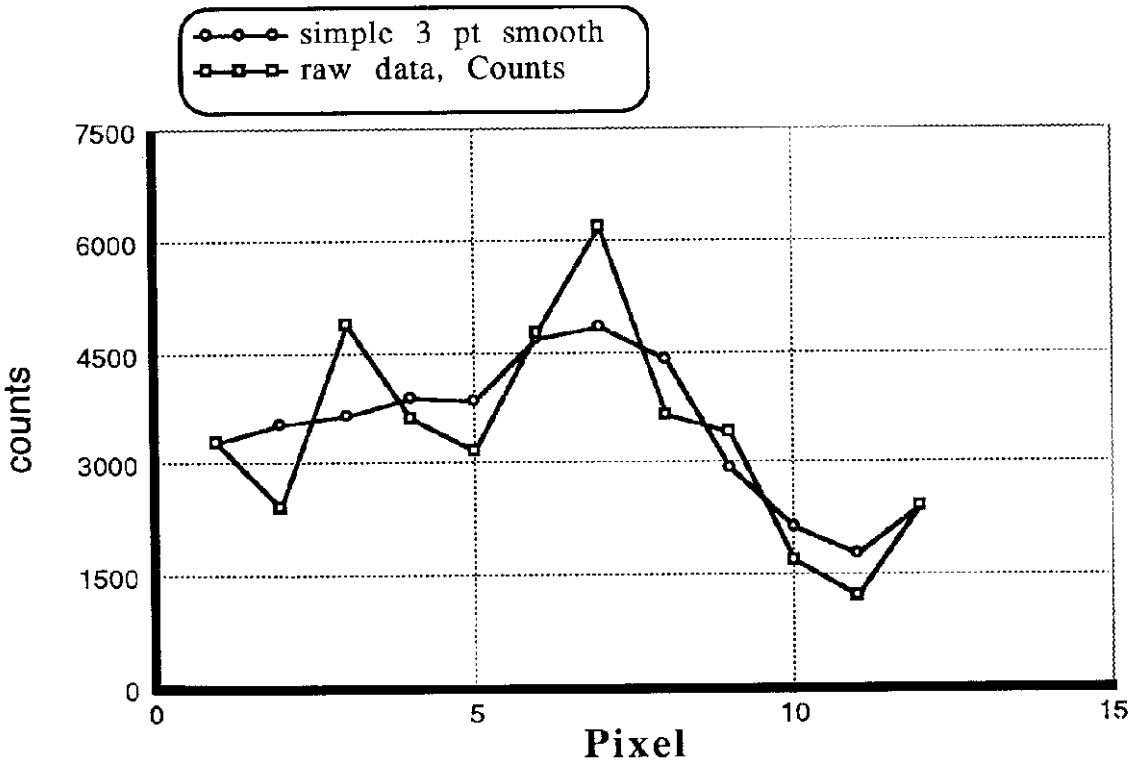


FIGURE 7-3 The effect of applying a simple three-point smoothing on a raw data curve.

The Moving Average method

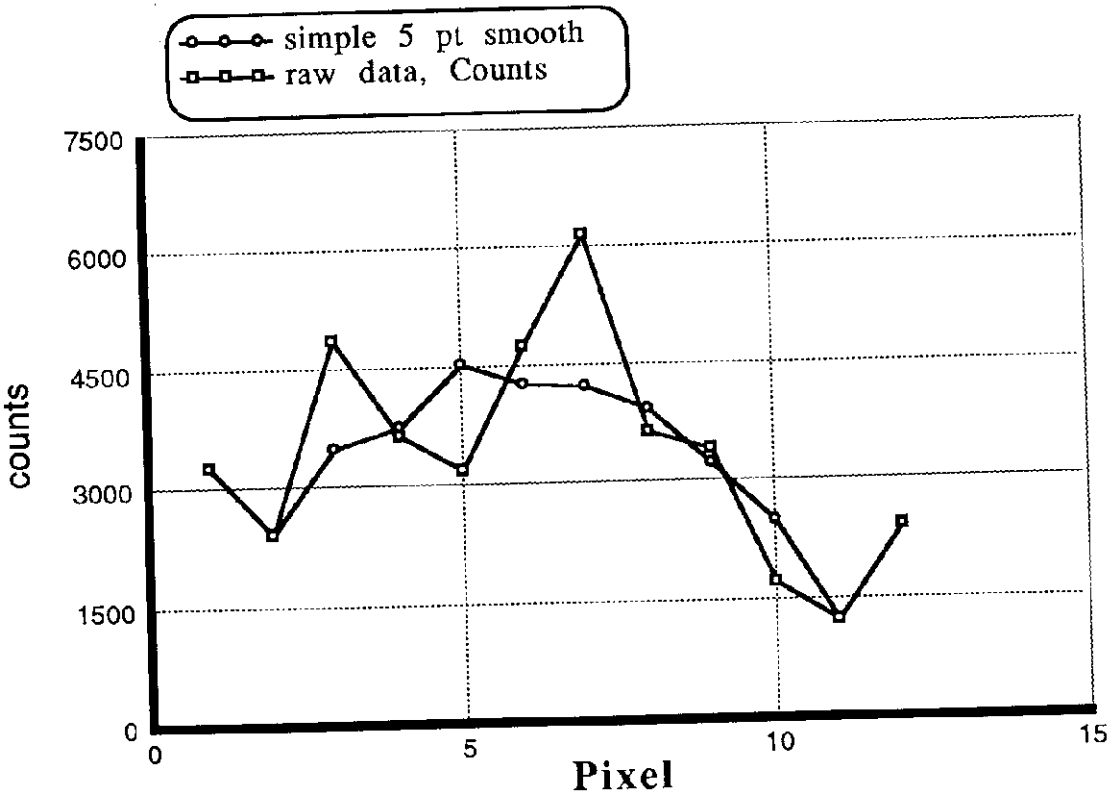


FIGURE 7-4 The effect of applying a simple five-point smoothing on a raw data curve.

Data smoothing by curve Fitting

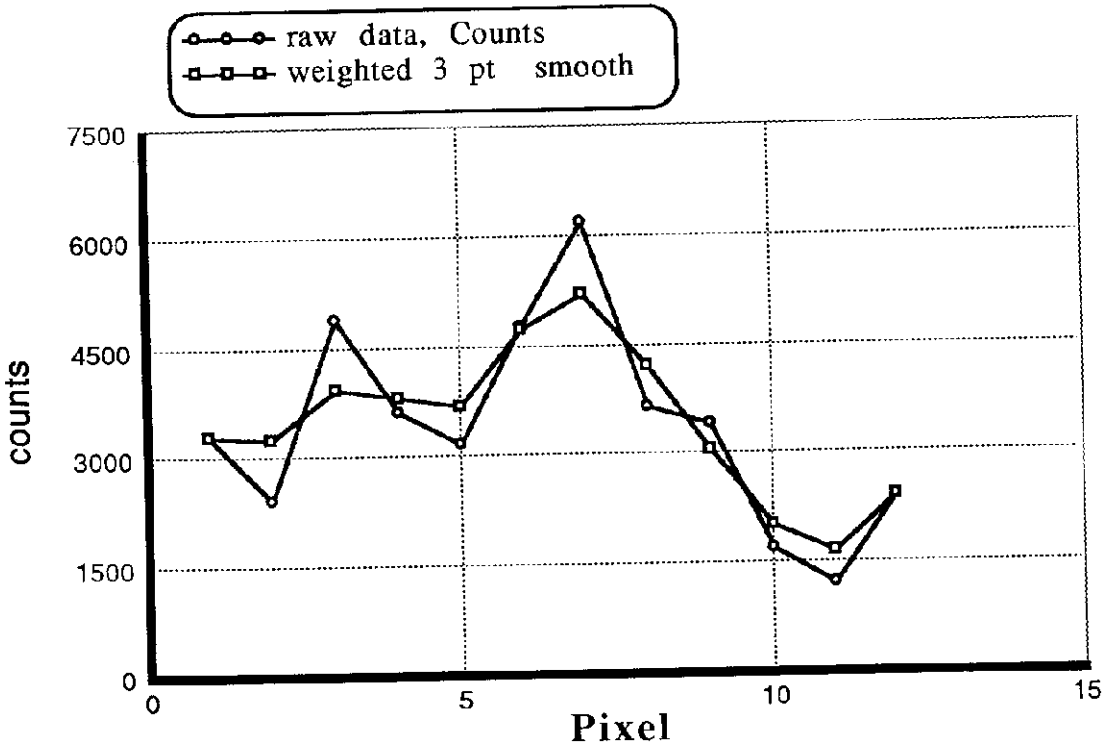


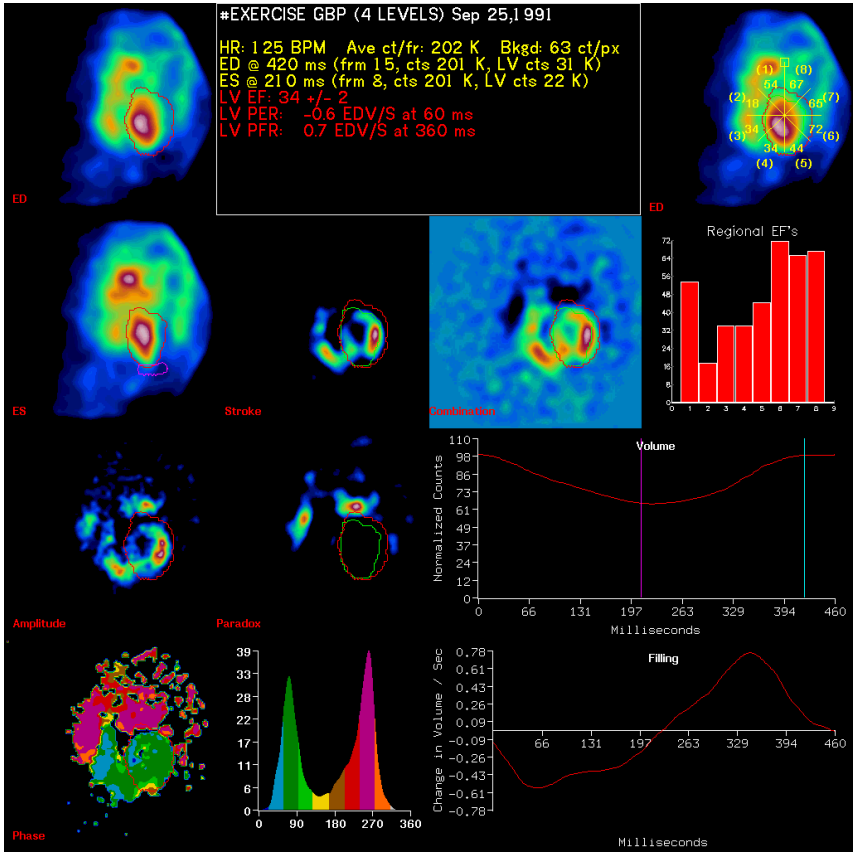
FIGURE 7-5 The effect of applying a weighted three-point smoothing on a raw data curve.

Clinical Mathematic in Nuclear Medicine

- Nuclear Cardiology
  - Multiple-gate equilibrium
  - First pass blood-pool
  - Static myocardial perfusion study
- Renal function
  - GFR
  - Kidney radio
  - ERPF
  - Diuretic renography (Lasix)
  - Captopril renography
- Other

Example for Ventricular Ejection Fraction

$$EF = \frac{(\text{ED counts} - \text{ED Bkg}) - (\text{ES counts} - \text{ES Bkg})}{\text{ED counts} - \text{ED Bkg}}$$



