DM – Nuclear medicine

Clinical problem	Radionuclide study
CAD	MPI : ^{201}Tl, ^{99m}Tc-agents, ^{18}F-FDG
DAN	Imaging of Sympathetic Innervation : ^{123}I-MIBG, ^{11}C-HED
Gastroparesis D.	Gastric emptying : ^{99m}Tc-col. meal
D. Cardiomyopathy	Systolic / Diastolic LV function ^{99m}Tc-RBC-MUGA, ^{99m}Tc-MIBI-gated SPECT
D. Nephropathy	GFR measurement : ^{51}Cr-EDTA
D. Foot	Bone scan : ^{99m}Tc-MDP Infection imaging : ^{99m}Tc-HMPAO- WBC

Heart Failure

inability of blood pumping
in accordance to metabolic demands,
under normal filling pressure

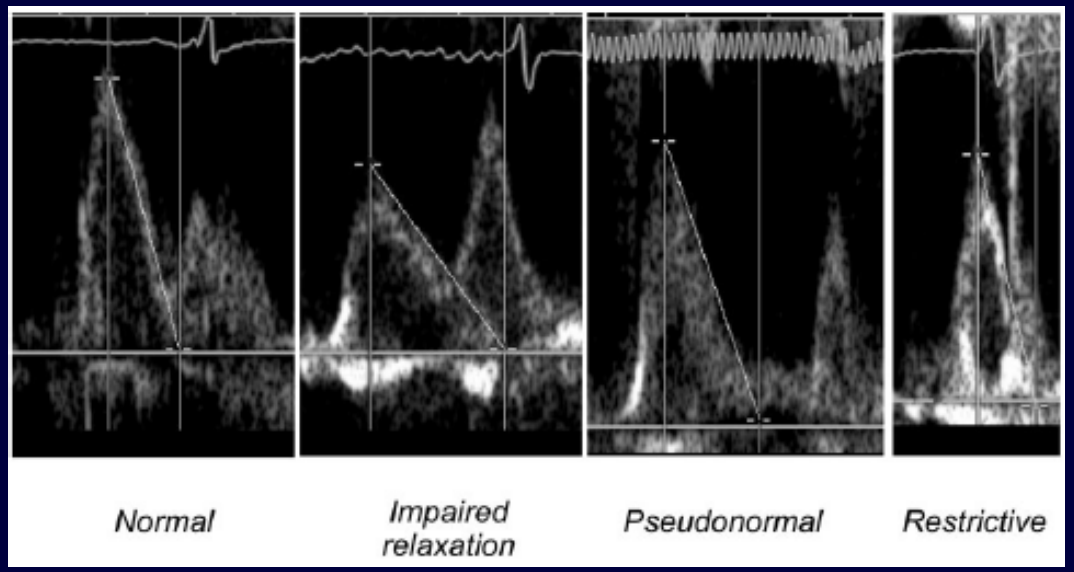
Systolic Dysfunction

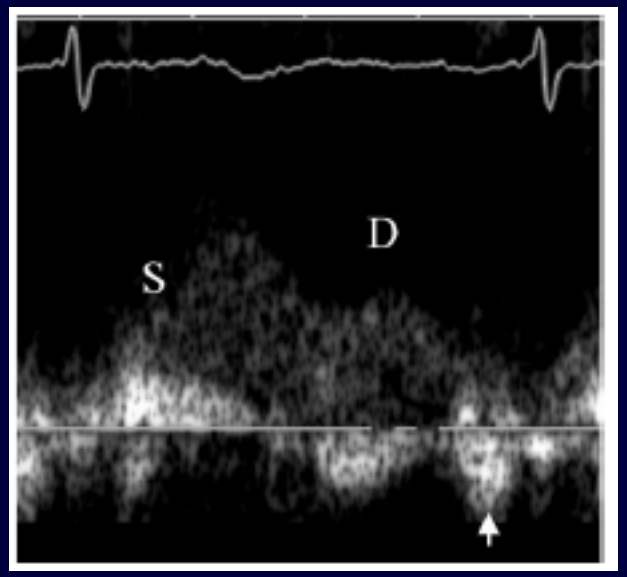
↓ LVEF + ↑ LVEDV

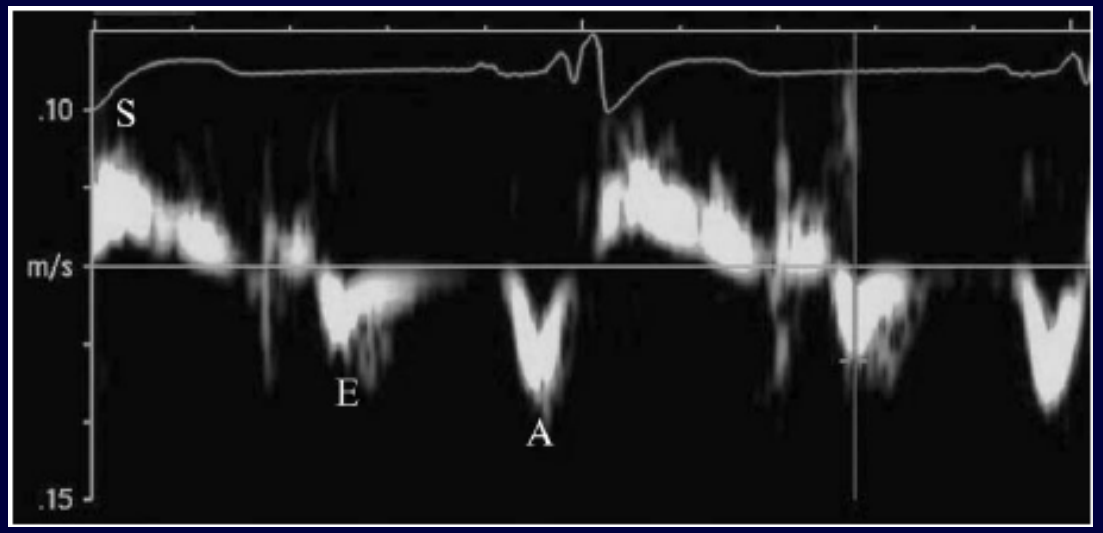
Diastolic Dysfunction

↑ LV filling pressure
LVEF, LVEDV, constant

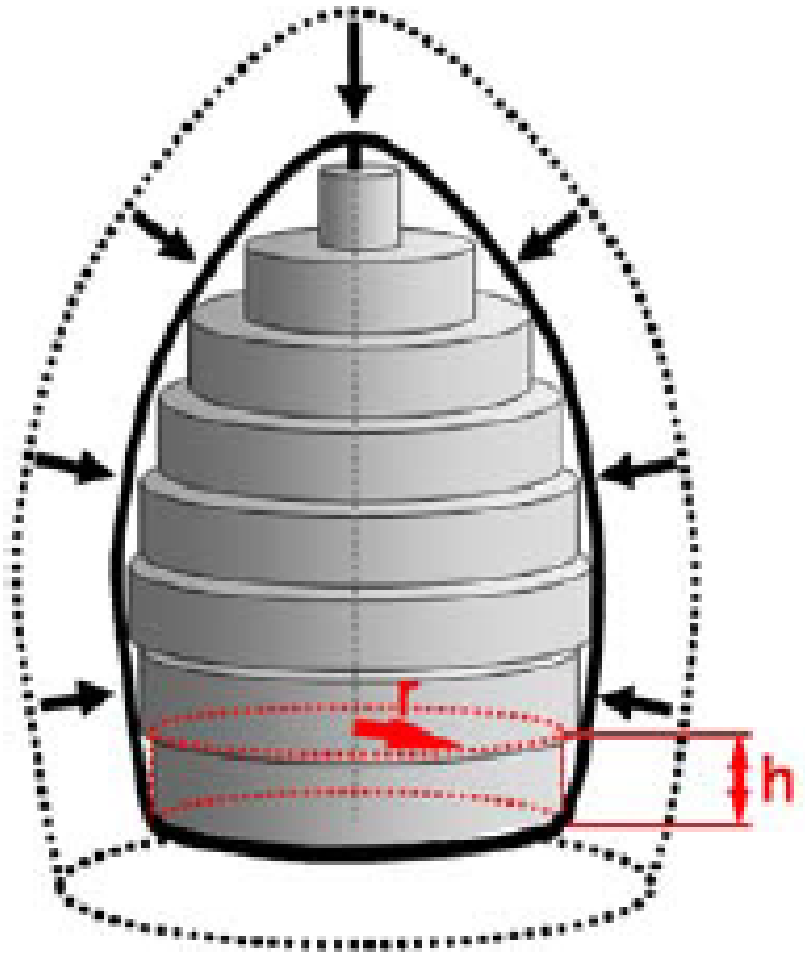
Diabetic Cardiomyopathy: Evidence, Mechanisms, and Therapeutic Implications