Multiple gate mode

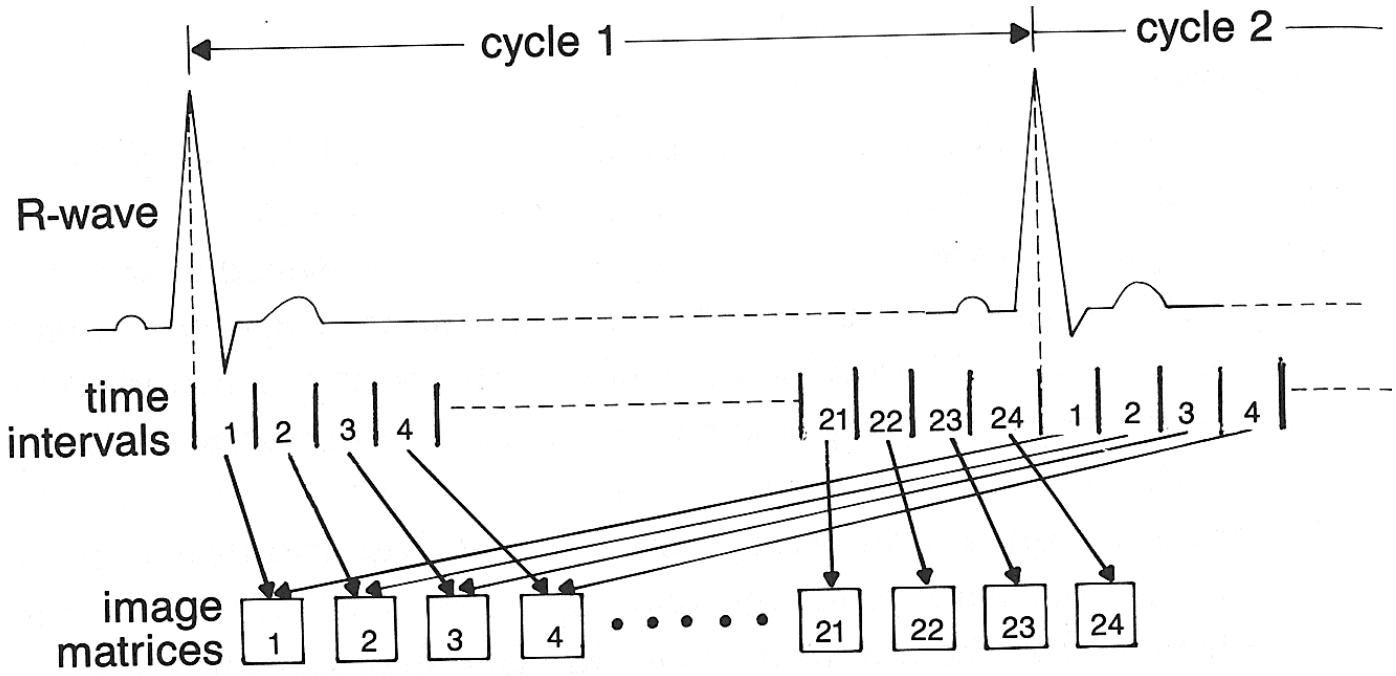
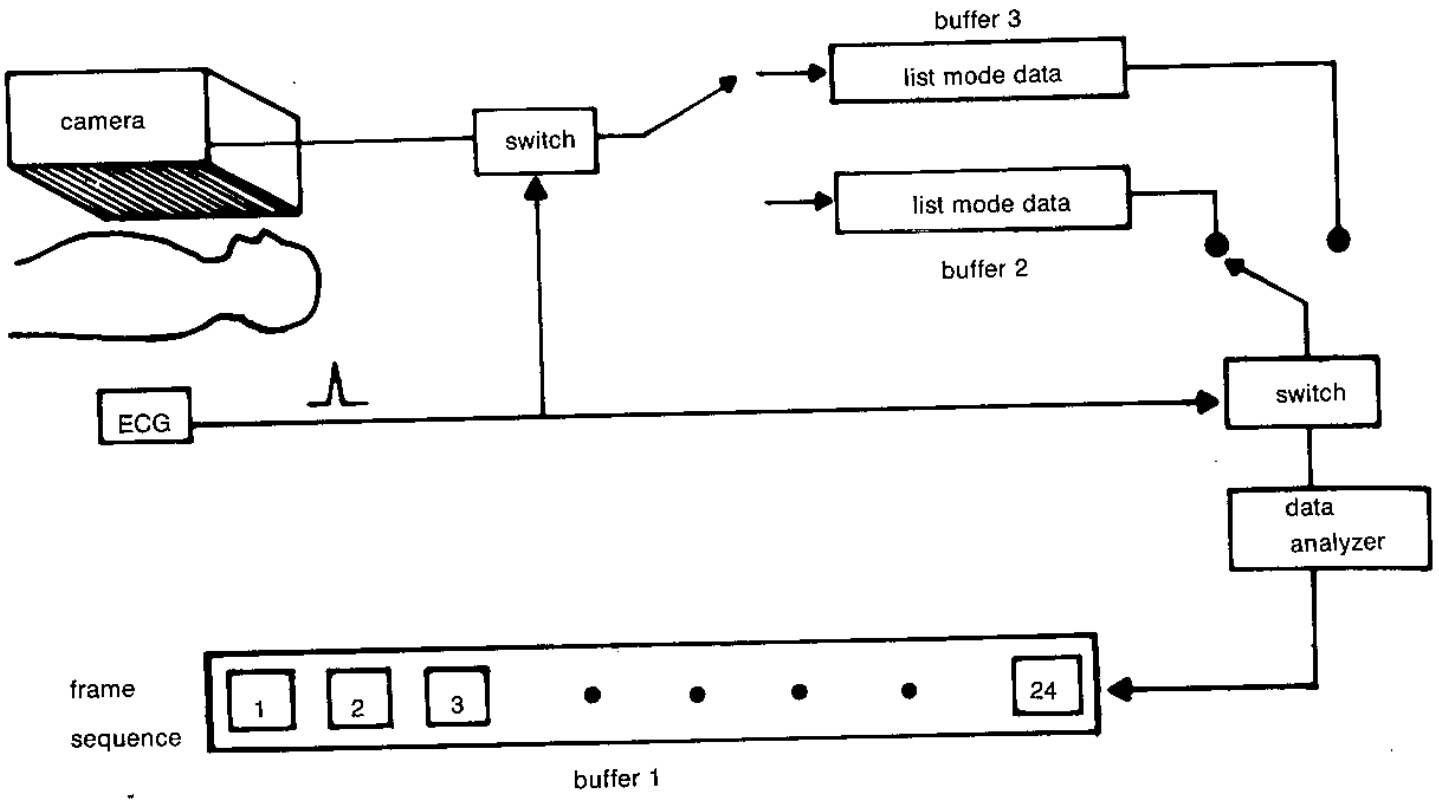
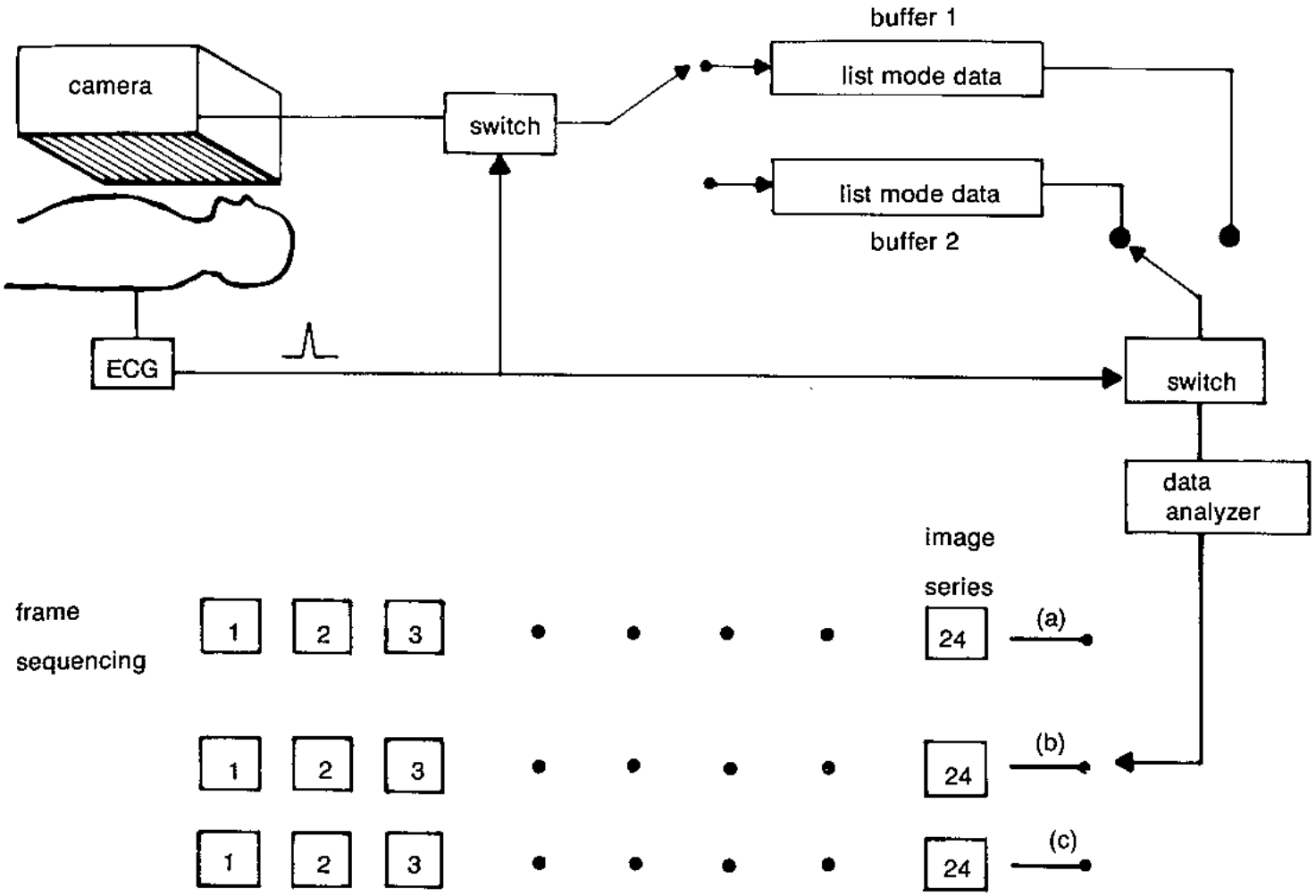


FIGURE 8-2 The R-wave from the ECG serves as the marker to sort data from the same phase of different heart cycles into one image frame.

Multiple gate mode



Multiple gate mode



Ejection Fraction

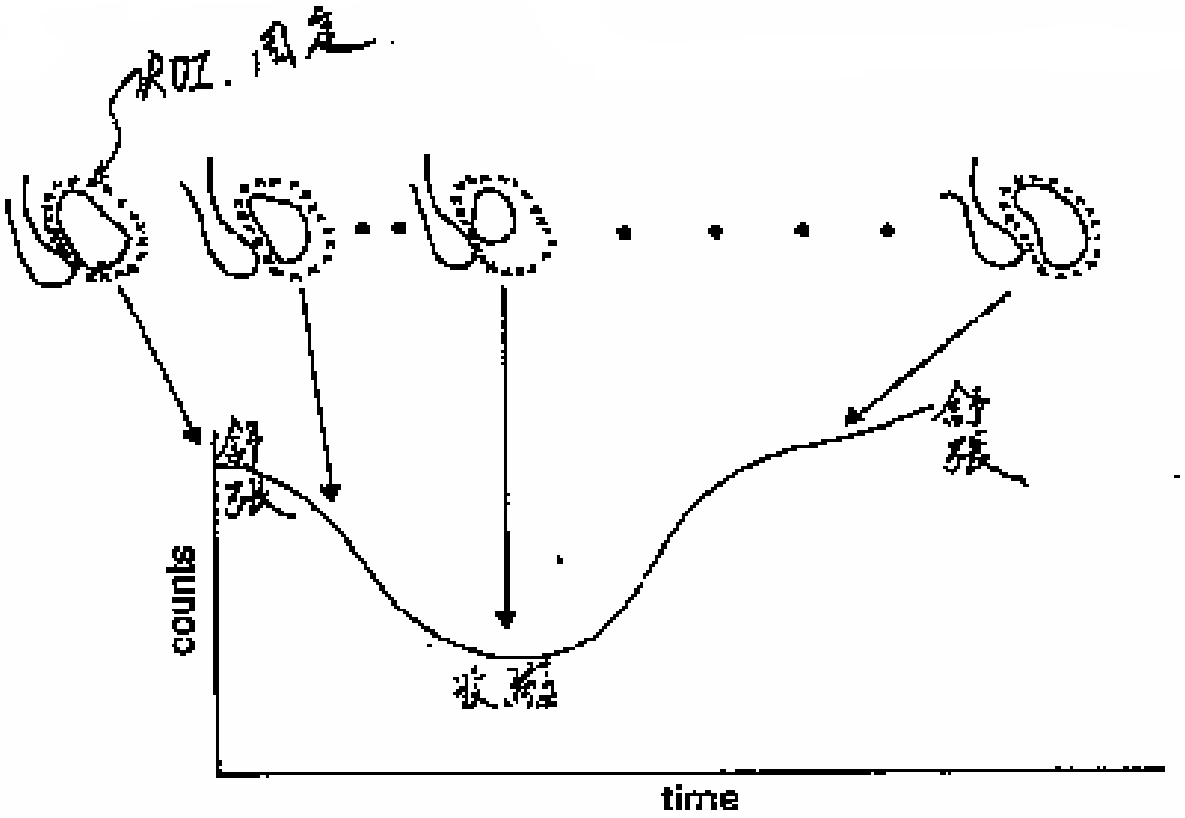


FIGURE 8-10 Counts within a fixed ROI over the left ventricle at different phases of the cardiac cycle were used to construct this volume curve.