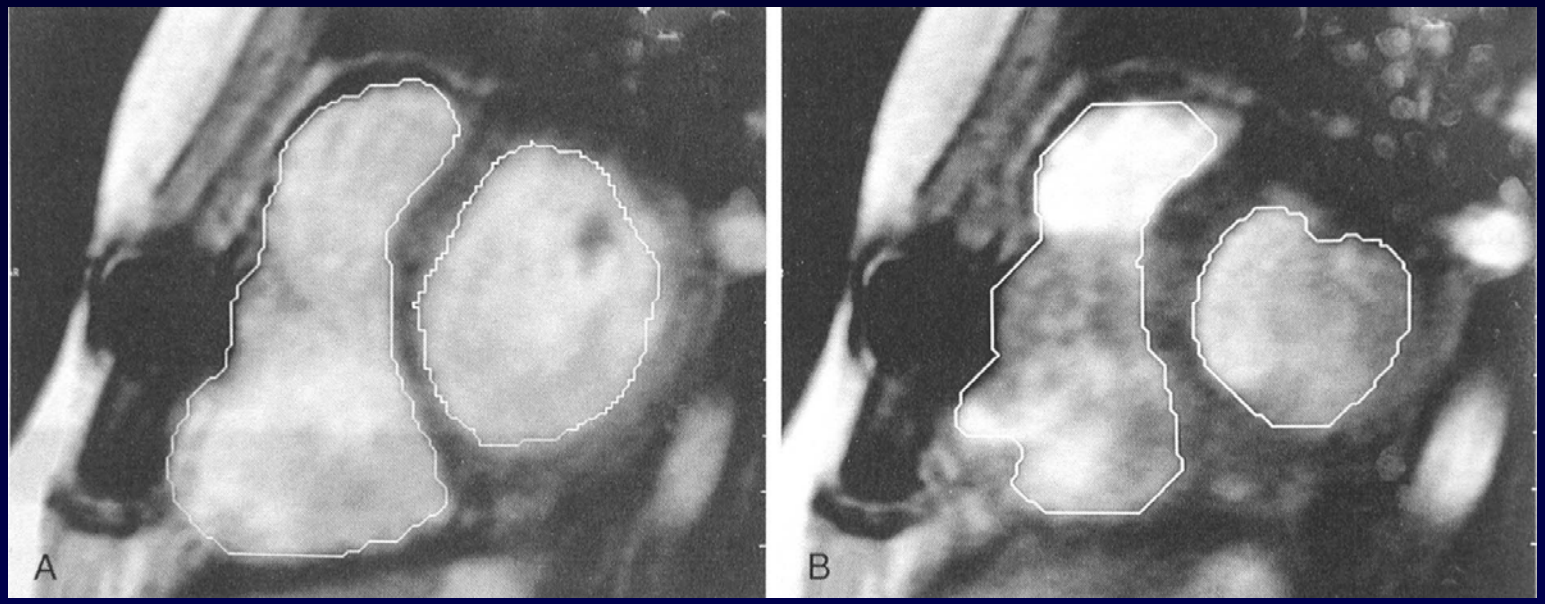


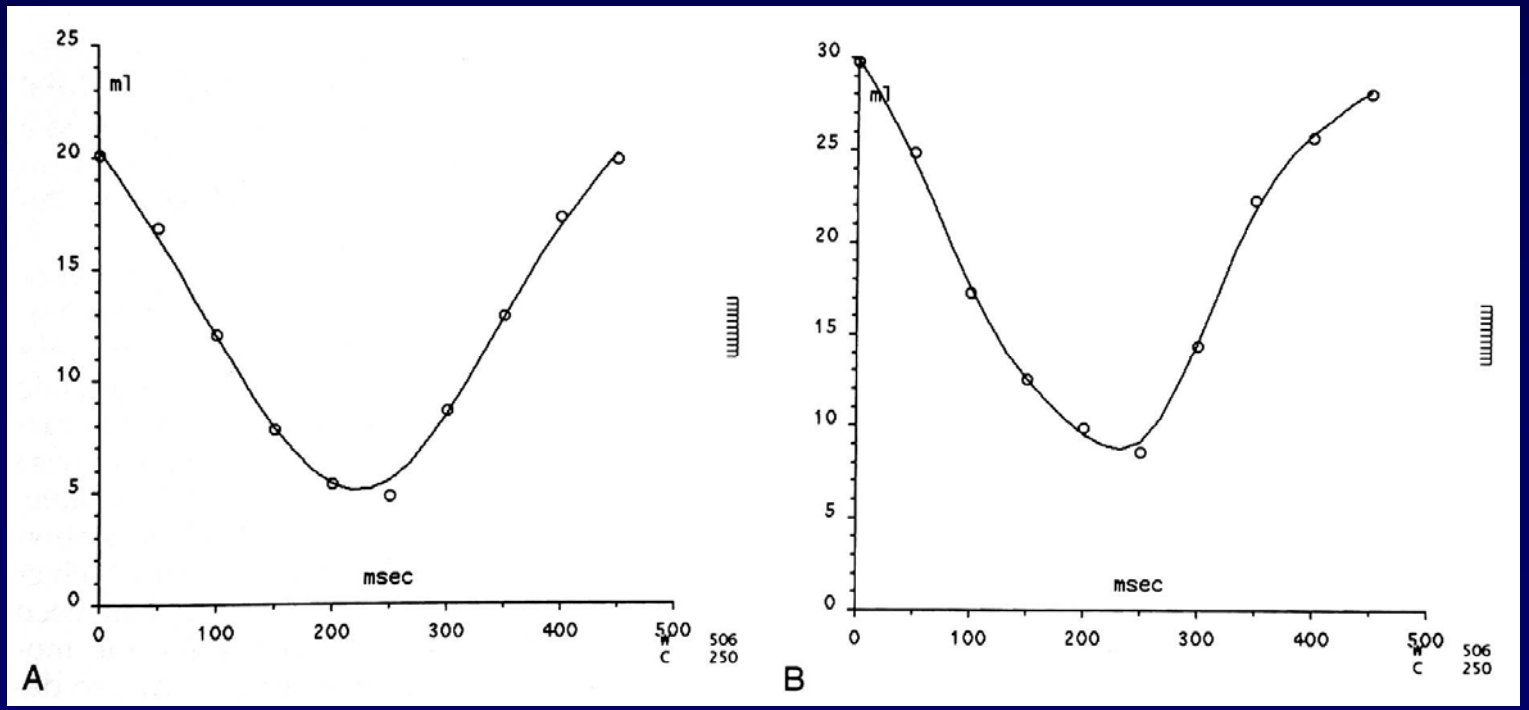
Fang ZY, *Endocrine Reviews*, 2004



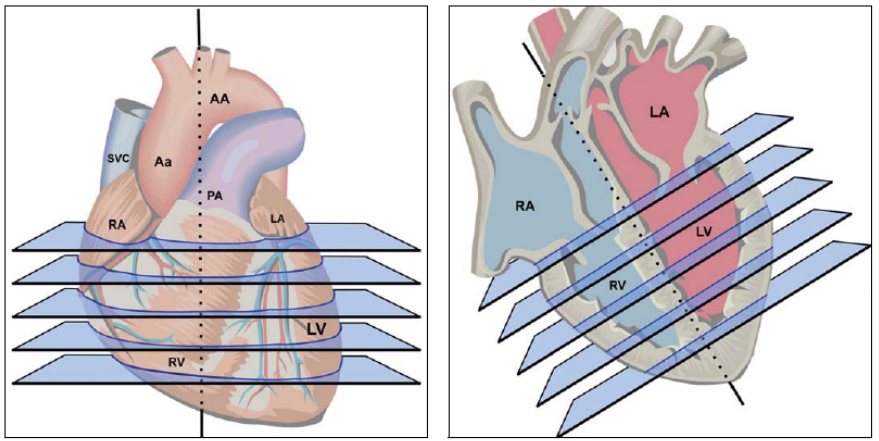
$$Vol = \sum_{i=1}^{n} \pi r_i^2 \cdot h$$

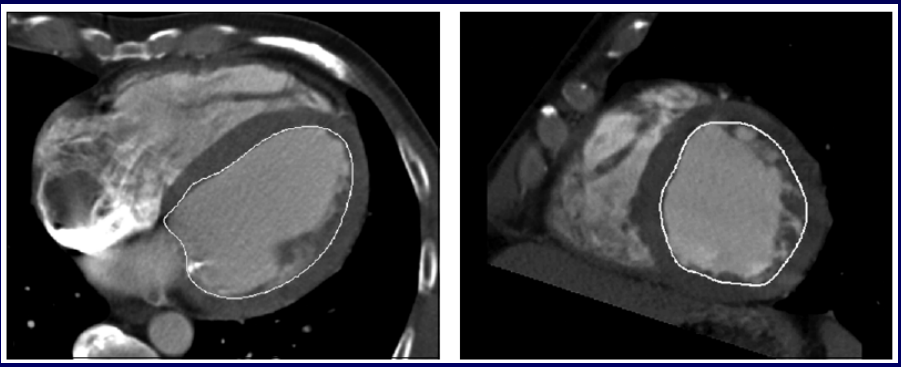
$$EF = \frac{Vol_{ed} - Vol_{es}}{Vol_{ed}}$$


A
B


25
20
15
10
5
0
ml
msec
0
100
200
300
400
500
W
C
506
250
A
30
25
20
15
10
5
0
ml
msec
0
100
200
300
400
500
W
C
506
250
B

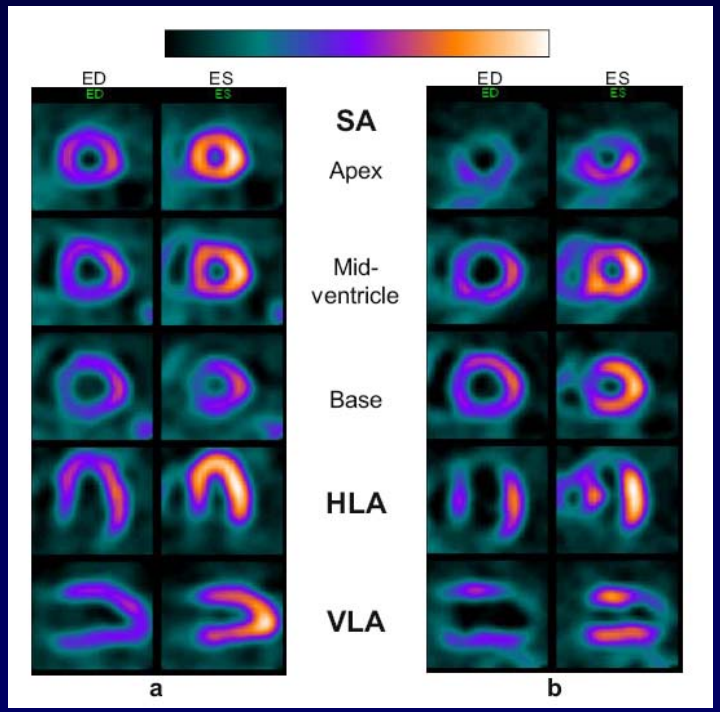
MDCT Determination of Volume and Function of the Left Ventricle: Are Short-Axis Image Reformations Necessary?

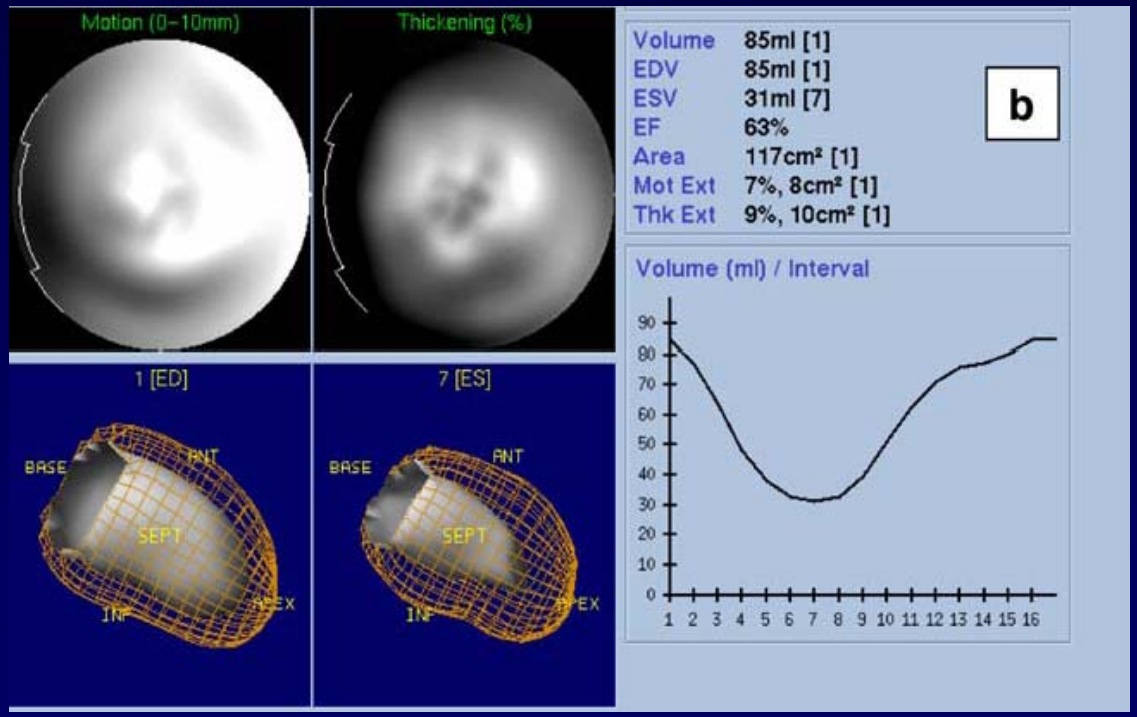




Juergens KU et al. *AJR*, 2006

Radionuclides Ventricular measurements 1 (Volumetric)





Radionuclides Ventricular measurements 2 (ERNV)