Ejection Fraction

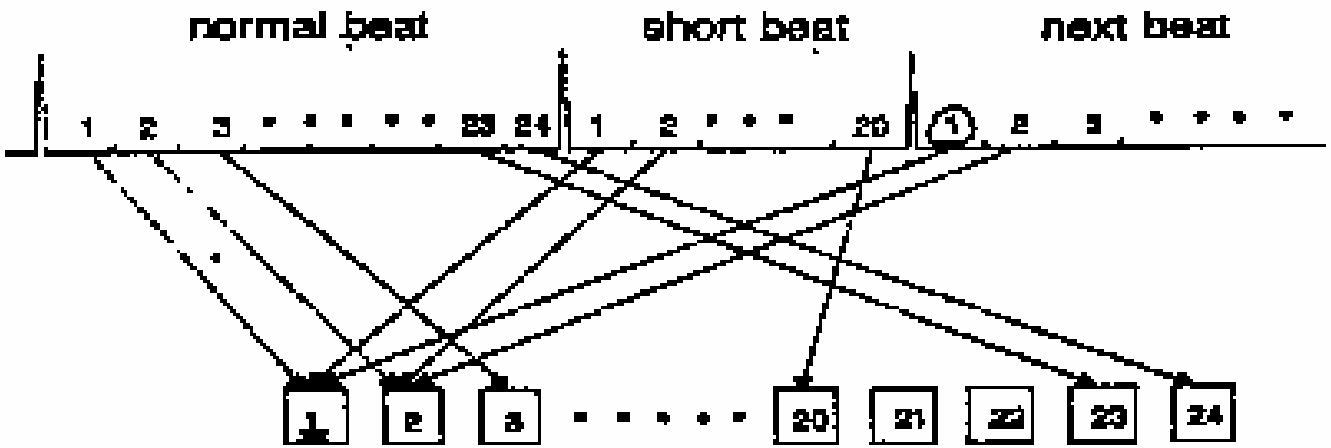


FIGURE 8-9 If an abnormal heart beat occurs while counts are accumulating in Frame 20, the unexpected R-wave resets the computer to direct incoming counts to Frame 1. No counts will be recorded in Frames 21-24 during this short cardiac cycle.

too short

Frame rate 35 msec

35 msec x 20 = 700 msec

Ejection Fraction

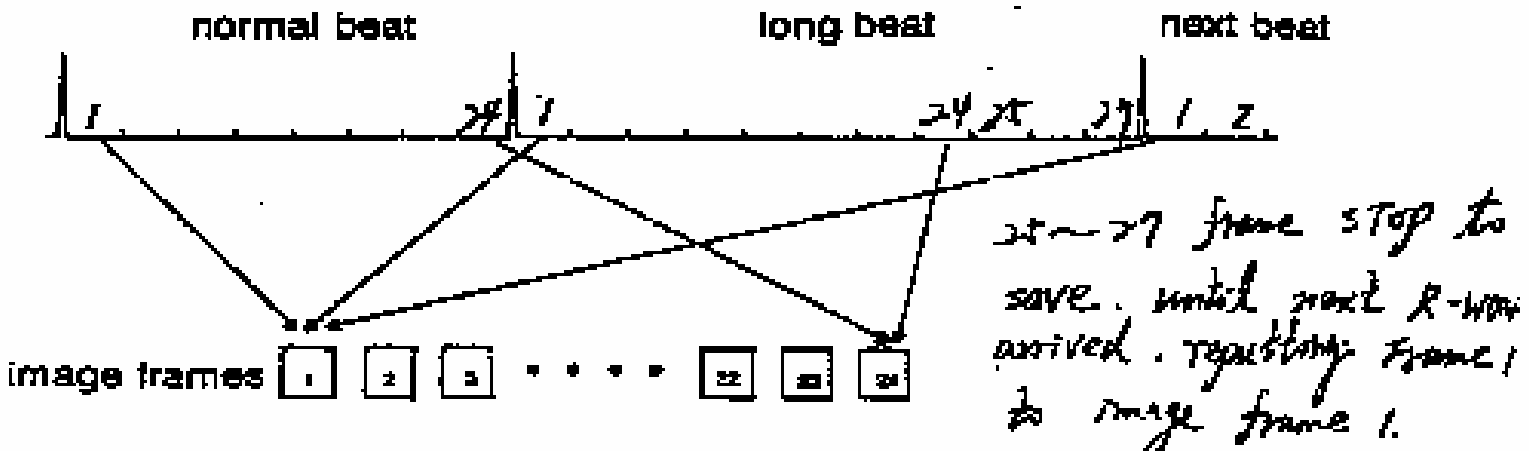


FIGURE 8-4 If an R-R interval lasts longer than the reference value, the last several image frames will be acquired before maximum filling. Hence, the ending frames will have fewer counts than the initial frames.

Ejection Fraction

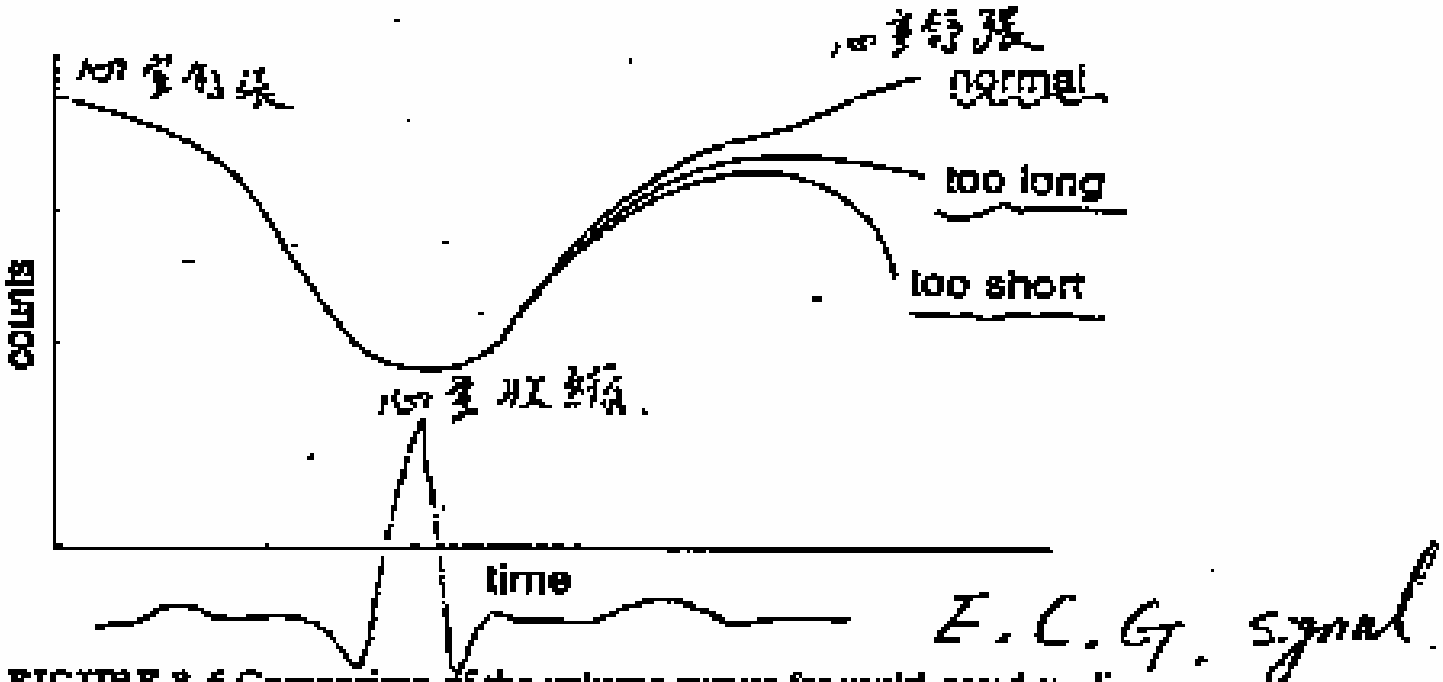
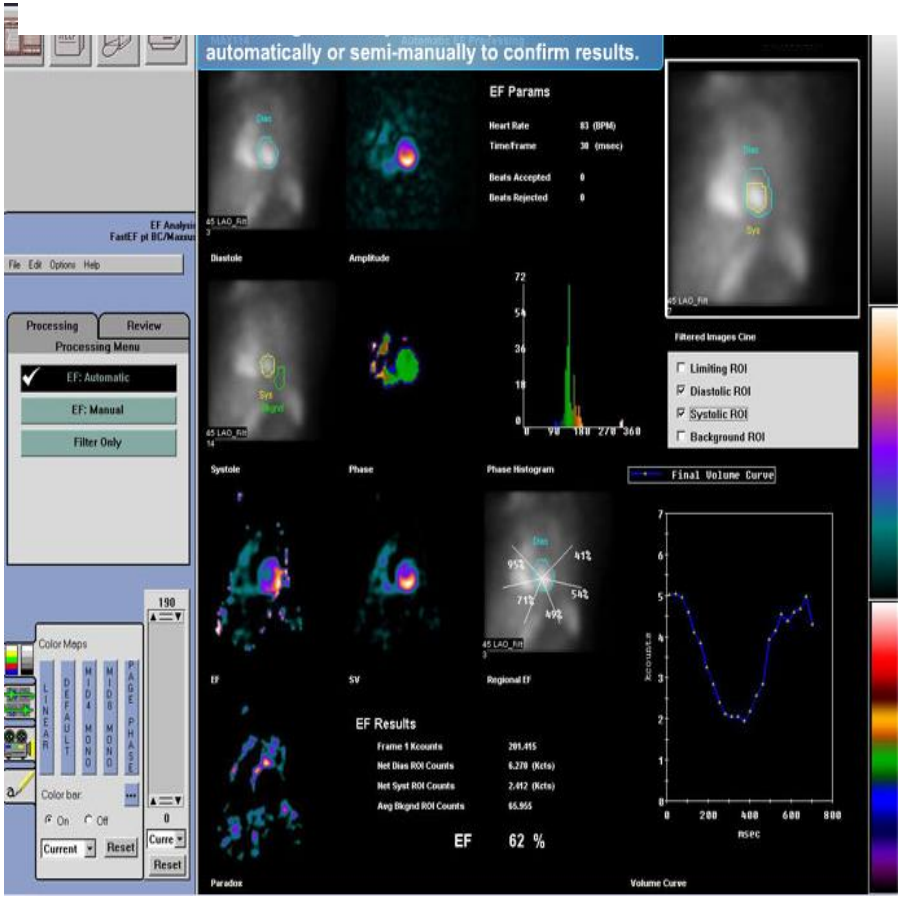
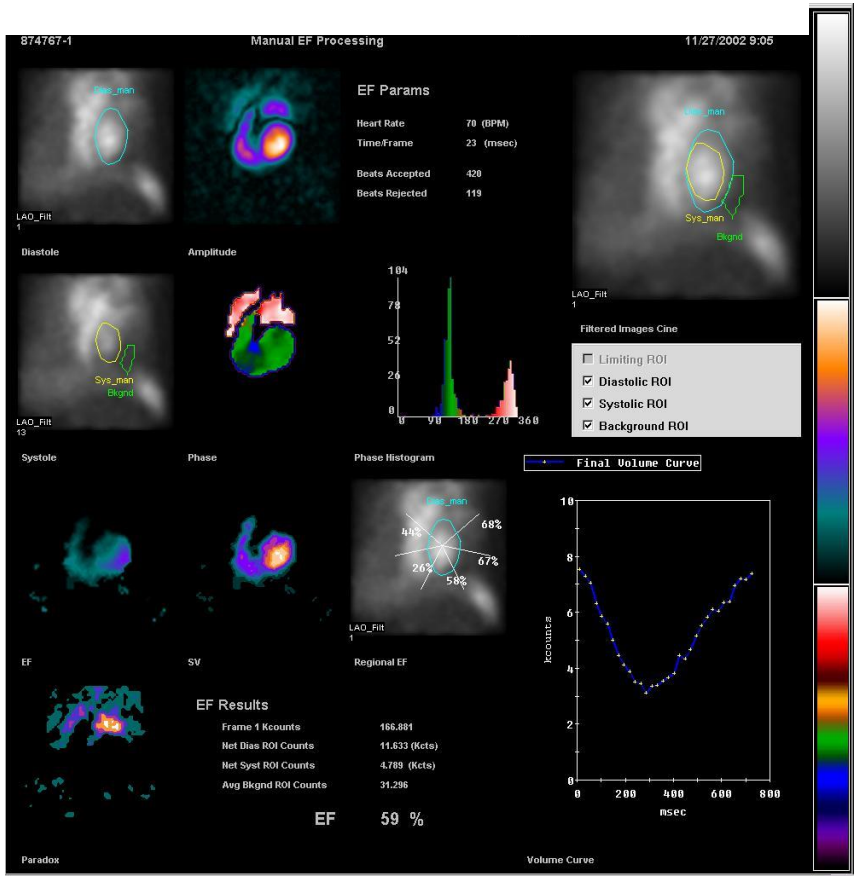


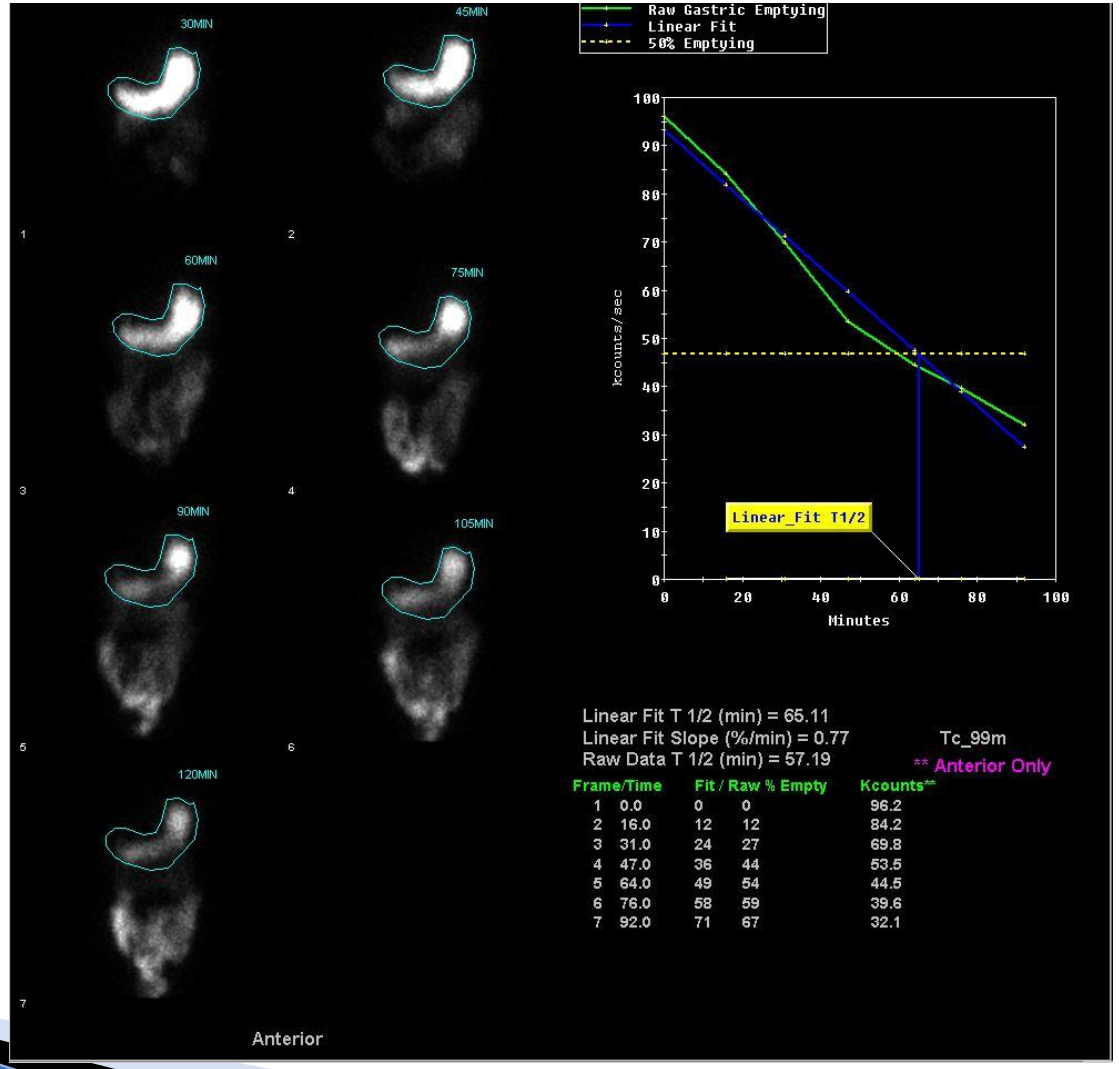
FIGURE 8-5 Comparison of the volume curves for gated studies acquired with heartbeats longer or shorter than normal.

Ejection fraction

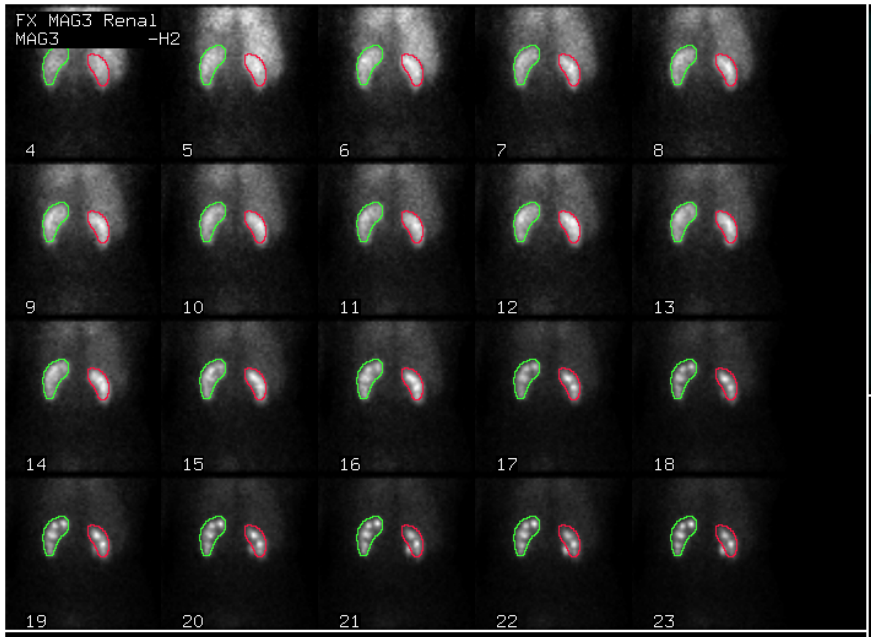


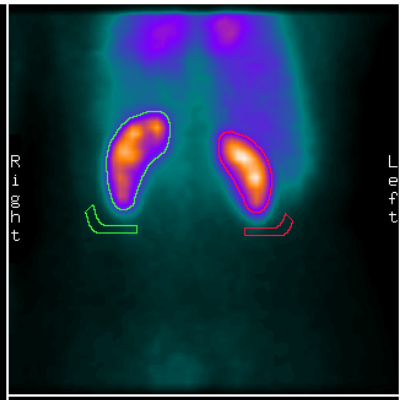


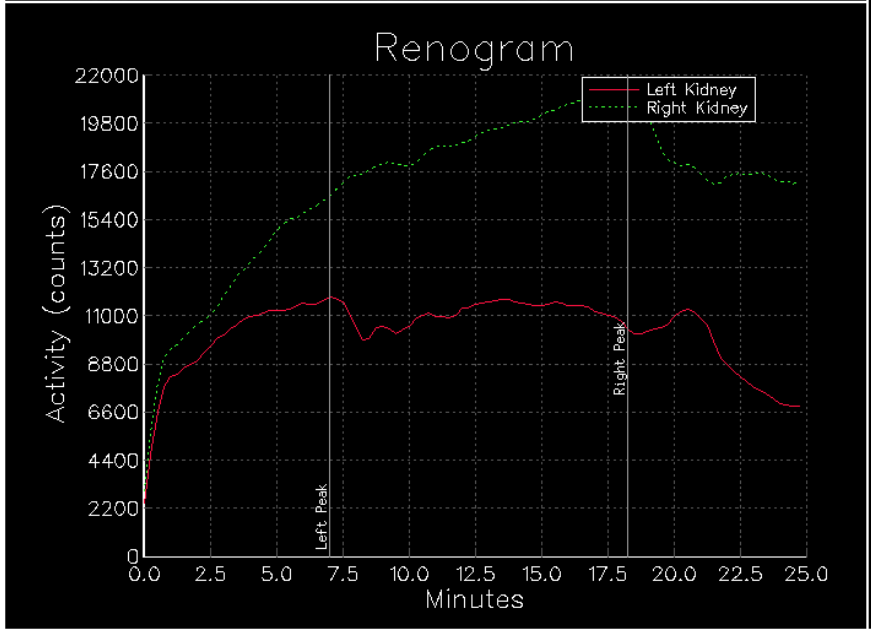
Gastric empty time study

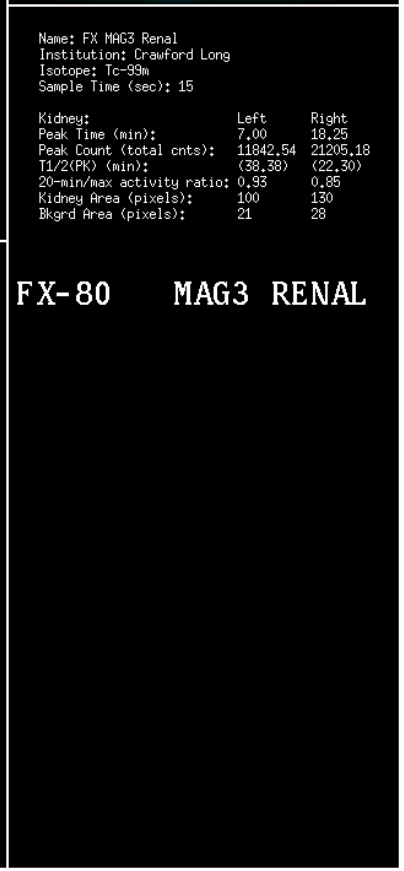


Example for renal function









Analysis tools

- For renal image ratio:
  1. Arithmetic method
  2. Geometric method
- For functional image :
  1. ROI(region of interesting)
  2. Histogram (Time activity curve,TAC)
  3. Curve fitting

Renal image ratio

Arithmetic v.s. Geometric

ROI information (RINFO)

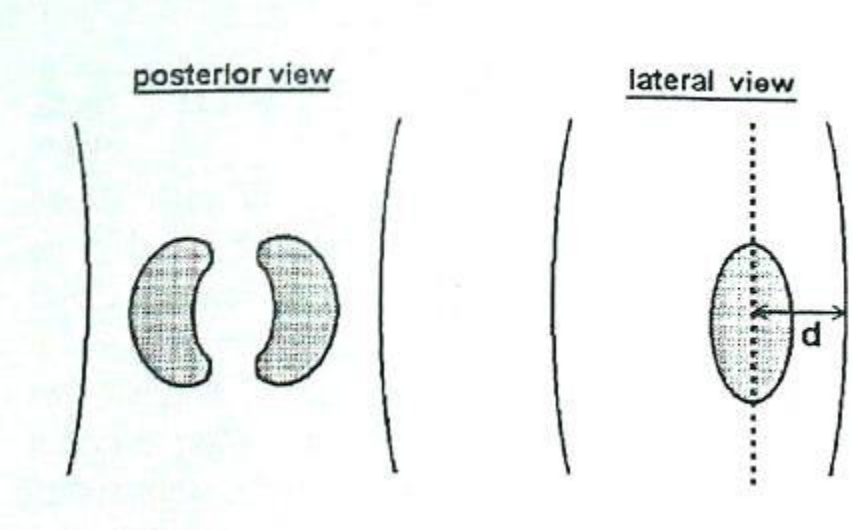


Image ratio

Arithmetic method:

anterior view:

right kidney count(Ra)

left kidney count(La)

Posterior view:

right kidney count(Rp)

left kidney count(Lp)

mean : (Ra+Rp)/2 =Rm , (La+Lp)/2=Lm

Ratio: Kr=Rm/(Rm+Lm), Kl=Lm/(Rm+Lm)

Image ratio

- Geometric method:

  anterior view: right kidney count(Ra)

  left kidney count(La)

  posterior view: right kidney count(Rp)

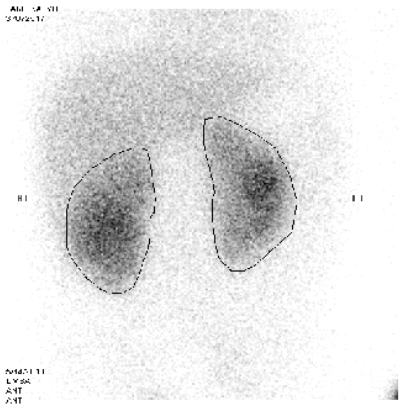
  left kidney count(Lp)

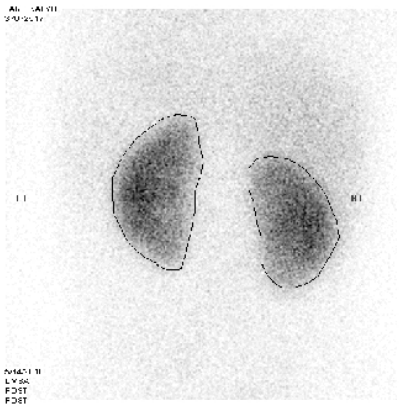
  mean : $\sqrt{Ra*Rp}=Rm, \sqrt{La*Lp}=Lm$