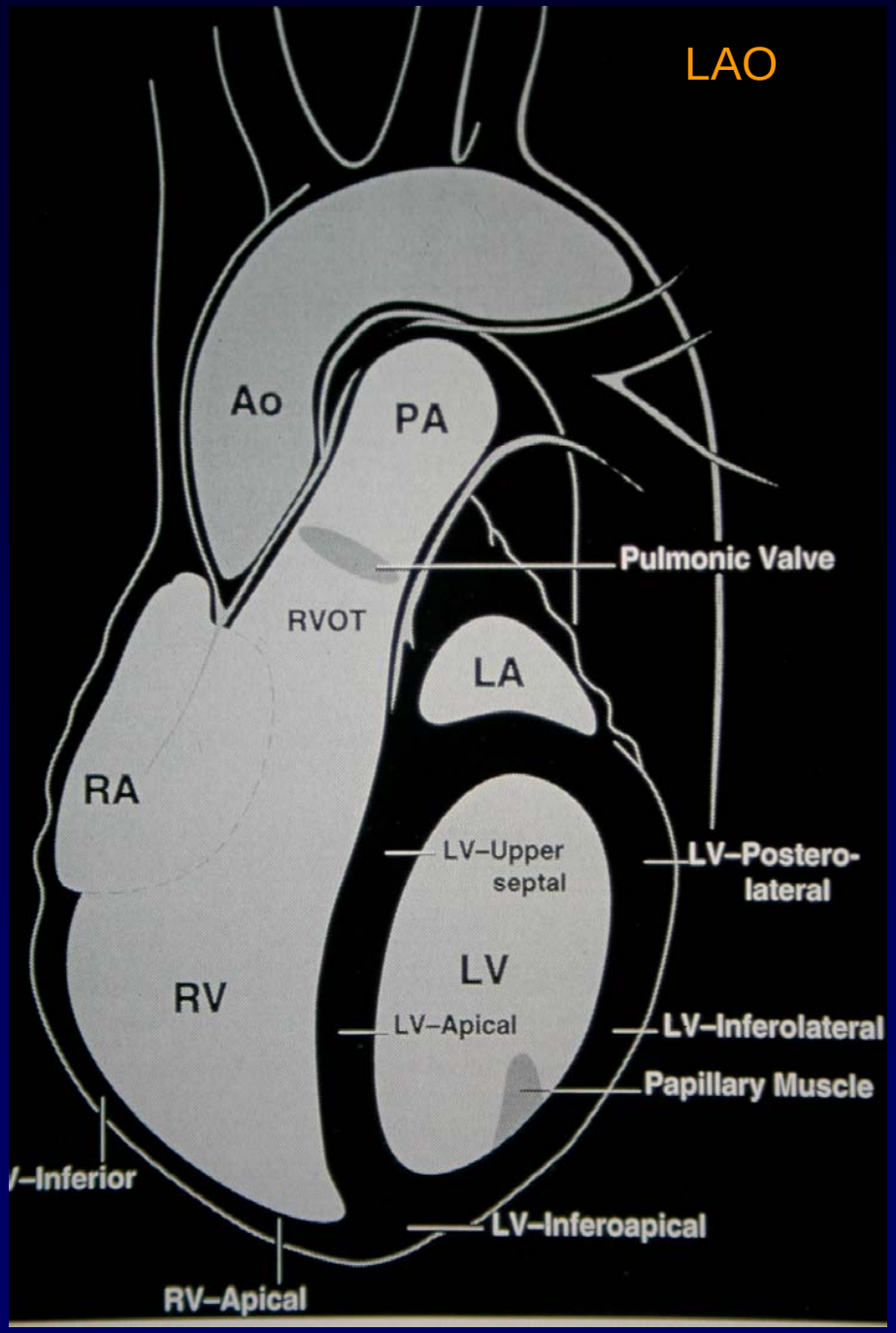
Tracer = ^{99m}Tc-labelled RBC

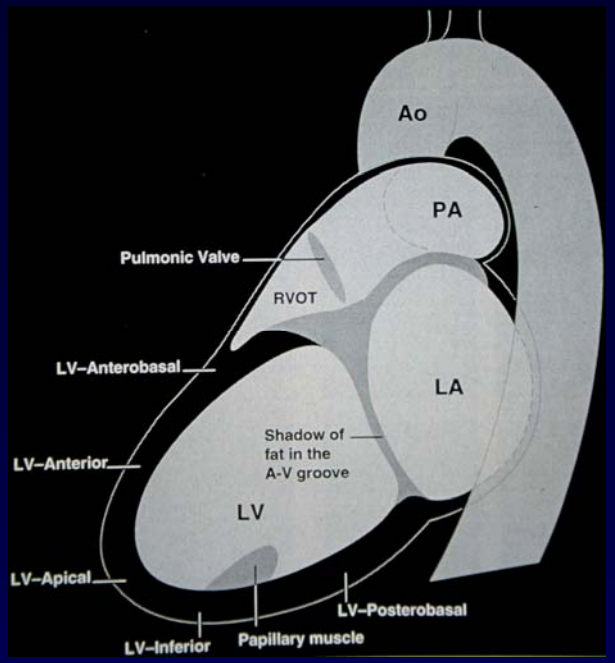
dA

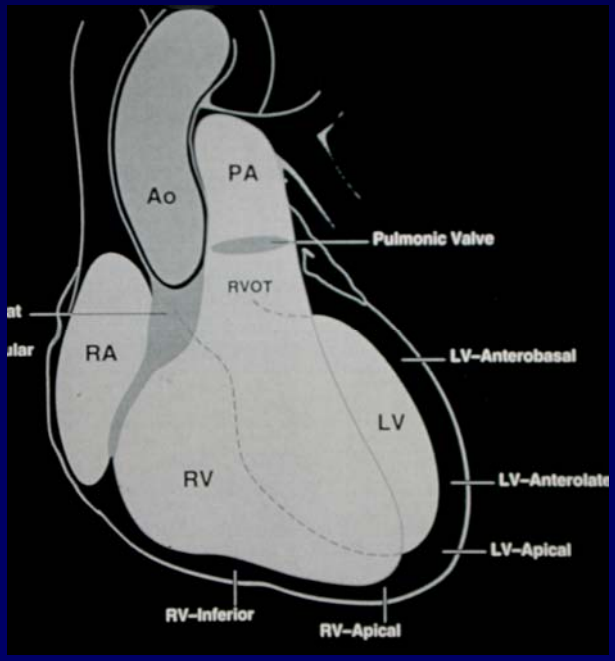
dV blood

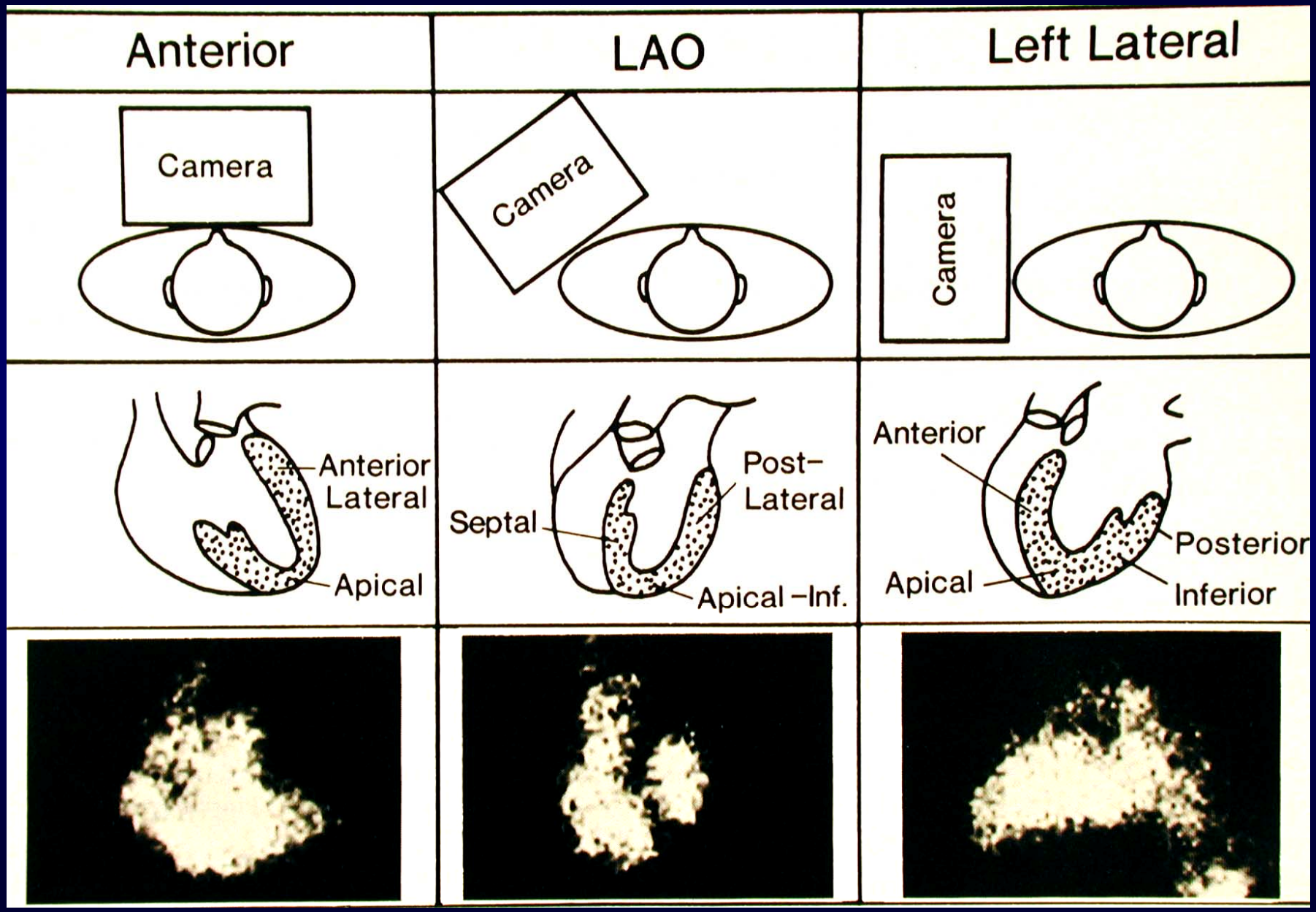
dV cardiac volumes

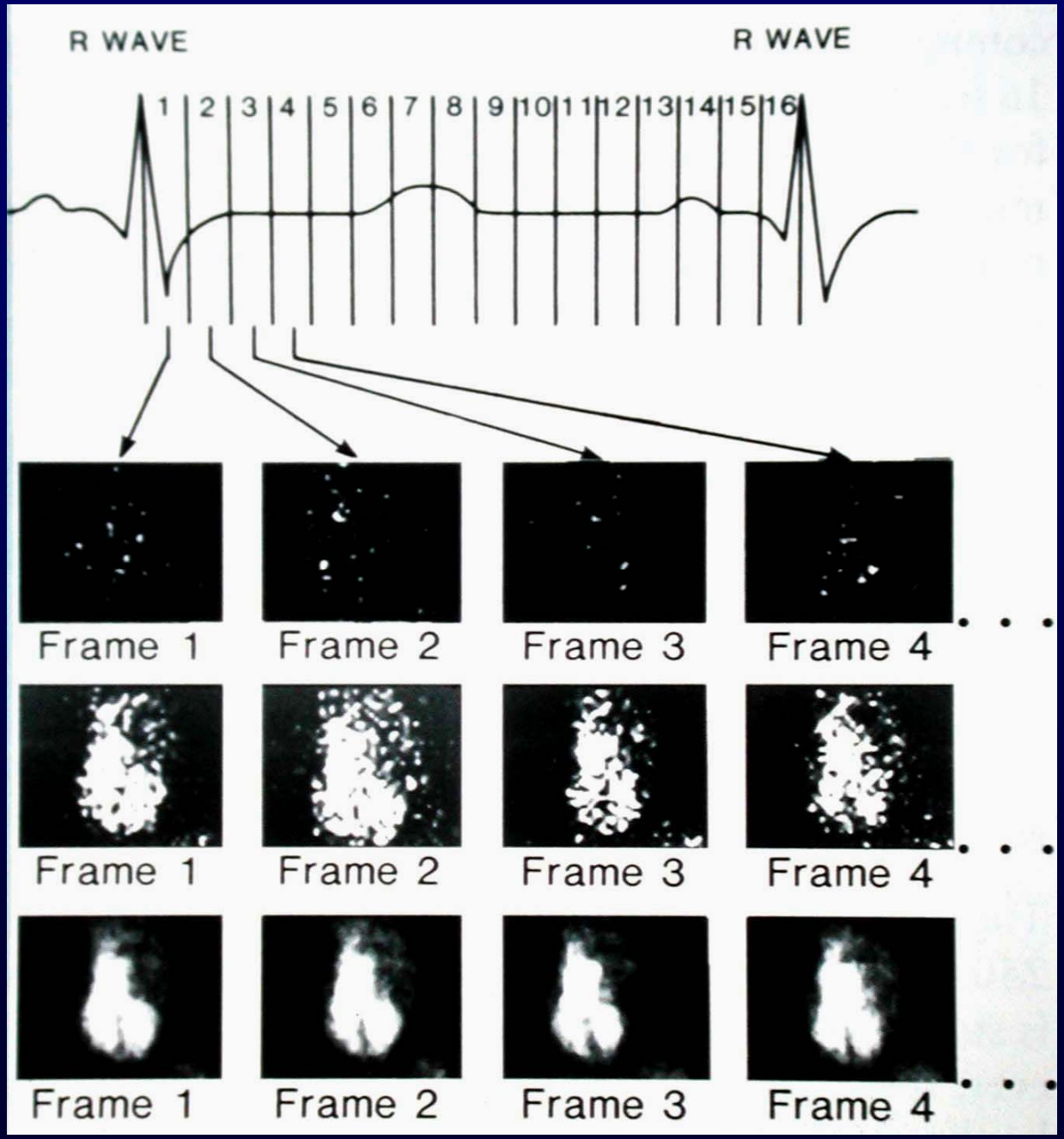
ECG Gated

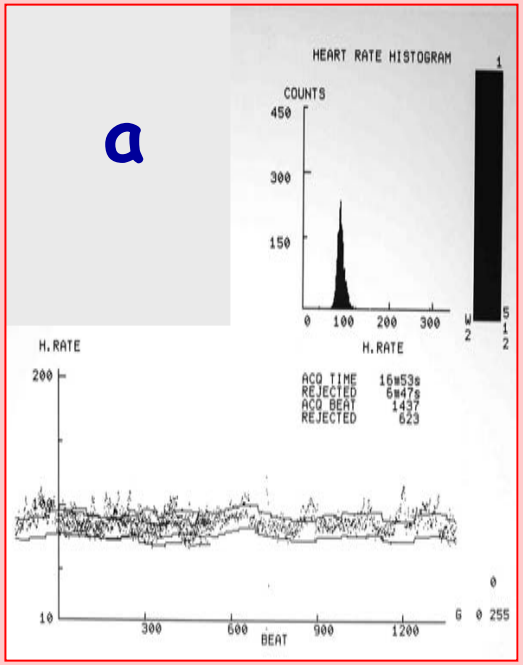

LAO
Ao
PA
Pulmonic Valve
RVOT
LA
RA
LV–Upper septal
LV–Postero-lateral
LV
RV
LV–Apical
LV–Inferolateral
Papillary Muscle
V–Inferior
LV–Inferoapical
RV–Apical