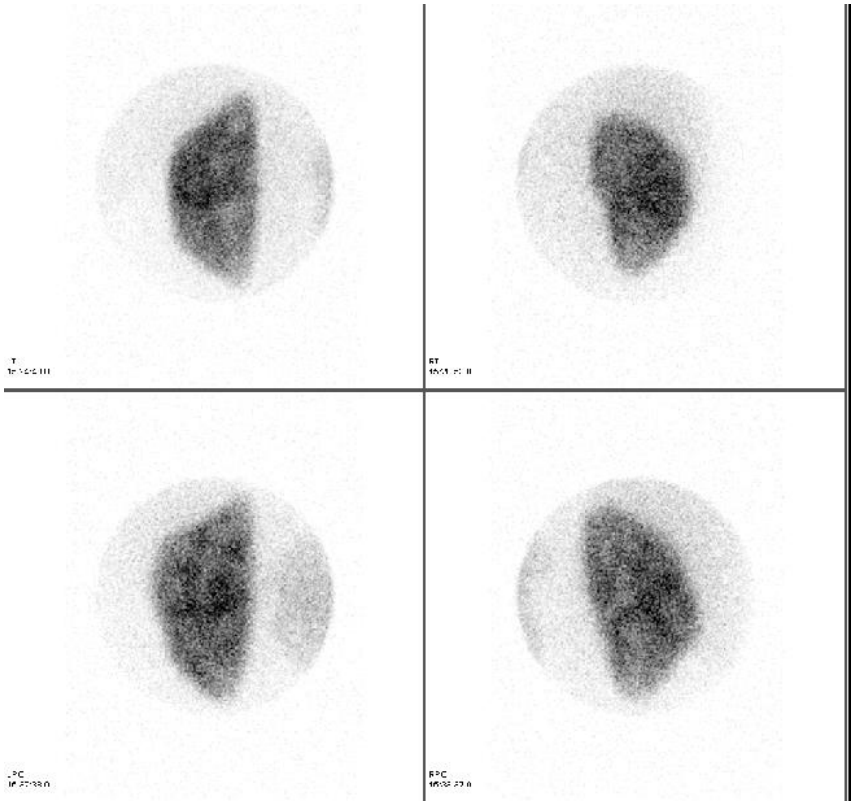
Ratio: Kr=Rm/(Rm+Lm),

Kl=Lm/(Rm+Lm)

Renal uptake ratio







ANT RT KIDNEY

TOTAL COUNT= 42349.00cnts

ANT LT KIDNEY

TOTAL COUNT= 39725.00cnts

POST RT

TOTAL COUNT= 45814.00cnts

POST LT KIDNEY

TOTAL COUNT= 51511.00cnts

GEOMETRIC MEAN

MEAN RT KIDNEY COUNT= 44047.44cnts

MEAN LT KIDNEY COUNT= 45235.77cnts

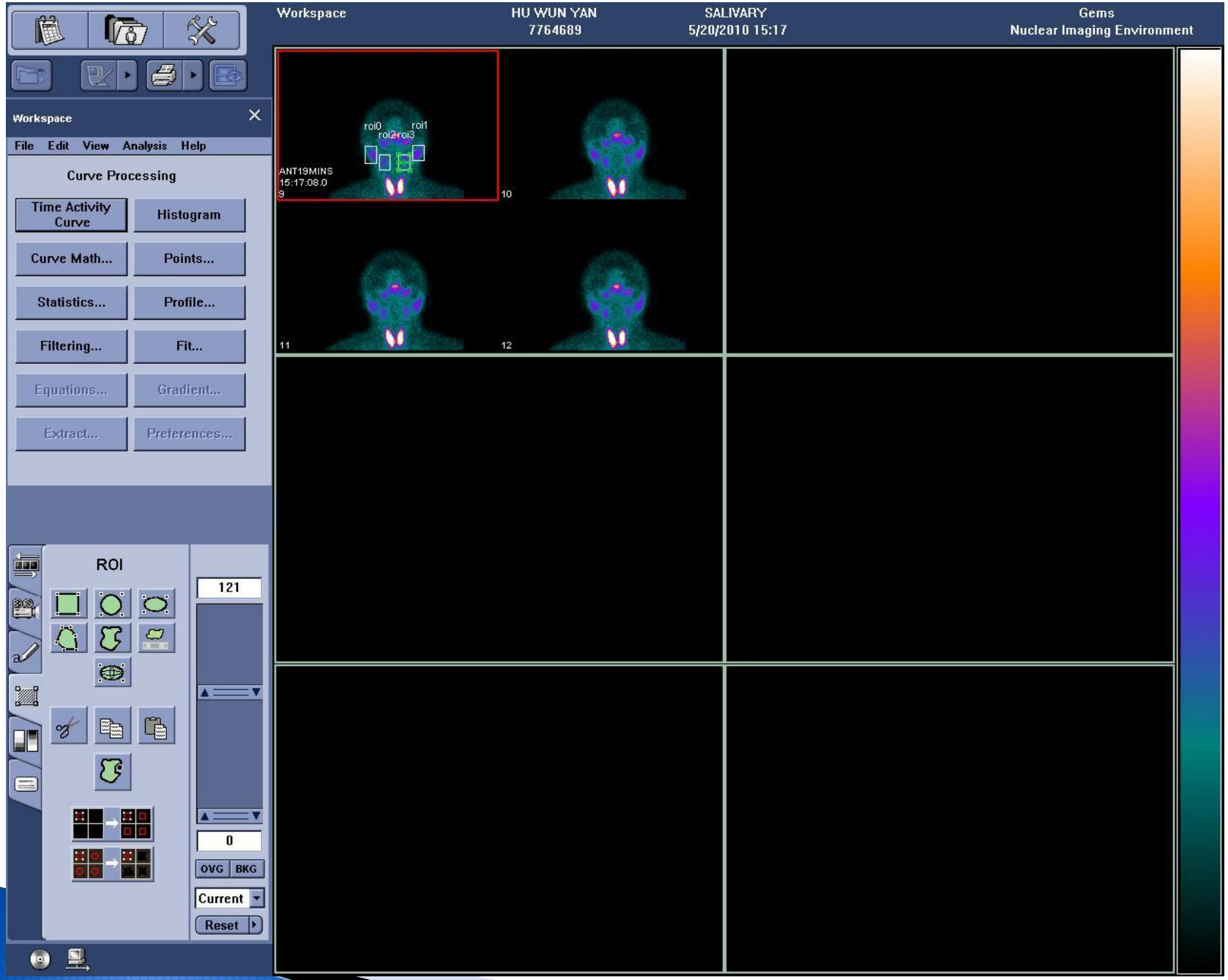
MEAN_TOTAL = 89283.21cnts

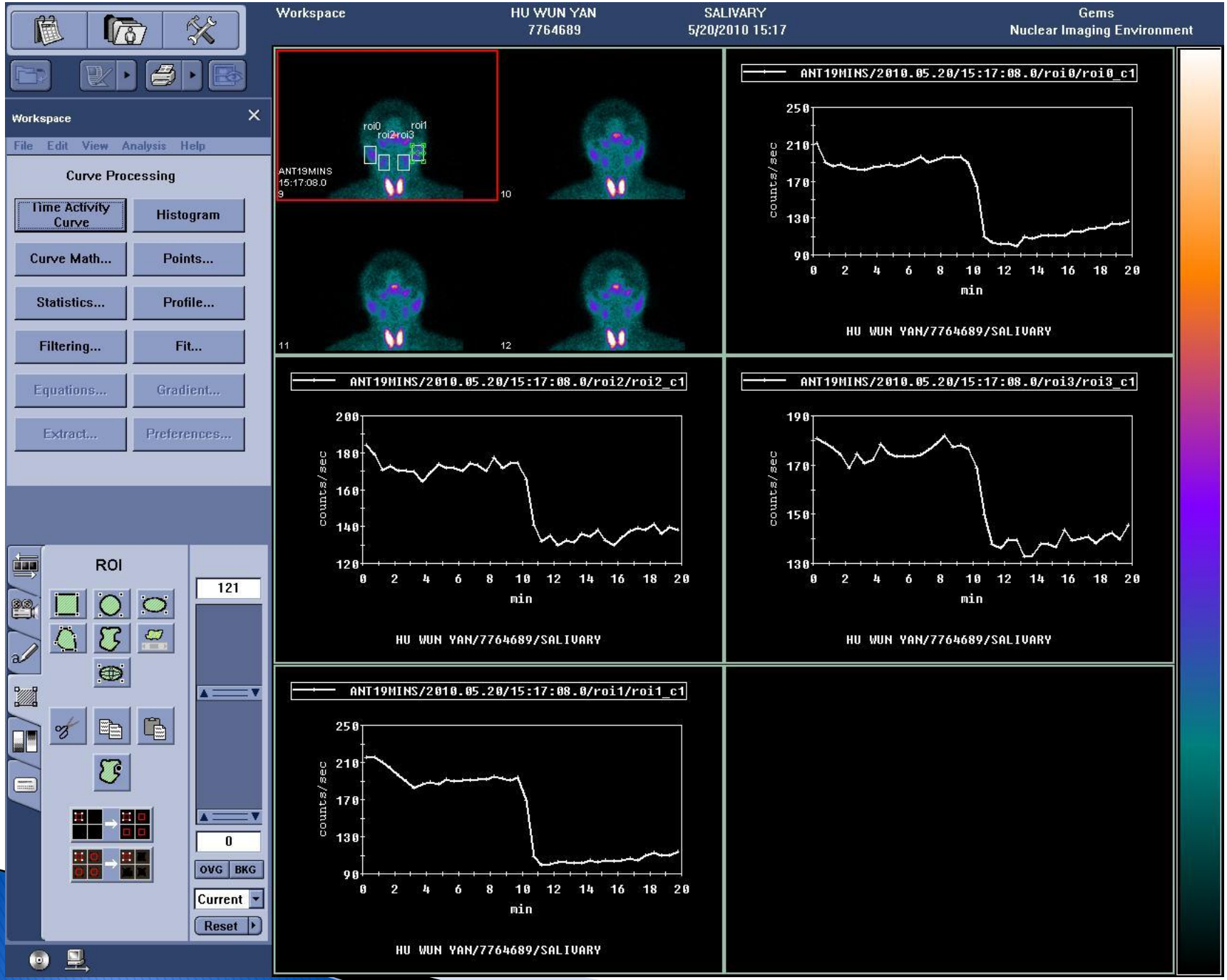
RT KIDNEY RATIO= 49.33%

LT KIDENY RATIO= 50.67%

TAC calculation

- TAC (time-activity curve) is based on the dynamic study
- TAC is depend on the dynamic study's ROI
- Quantitative method with TAC
  - Curve calculation
  - Normalization or smooth
  - Curve fitting (for $T_{1/2}$)


Workspace
HU WUN YAN
7764689
SALIVARY
5/20/2010 15:17
Gems
Nuclear Imaging Environment
Workspace
File Edit View Analysis Help
Curve Processing
Time Activity Curve
Histogram
Curve Math...
Points...
Statistics...
Profile...
Filtering...
Fit...
Equations...
Gradient...
Extract...
Preferences...
roi0
roi1
roi2
roi3
ANT19MINS
15:17:08.0
9
10
11
12
ROI
121
0
OVG
BKG
Current
Reset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HU WUN YAN
7764689
SALIVARY
5/20/2010 15:17
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Nuclear Imaging Environment
Workspace
File Edit View Analysis Help
Curve Processing
Time Activity Curve
Histogram
Curve Math...
Points...
Statistics...
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Fit...
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Gradient...
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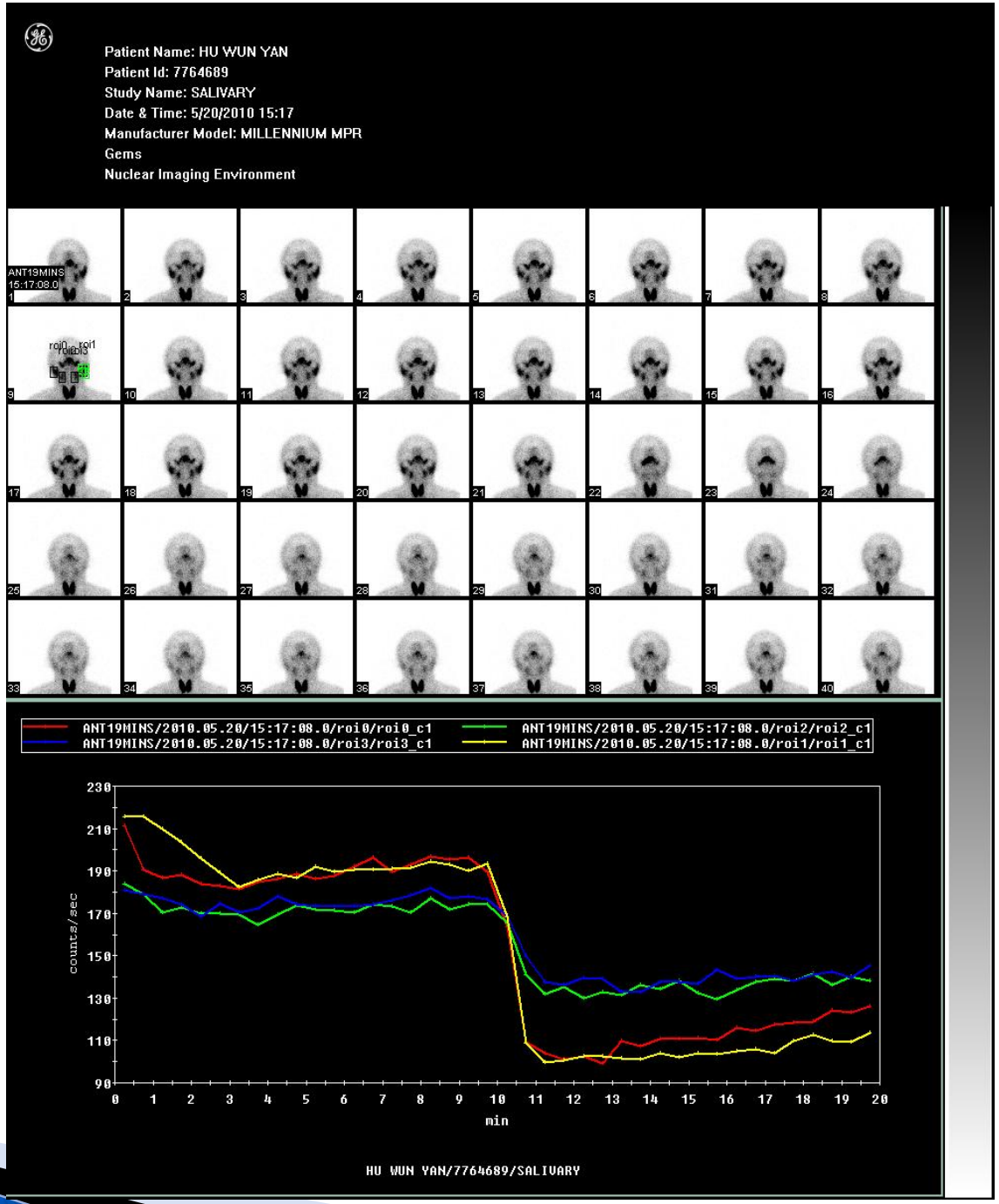
Preferences...
roi0
roi1
roi2
roi3
ANT19MINS
15:17:08.0
9
10
11
12
ANT19MINS/2010.05.20/15:17:08.0/roi0/roi0_c1
counts/sec
min
HU WUN YAN/7764689/SALIVARY
ANT19MINS/2010.05.20/15:17:08.0/roi2/roi2_c1
counts/sec
min
HU WUN YAN/7764689/SALIVARY
ANT19MINS/2010.05.20/15:17:08.0/roi3/roi3_c1
counts/sec
min
HU WUN YAN/7764689/SALIVARY
ANT19MINS/2010.05.20/15:17:08.0/roi1/roi1_c1
counts/sec
min
HU WUN YAN/7764689/SALIVARY
ROI
121
0
OVG
BKG
Current
Reset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Patient Id: 7764689
Study Name: SALIVARY
Date & Time: 5/20/2010 15:17
Manufacturer Model: MILLENNIUM MPR
Gems
Nuclear Imaging Environment
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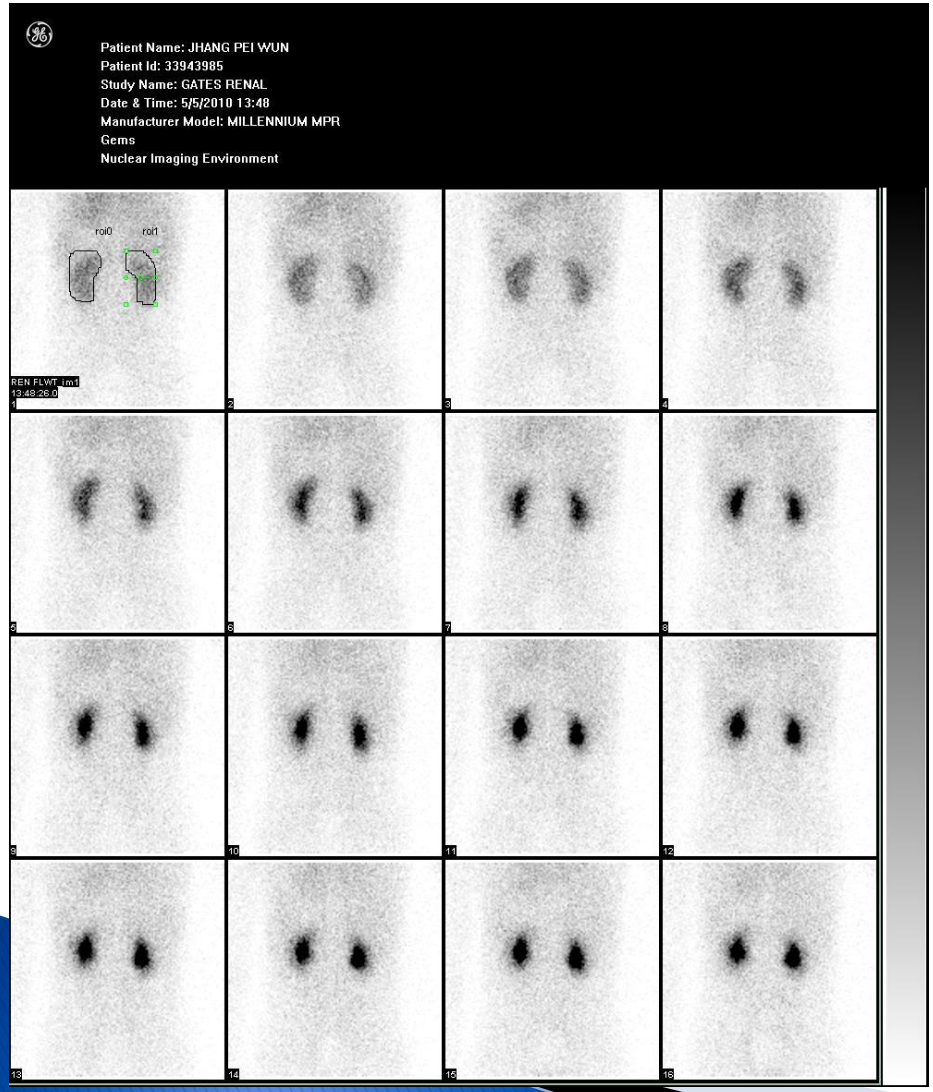
counts/sec
min
HU WUN YAN/7764689/SALIVARY

TAC analysis



- Gate's method

kidney depth:

$$\text{Right kidney} = 13.3 * \text{W/H} + 0.7$$

$$\text{Left kidney} = 13.2 * \text{W/H} + 0.7$$

$$\text{W}: \text{Weight in Kg}$$

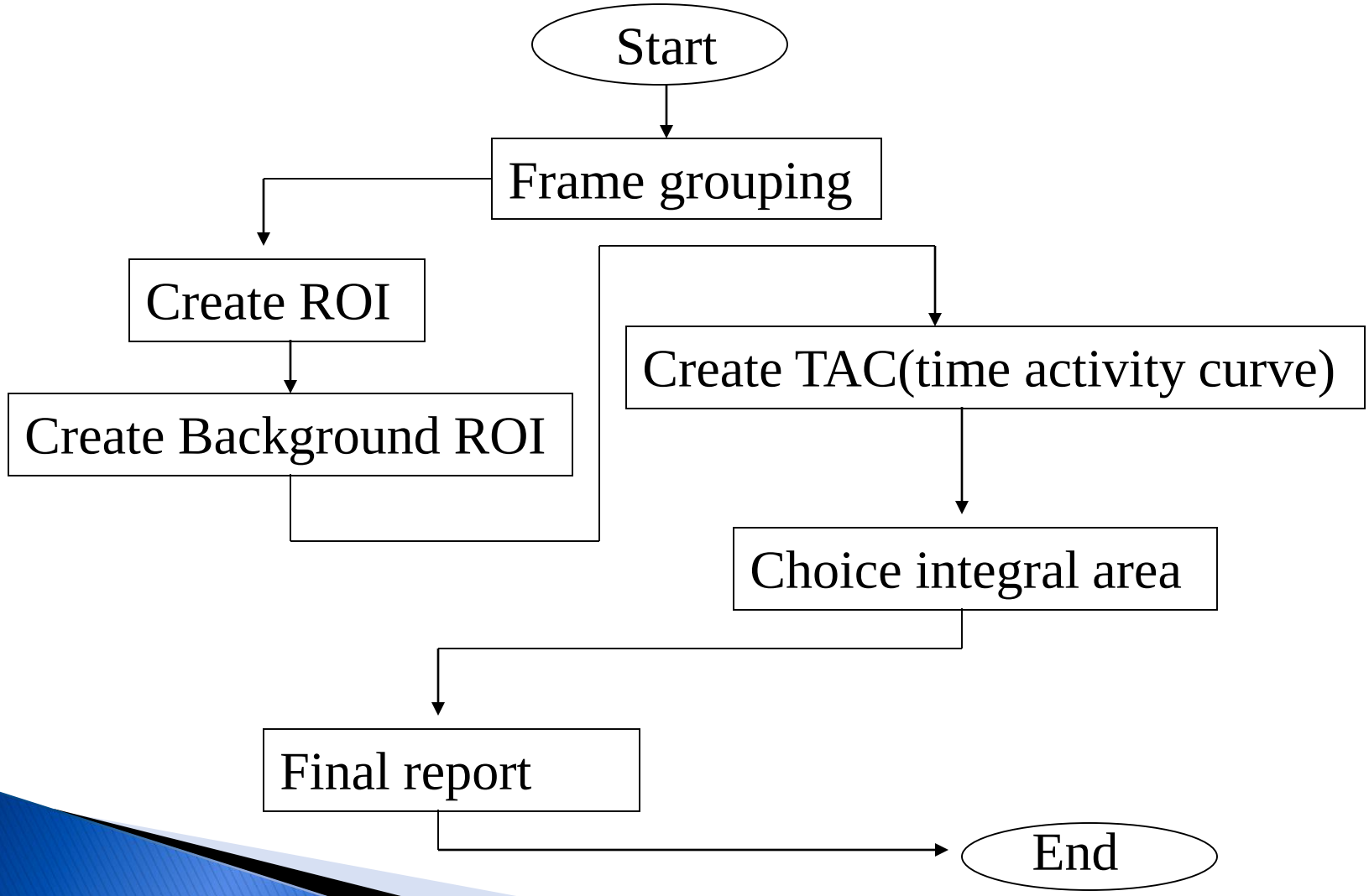
$$\text{H}: \text{Hight in cm}$$

$$GFR = (\%\ renal\ uptake\ of\ {}^{99m}Tc - DTPA)(9.81270) - (6.85219)$$

$$\%\ renal\ uptake\ of\ {}^{99m}Tc - DTPA$$

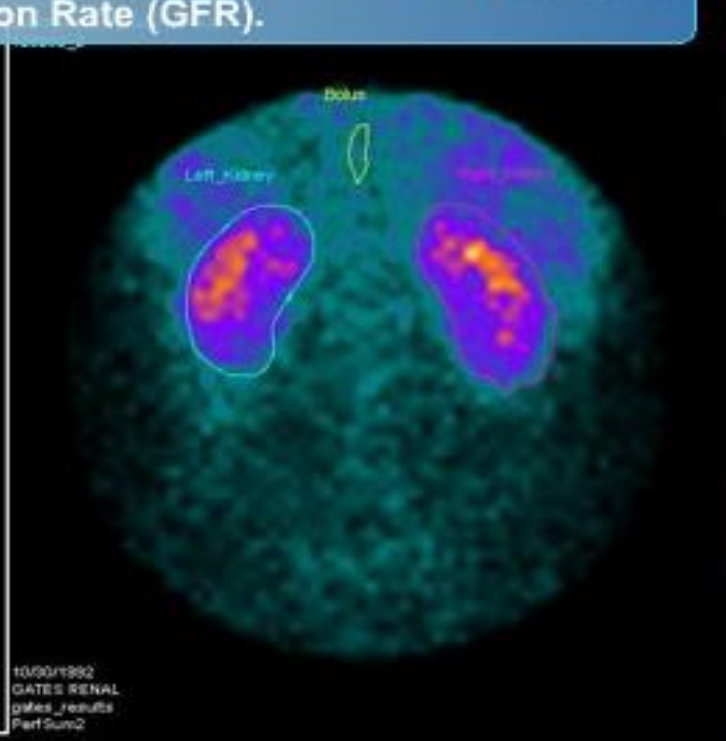
$$= \frac{\dfrac{(R\ Kidney\ cts - Bkgd)}{e^{-ux}} + \dfrac{(L\ Kidney\ cts - Bkgd)}{e^{-ux}}}{\text{preinjection counts} - \text{postinjection counts}}$$

Procedure Flow Chart



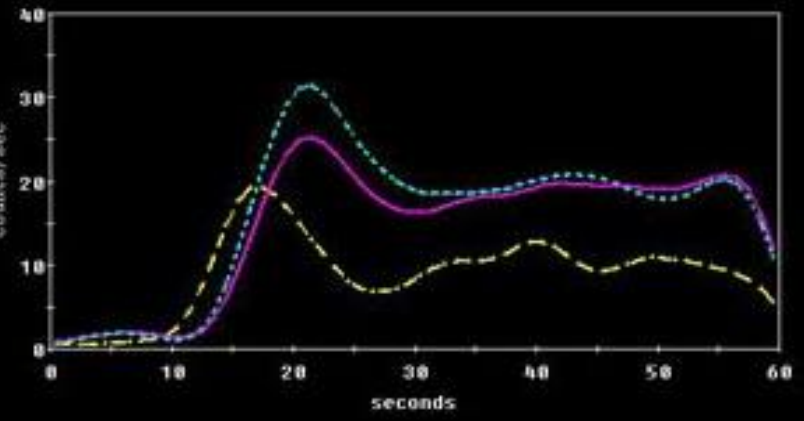
The Gates Renal Analysis protocol provides a count-based method of estimating Glomerular Filtration Rate (GFR).