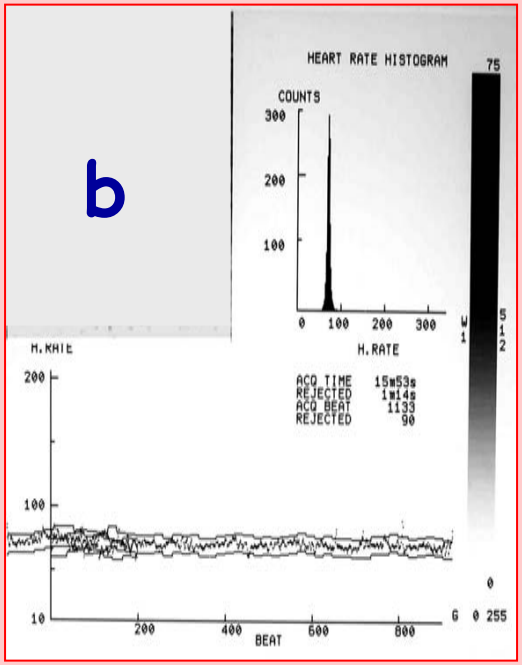

Ao
PA
Pulmonic Valve
RVOT
LV–Anterobasal
LA
Shadow of fat in the A-V groove
LV–Anterior
LV
LV–Apical
LV–Posterobasal
LV–Inferior
Papillary muscle

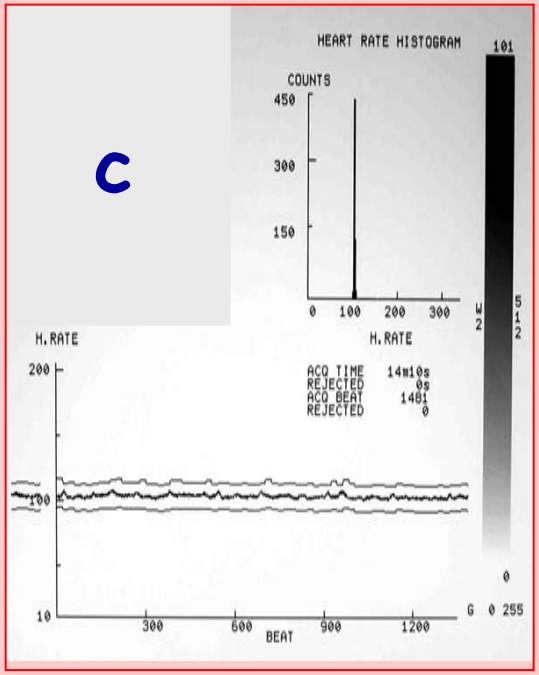

Ao
PA
Pulmonic Valve
RVOT
RA
LV–Anterobasal
LV
RV
LV–Apical
RV–Inferior
RV–Apical

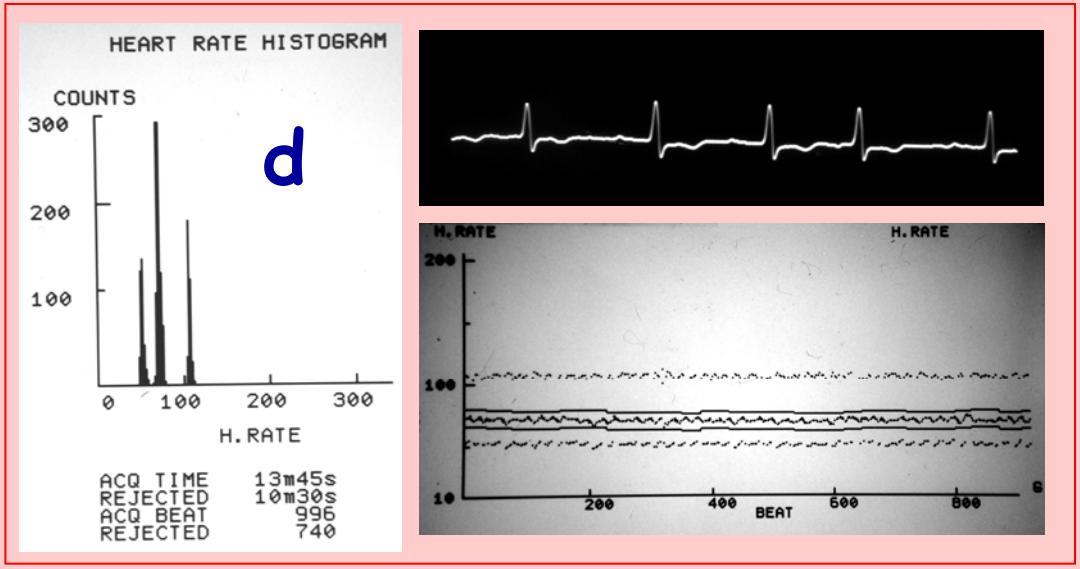

Anterior
LAO
Left Lateral
Camera
Camera
Camera
Anterior
Lateral
Apical
Septal
Post–
Lateral
Apical –Inf.
Anterior
Posterior
Apical
Inferior


R WAVE
R WAVE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Frame 1
Frame 2
Frame 3
Frame 4
Frame 1
Frame 2
Frame 3
Frame 4
Frame 1
Frame 2
Frame 3
Frame 4









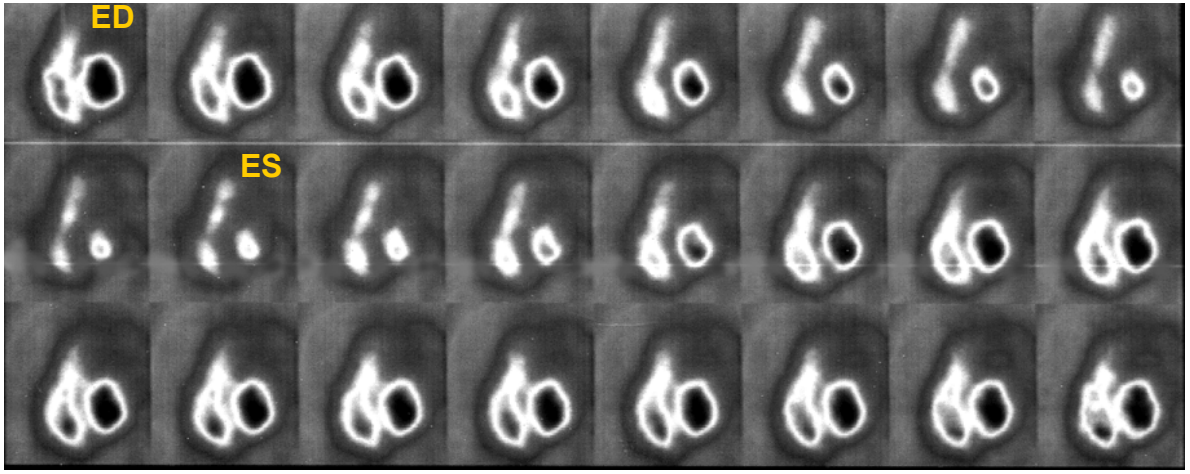
a, child

b, adult

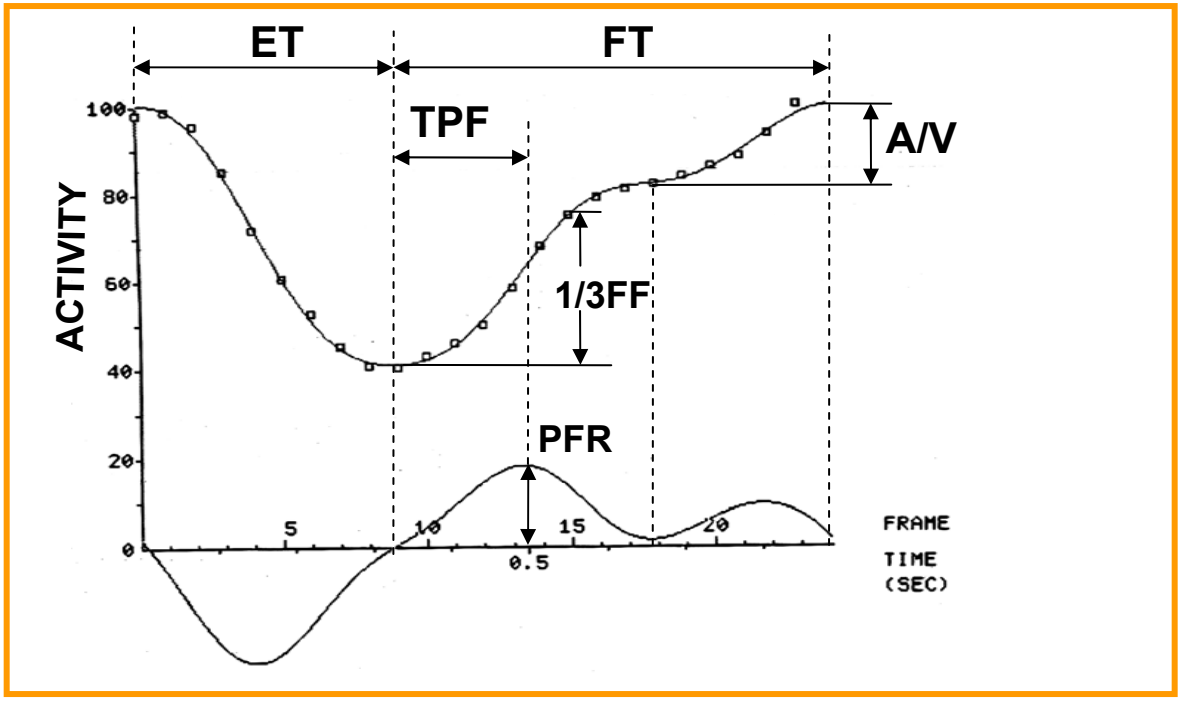
c, DM adult

d, AF adult

24 frames/cycle radionuclide ventriculography

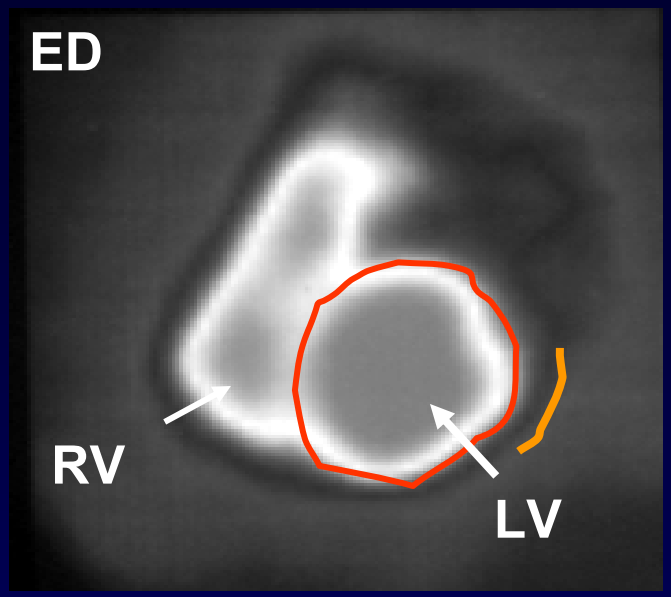


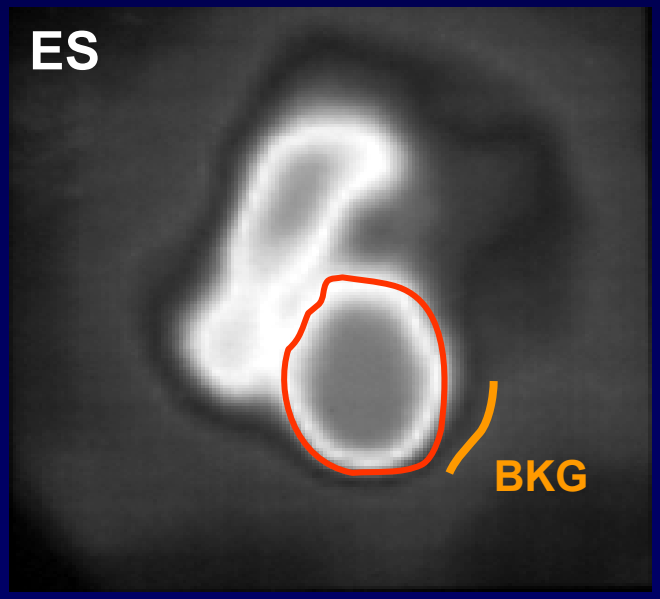
ED, end diastolic;
ES, end systolic



Left ventricle time-activity curve (upper).
Open boxes represent data, approximated by the curve.
Lower curve is the 1st derivative of the upper one, thus representing rates

ET, emptying time;
FT, filling time;
PFR, peak filling rate;
TPF, time to peak filling rate;
1/3FF, first third filling fraction;
A/V, atrial contribution to ventricular filling