0-30 Second Summed Image



30-60 Second Summed Image

Normalised Perfusion Curves



Bolus Curve
Left Kidney Curve
Right Kidney Curve

Patient Information

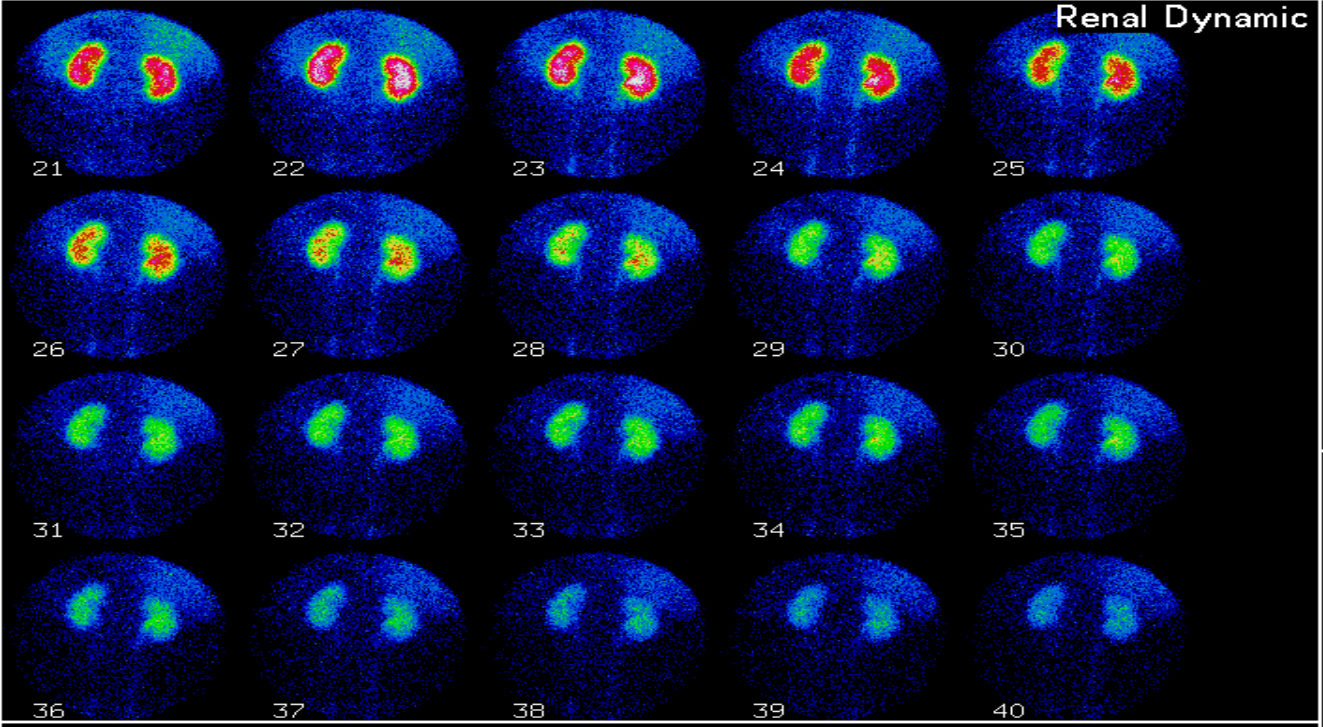
Height (cm)	183
Weight (kg)	98.0
Age (years)	33.0
Isotope	DTPA
Dose Injected (mCi)	3.00
Transplant	NO
No Lasix	

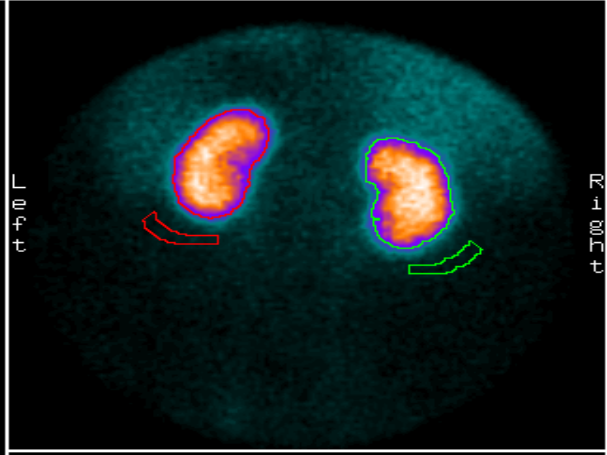
Perfusion Results

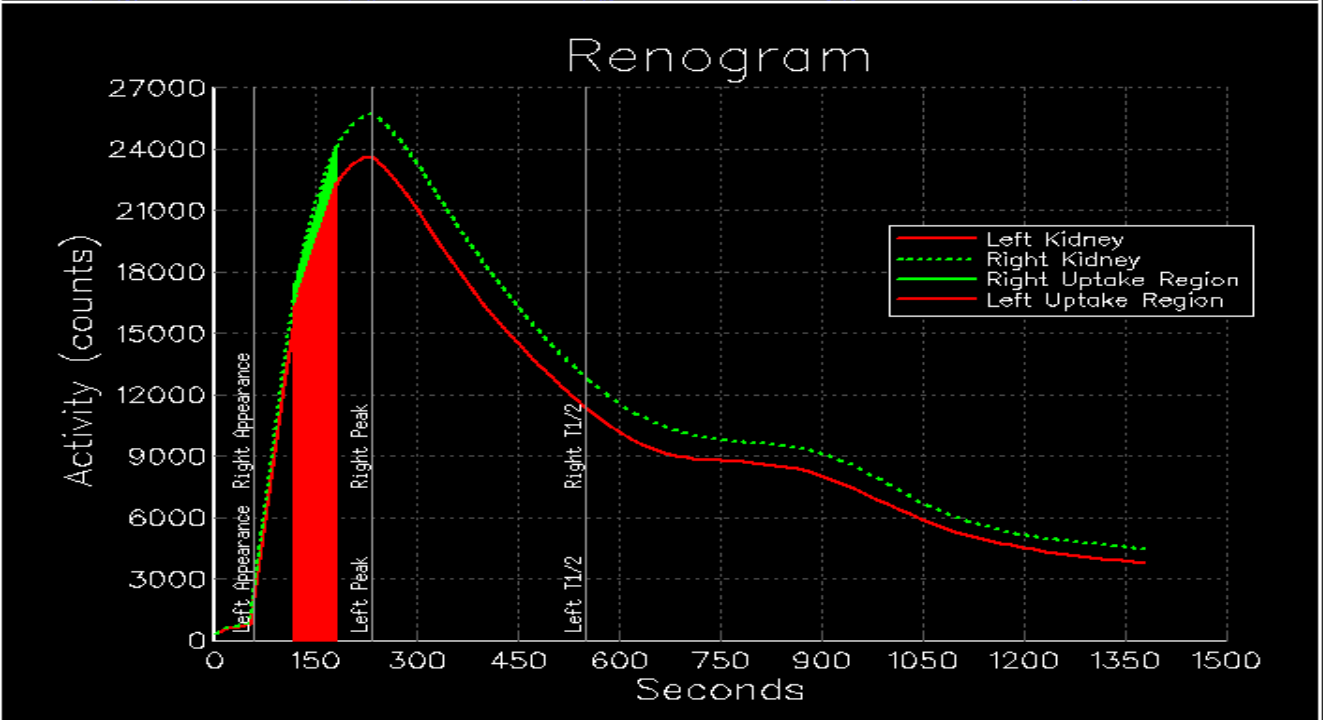
Right perfusion index:	149.8
Left perfusion index:	128.3

Review Menu

- Perfusion Images
- Perfusion Summary
- Function Images
- Function Summary
- Gates GFR Values







Name: Renal Dynamic
Height (cm): 182.8
Weight (kg): 70
Age (years):
Institution: SWEDISH MEDICAL CENTER
Isotope: Tc-99m
Sample Time (sec): 3, 60
Analysis T1 (sec): 120
Analysis T2 (sec): 180
Injected Dose (cnts): 962575
Total GFR (ml/min): 130.01

Kidney:	Left	Right
Appearance Time (sec):	60.00	60.00
Peak Time (sec):	235.27	235.27
Peak Count (total cnts):	23627.96	25700.73
T1/2(AT) (sec):	490.48	490.48
T1/2(PK) (sec):	315.22	315.22
20-min/max activity ratio:	0.19	0.20
Kidney Area (pixels):	487	497
Bkgrd Area (pixels):	77	75
Kidney Depth (cm):	5.75	5.79
Kidney Cnts (cnts):	64208	70020
Percent Uptake (%):	6.67	7.27
Kidney GFR (ml/min):	62.19	67.82
GFR Contribution (%):	47.84	52.16

Split Uptake:	Left	Right
Area (cnts-sec):	1158711.	1244212.
Area (%):	48.22	51.78
Slope (cnts/sec):	99.11	110.78
Corrected for depth of kidney:		
Area (cnts-sec):	2794849.	3018715.
Area (%):	48.07	51.93
Slope (cnts/sec):	239.06	268.78
Time interval (sec):	120.00 to 180.00	

Curve Fitting

- In many dynamic radionuclide studies, we are more interested in the flow characteristics of the tracer than visualization of the anatomical details of the involved organ.