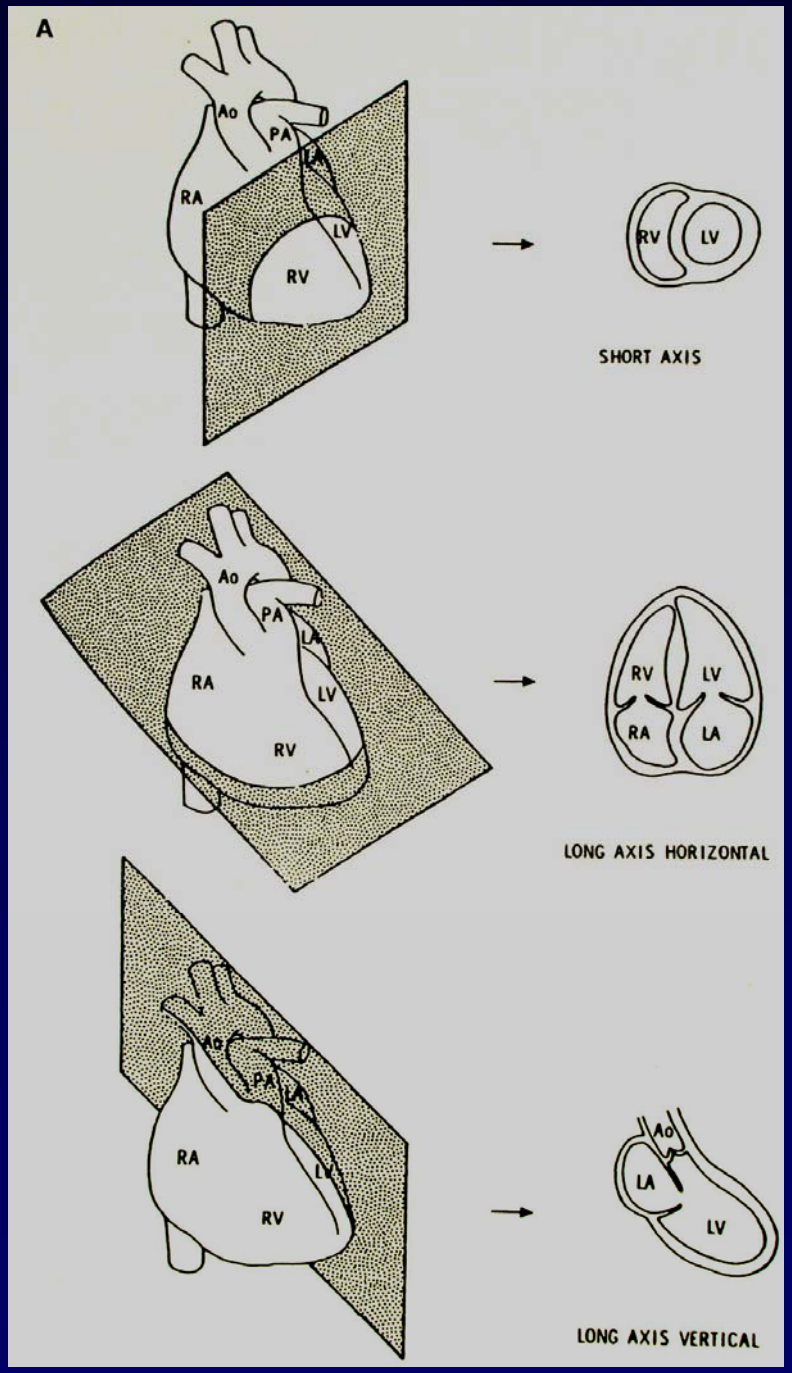


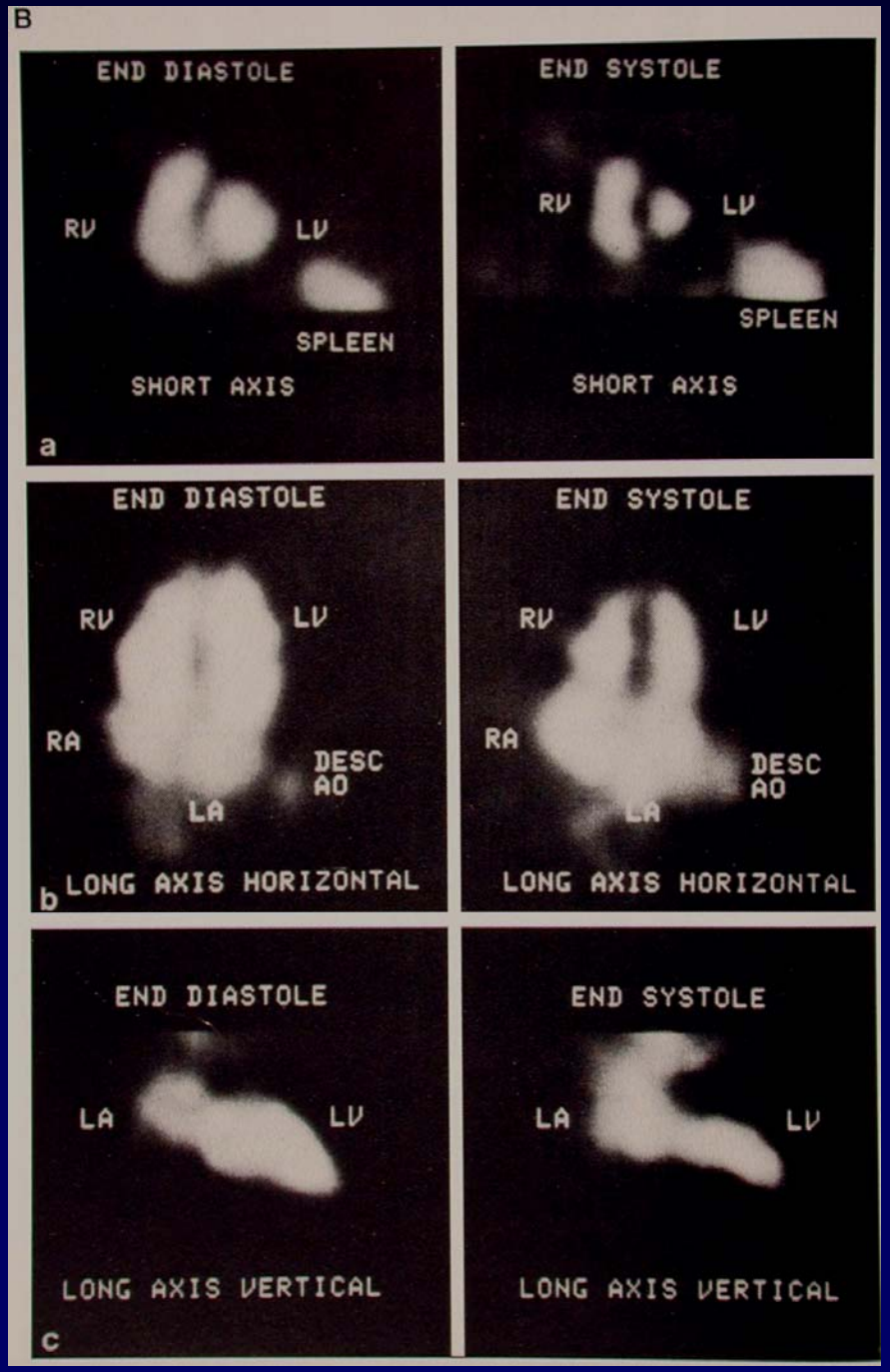


RV Right Ventricle
LV Left Ventricle
BKG Background
ED End Diastolic
ES End Systolic
Cts activity in counts

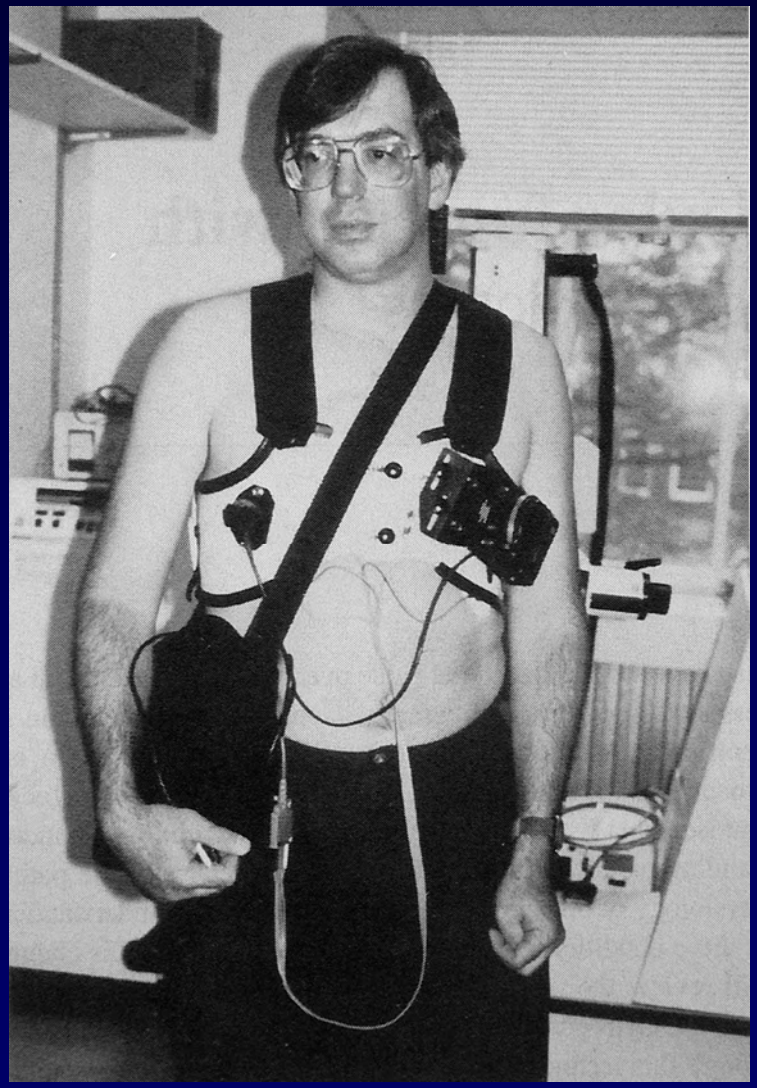
Ejection Fraction (EF)

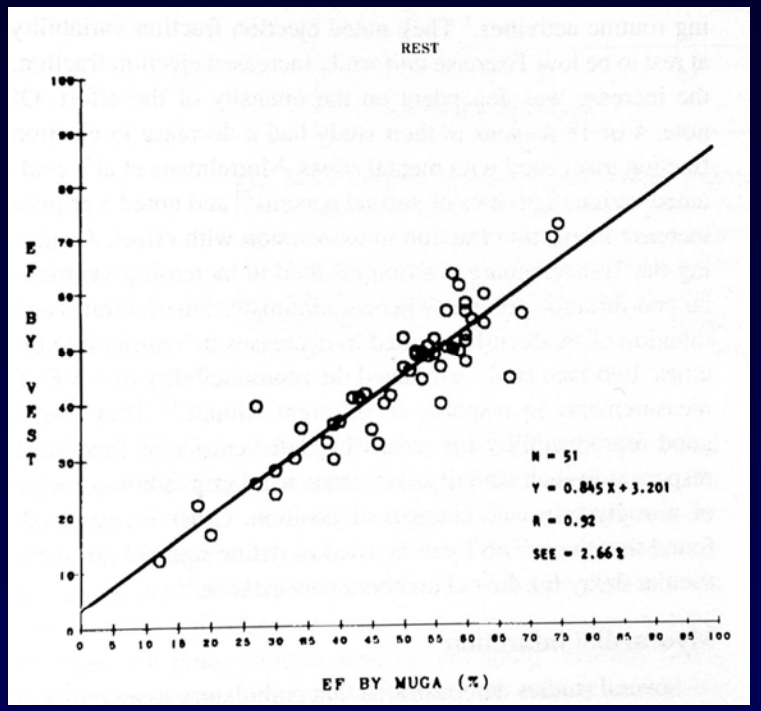
[(EDcts - EScts) / EDcts] x 100

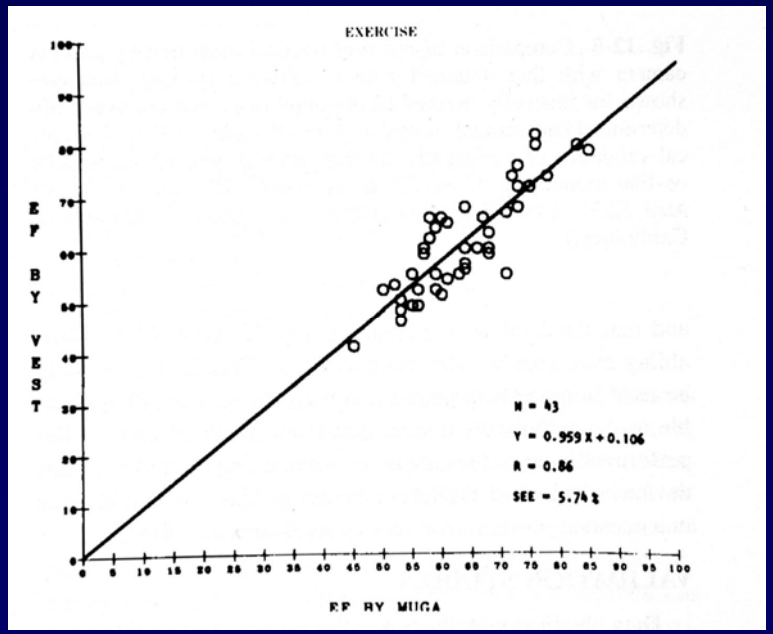

A
Ao
PA
LA
RA
LV
RV
RV
LV
SHORT AXIS
Ao
PA
LA
RA
LV
RV
RV
LV
RA
LA
LONG AXIS HORIZONTAL
Ao
PA
LA
RA
LV
RV
Ao
LA
LV
LONG AXIS VERTICAL


B
END DIASTOLE
RV
LV
SPLEEN
SHORT AXIS
a
END SYSTOLE
RV
LV
SPLEEN
SHORT AXIS
END DIASTOLE
RV
LV
RA
DESC AO
LA
b
LONG AXIS HORIZONTAL
END SYSTOLE
RV
LV
RA
DESC AO
LA
LONG AXIS HORIZONTAL
END DIASTOLE
LA
LV
LONG AXIS VERTICAL
c
END SYSTOLE
LA
LV
LONG AXIS VERTICAL

c-VEST




REST
EF BY VEST
EF BY MUGA (%)
N = 51
Y = 0.845 X + 3.201
R = 0.92
SEE = 2.66 %

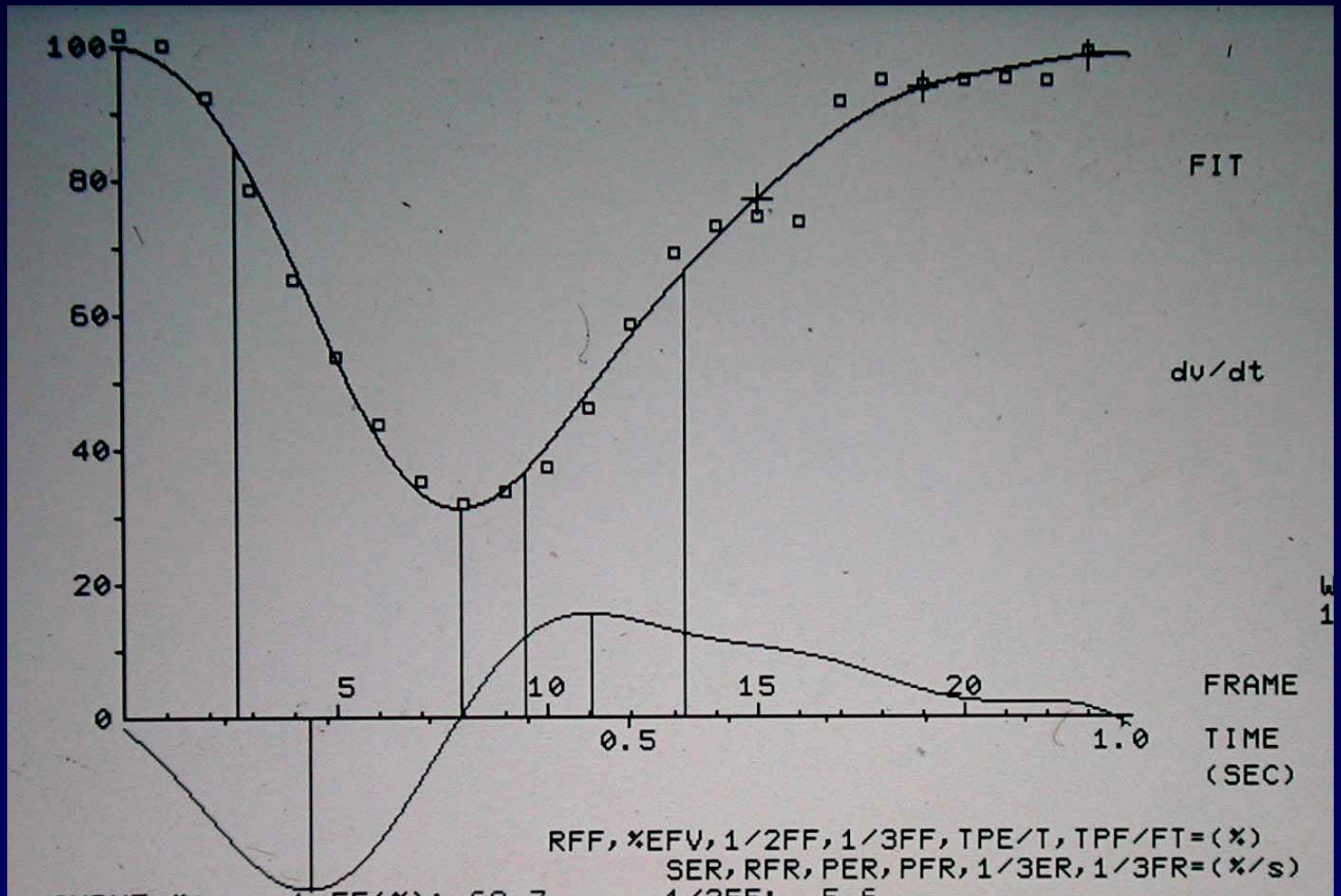

EXERCISE
EF BY VEST
EF BY MUGA
N = 43
Y = 0.959 X + 0.106
R = 0.86
SEE = 5.74 %

ERNV measurements

- LVEF, RVEF, stress-rest
- Regional LV wall motion, stress-rest
- LV diastolic function
- EDV, ESV, SV, CO
- Shunt quantification
- Intra- Inter- ventricular contraction synchronization

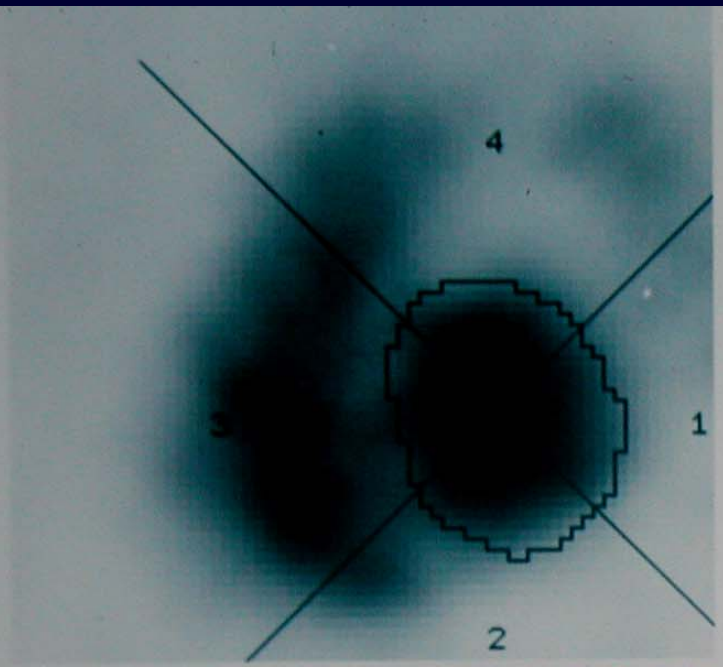
P9290003.mov

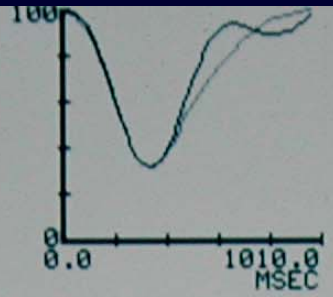
P9290003.mov

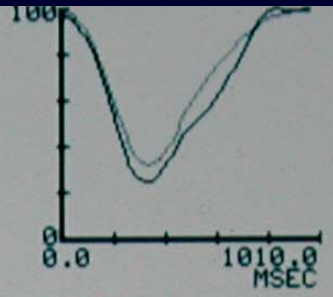


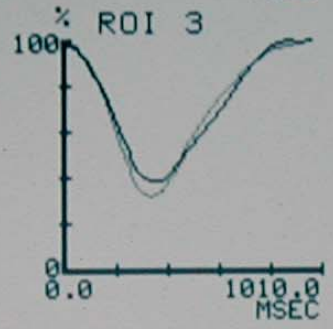
RFF,%EFV,1/2FF,1/3FF,TPE/T,TPF/FT=(%)
SER,RFR,PER,PFR,1/3ER,1/3FR=(%/s)

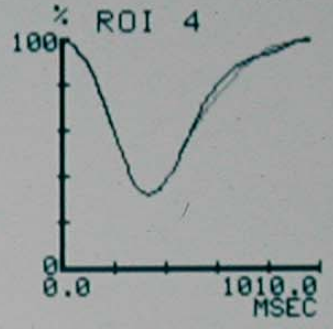
CURVE #:	1	EF(%):	68.7	1/2FF:	5.6		
HARMONICS:	3	TPE(ms):	182:177	TPF(ms):	130:123	RFT(ms):	297:273
FRM T(ms):	42	PERedc:	342:357	PFRedc:	204:225	RFFsc:	67.7:68.3
H.R.(bpm):	60	PERsc:	498:532	PFRsc:	296:340	RFRsc:	228:250
%EFVedc:	11.8	TPE/T:	18	TPF/FT:	19	ET(ms):	333:322
%EFVsc:	17.2	1/3EF:	14.5	1/3FF:	35.7:28.0	FT(ms):	675:597
		1/3ERed:	131	1/3FRed:	159		
		1/3ERsc:	190	1/3FRsc:	231:247	A/V(%):	7.5
SER:	206:210	EDC(kcps):	368	ESC(kcps):	115	SC(kcps):	252