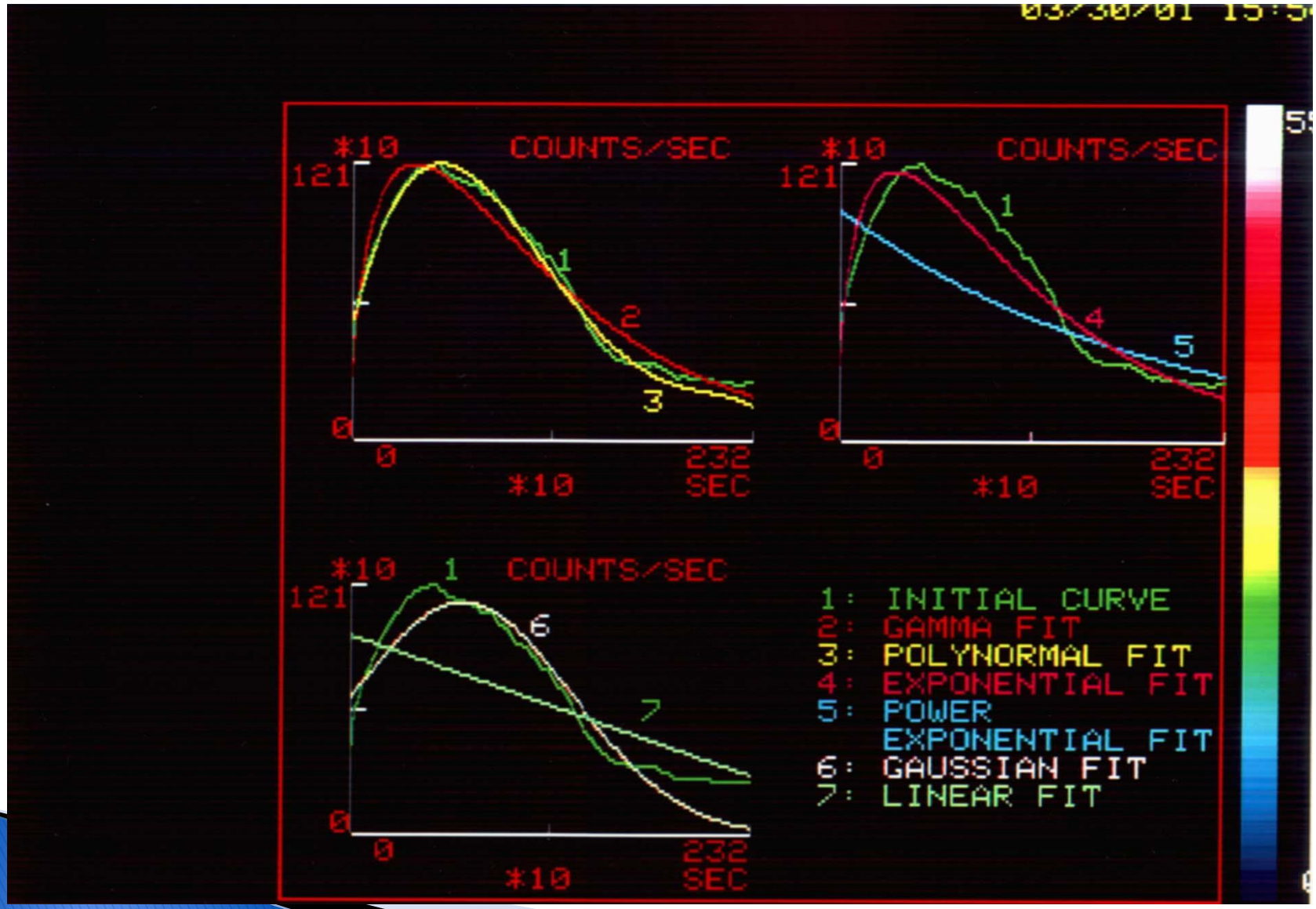
Curve Fitting

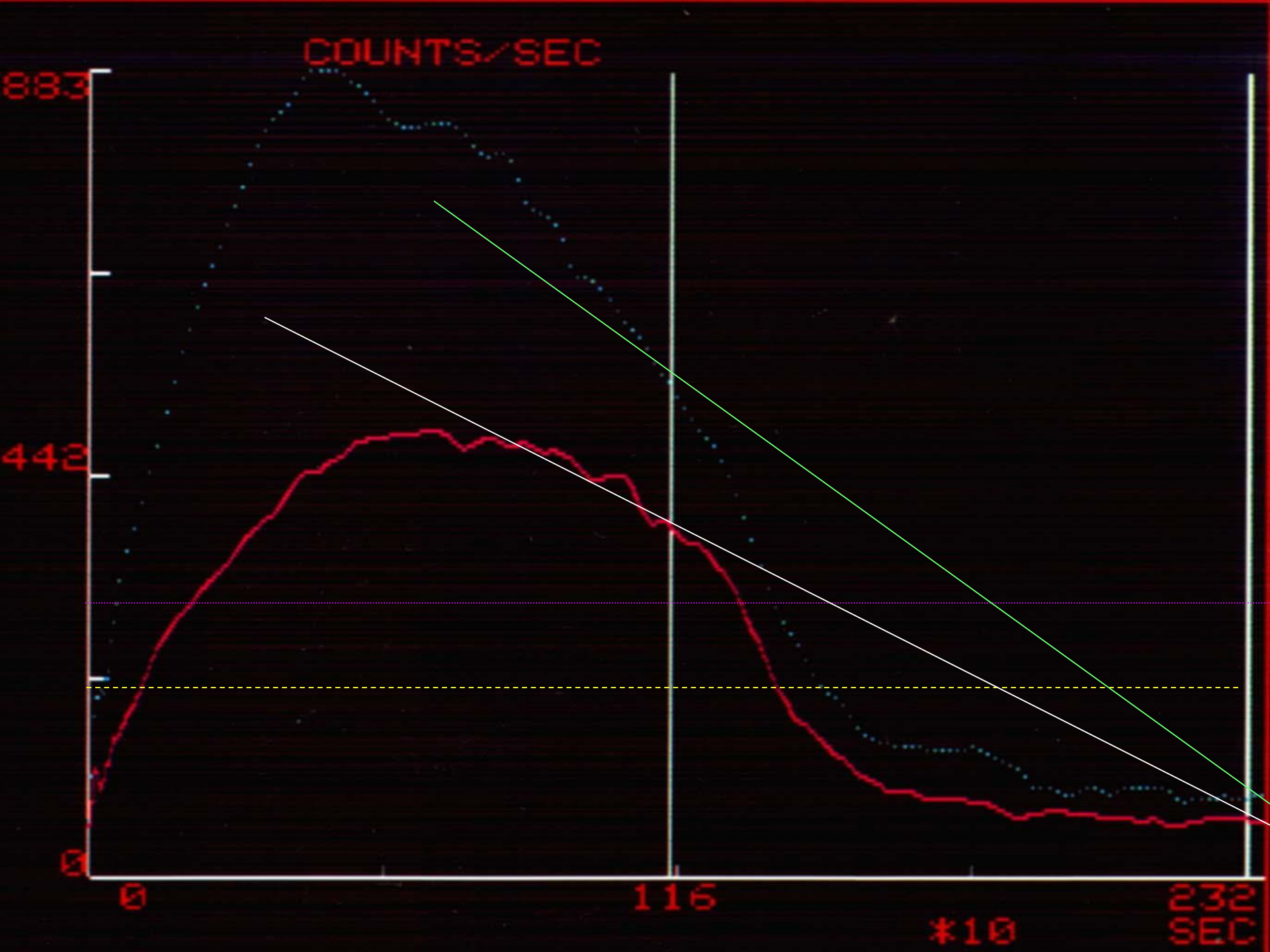
- Fitting method:
  1. Extrapolate
  2. Interpolating
  3. Define model
  4. Mathematically manipulated

Curve Fitting

- Fitting :
  linear fits : $Y=AX+B$
  polynormal fits : $Y=A_1X^n+A_2X^{n-1}+\ldots+C$
  logarithmic fits : $Y=A\log X+C$
  exponential fits : $Y=Ae^X+c$

Curve Fitting




COUNTS/SEC
883
442
0
0
116
232
*10
SEC

ELSCINT'S "APEX SPX-1" 03/30/01 15:0

STUDY 51 K.J. , C. 2850036-6
02/28/01

GFR

Time to Max

Rt= 7.5 M
Lt= 11. M

Max Counts

Rt= 932.3
Lt= 534.9

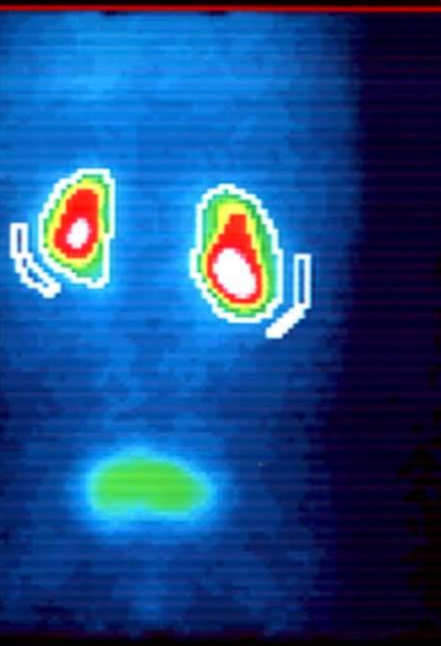
Percent Max

Rt= 64. %
Lt= 36. %

T 1/2 Max

Rt= 7.74 M
Lt= 7.24 M

LT ----
RT ....

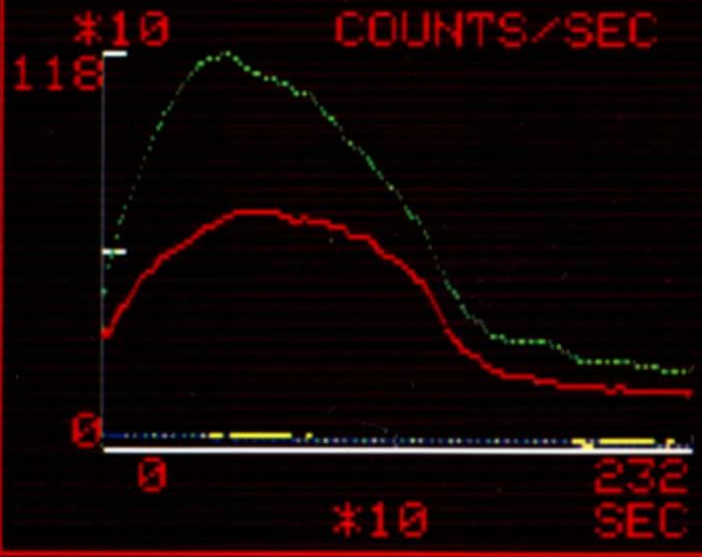


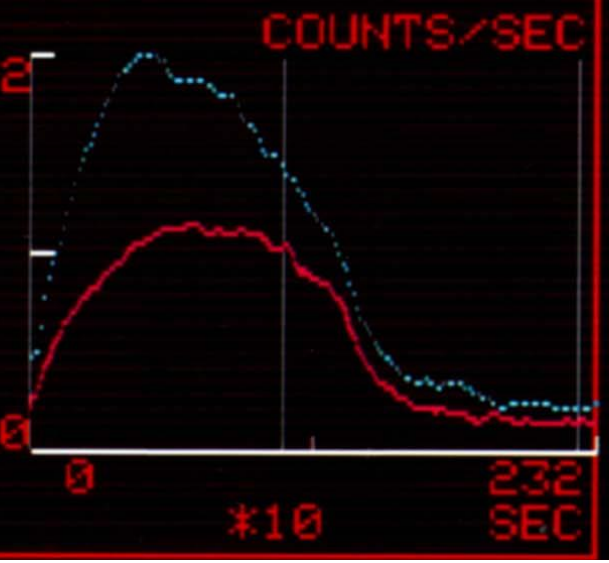
* Lasix Results *

Inj at 17. M
% eliminated at
Rt= 37. M
Lt= 37. M
Rt= 84. %
Lt= 85. %

T 1/2 Max Lasix

Rt= 7.0 M
Lt= 6.5 M
MKR AT LASIX INJ






COUNTS/SEC
883
442
0
0
116
232
*10
SEC

ELSCINT'S "APEX SPX-1" 03/30/01 15:1

STUDY 51 K.J. , C. 2850036-6
02/28/01

GFR

Time to Max

Rt= 7.5 M
Lt= 11. M

Max Counts

Rt= 932.3
Lt= 534.9

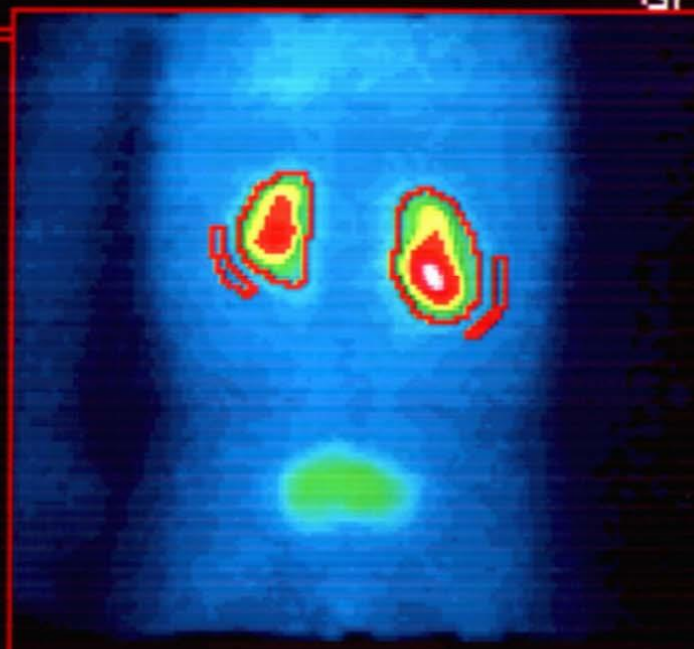
Percent Max

Rt= 64. %
Lt= 36. %

T 1/2 Max

Rt= 7.24 M
Lt= 7.24 M

LT ----
RT ....

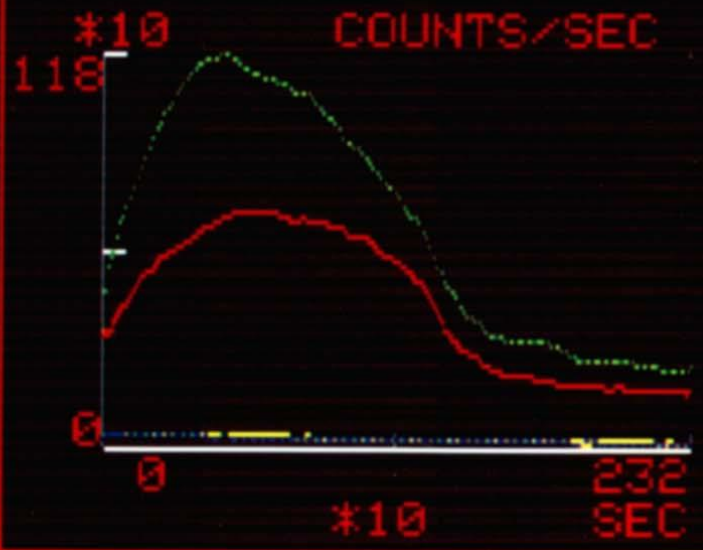


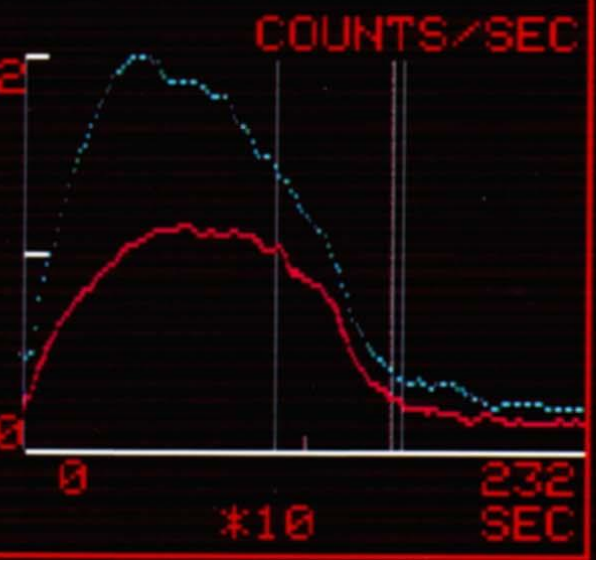
* Lasix Results *

Inj at 17. M
% eliminated at
Rt= 26. M
Lt= 32. M
Rt= 74. %
Lt= 83. %

T 1/2 Max Lasix

Rt= 4.0 M
Lt= 4.9 M
MKR AT LASIX INJ





Conclusion

- 核子醫學造影檢查
  - 造影過程
  - 電腦資料分析
- 未來發展趨勢
  - Trace Kinetics model
  - Mathematic Tools
  - New Procedure
  - More powerful Image process tool
  - AI 應用

THE END


MARCH 2002
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