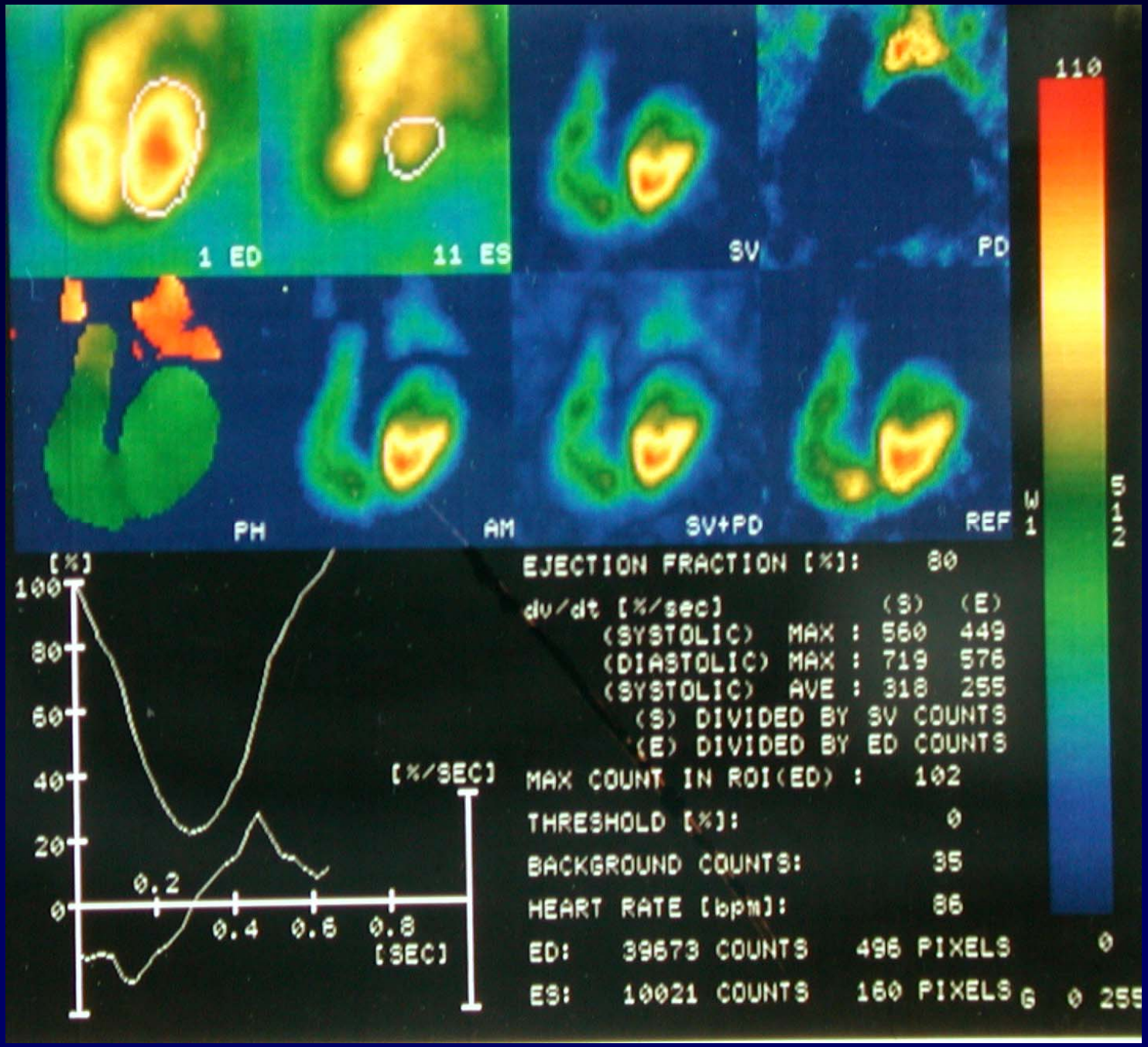


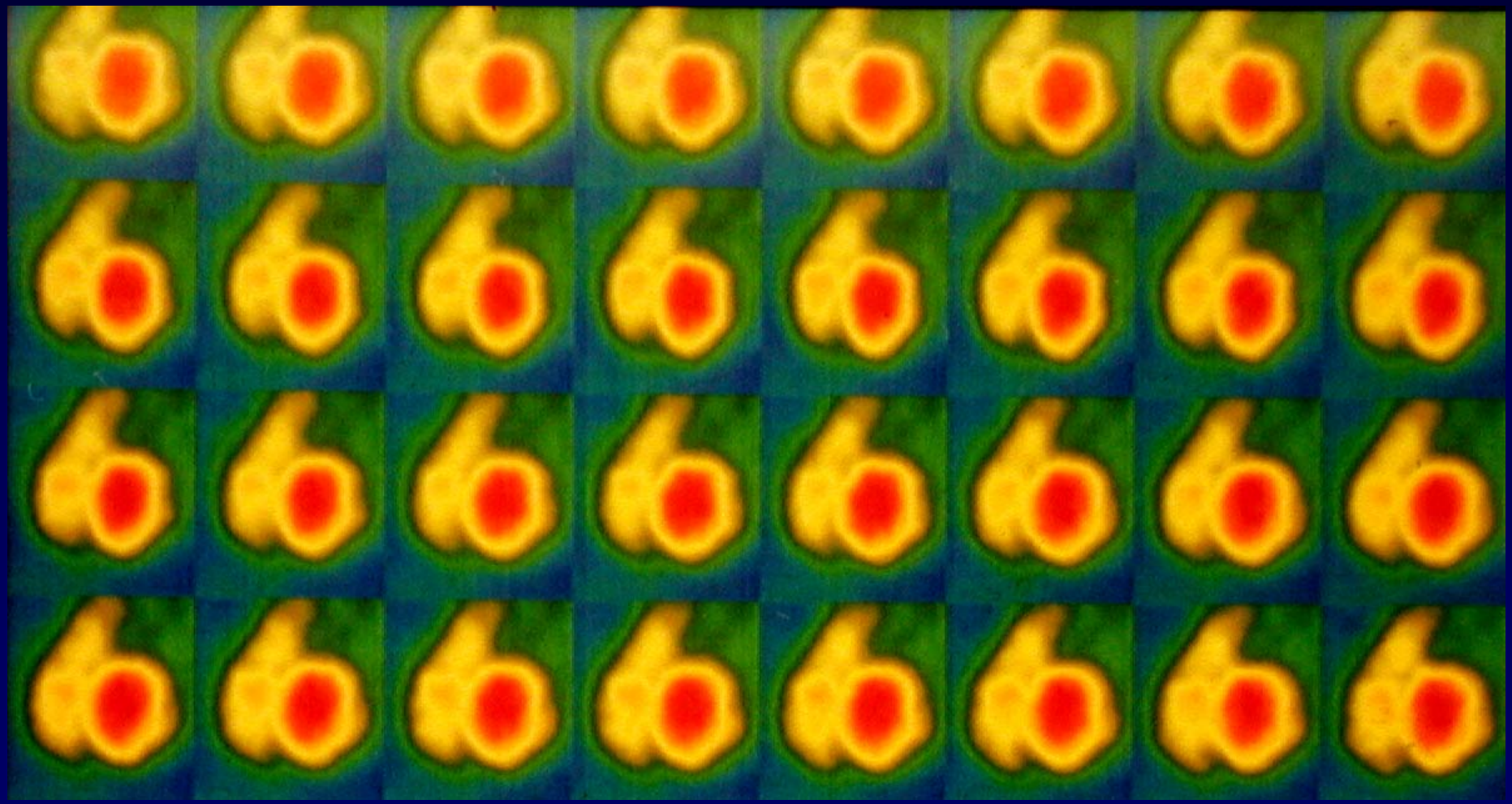


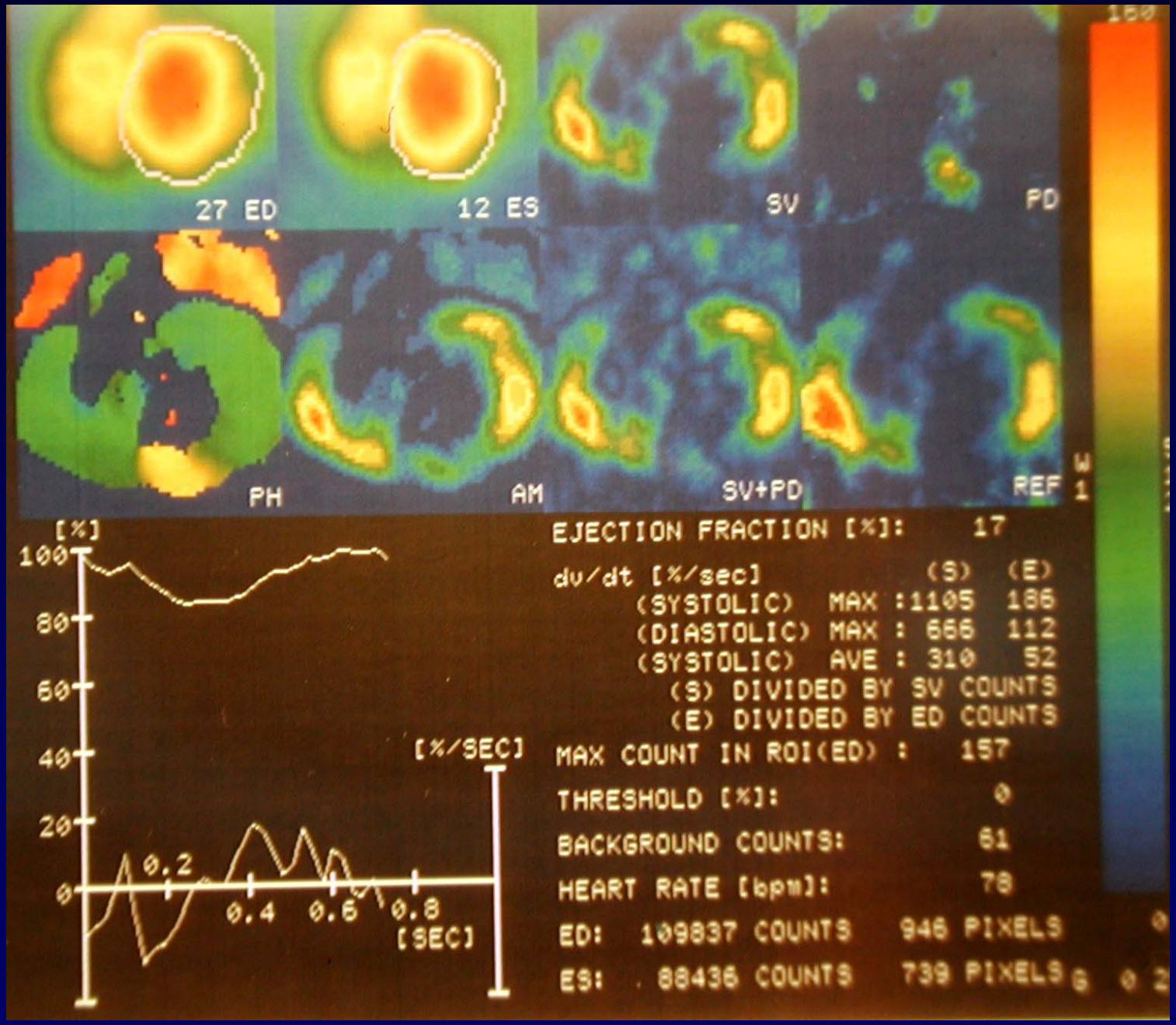
ROI	EF	TPE	PER	1/3EF	1/3ER	TPF	PFR	1/3FF	1/3FR	TPF/T-TES	1/2FF
1	68.3	186	511	12.2	161	141	450	51.2	333	21	8.4
2	75.1	183	521	14.8	182	367	314	29.9	175	54	24.8
3	61.2	187	472	14.1	200	327	275	24.9	184	49	16.9
4	68.0	178	474	16.2	213	148	347	39.9	262	22	7.1
ALL	68.6	183	497	14.5	190	130	299	35.9	232	19	5.6

FRAME TIME: 42
START FRAME: 1
OF FRAMES: 24

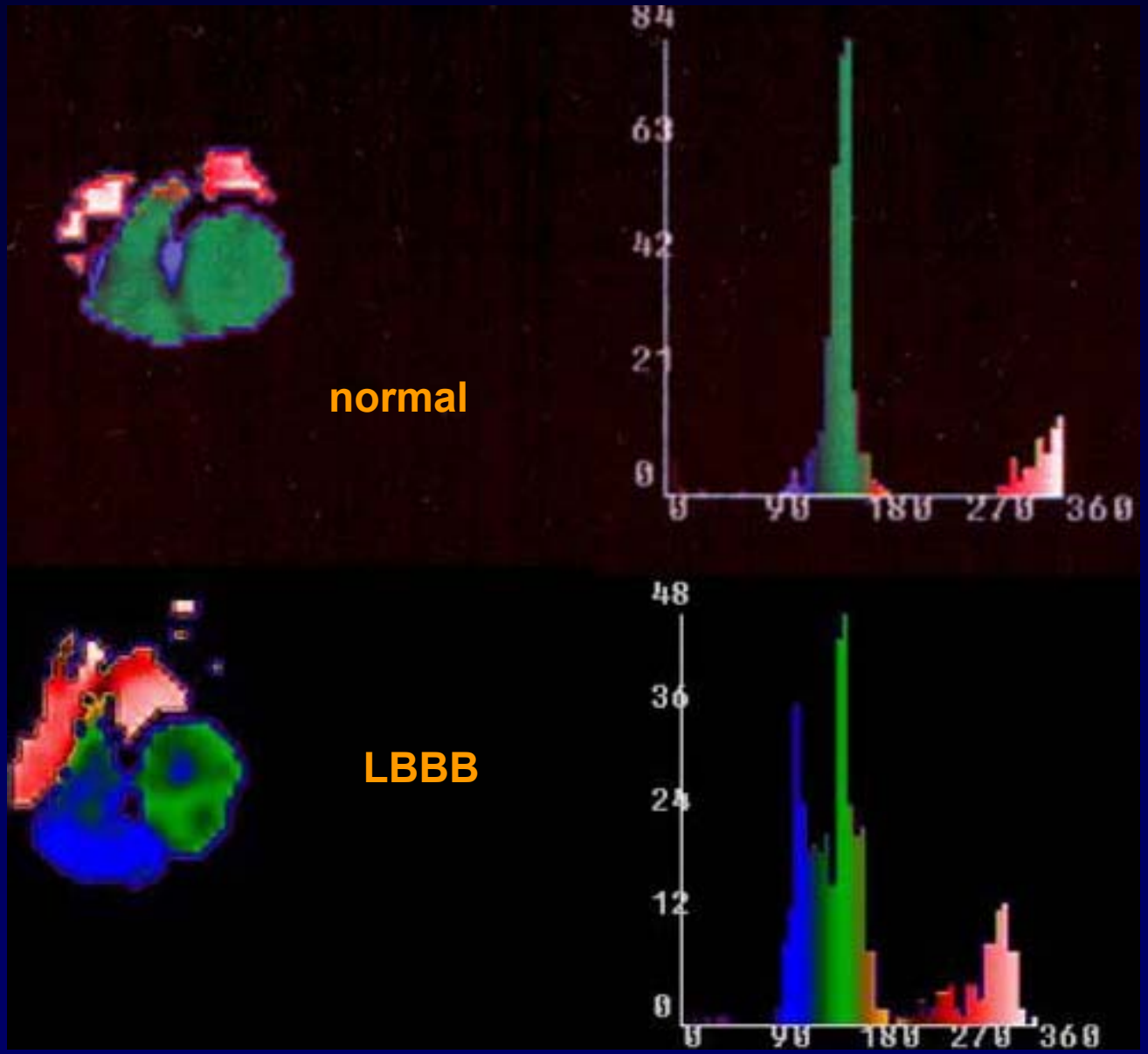
OF HARMONICS: 3
VARIABLE ROI
GEOMETRIC CENTER

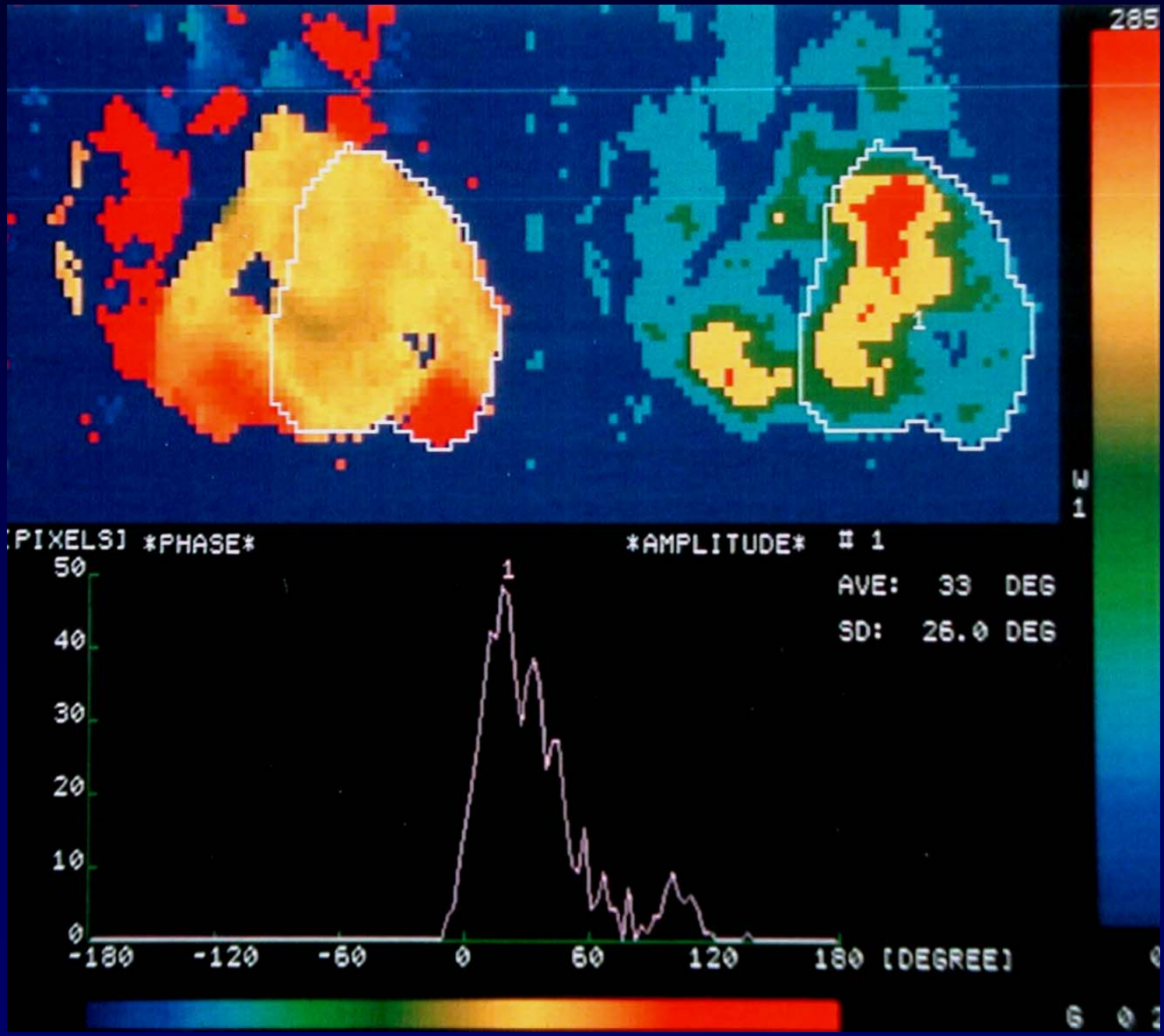

1 ED
11 ES
SV
PD
PH
AM
SV+PD
REF
110
W
1
512
0
[%]
100
80
60
40
20
0
[%/SEC]
0.2
0.4
0.6
0.8
[SEC]
EJECTION FRACTION [%]: 80
dv/dt [%/sec] (S) (E)
(SYSTOLIC) MAX : 560 449
(DIASTOLIC) MAX : 719 576
(SYSTOLIC) AVE : 318 255
(S) DIVIDED BY SV COUNTS
(E) DIVIDED BY ED COUNTS
MAX COUNT IN ROI(ED) : 102
THRESHOLD [%]: 0
BACKGROUND COUNTS: 35
HEART RATE [bpm]: 86
ED: 39673 COUNTS 496 PIXELS
ES: 10021 COUNTS 160 PIXELS
G
0 255

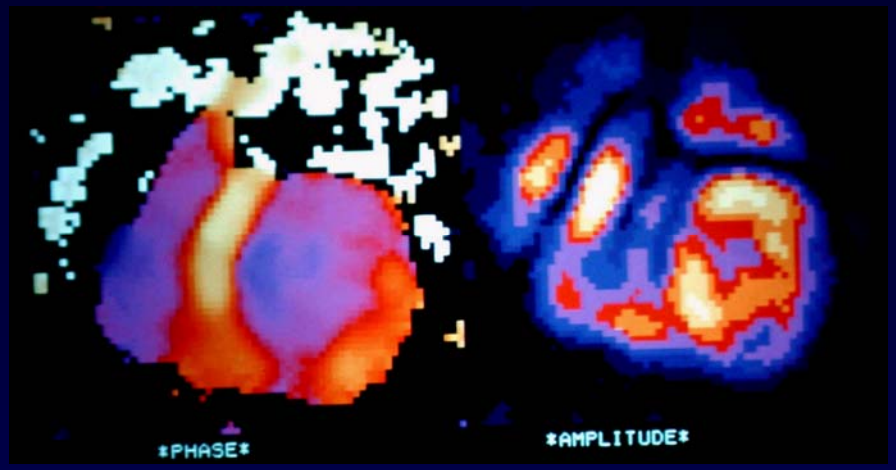


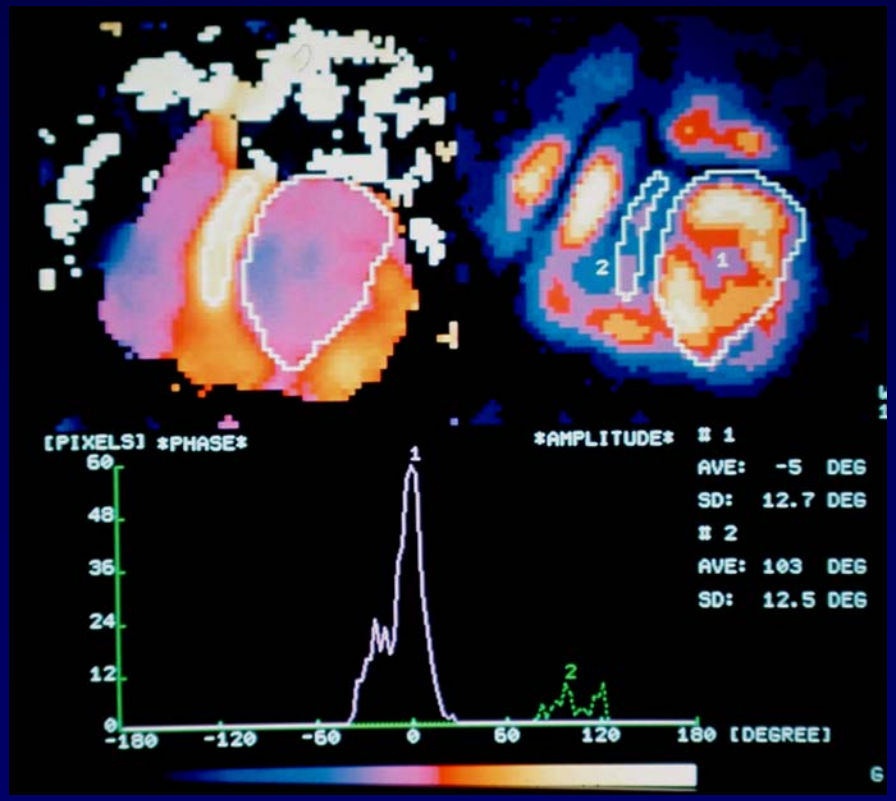

27 ED
12 ES
SV
PD
PH
AM
SV+PD
REF
[%]
100
80
60
40
20
0
[%/SEC]
0.2
0.4
0.6
0.8
[SEC]
EJECTION FRACTION [%]: 17
dv/dt [%/sec] (S) (E)
(SYSTOLIC) MAX :1105 186
(DIASTOLIC) MAX : 666 112
(SYSTOLIC) AVE : 310 52
(S) DIVIDED BY SV COUNTS
(E) DIVIDED BY ED COUNTS
MAX COUNT IN ROI(ED) : 157
THRESHOLD [%]: 0
BACKGROUND COUNTS: 61
HEART RATE [bpm]: 78
ED: 109837 COUNTS 946 PIXELS
ES: 88436 COUNTS 739 PIXELS

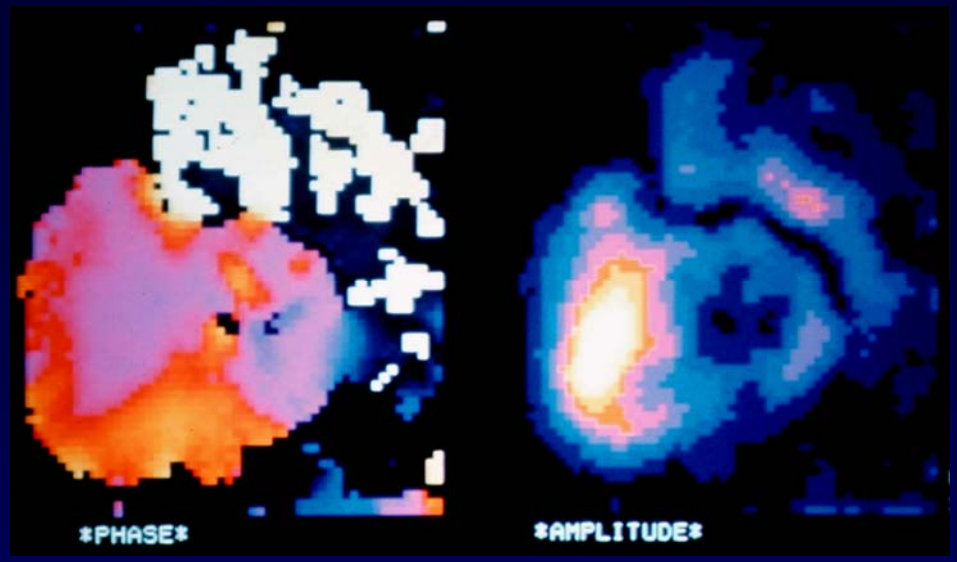
ERNV phase analysis

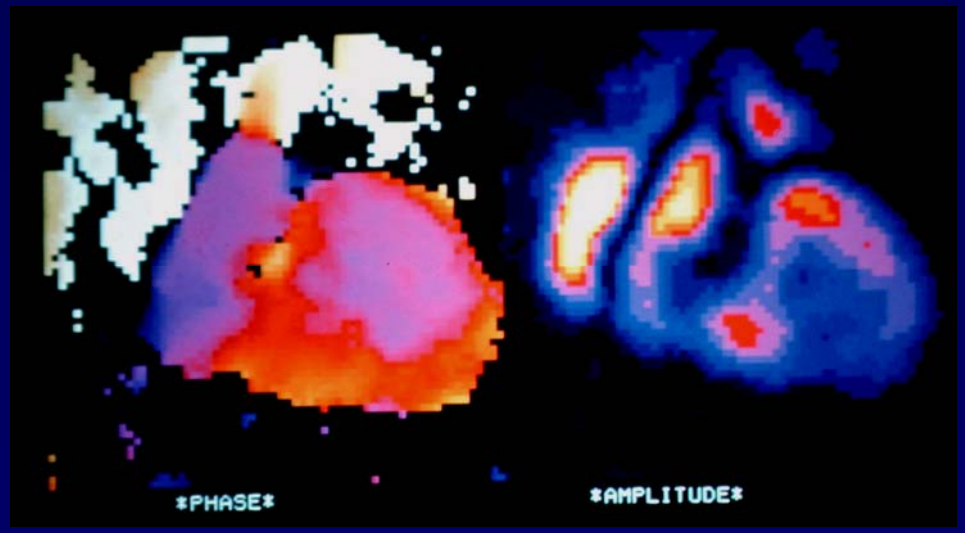


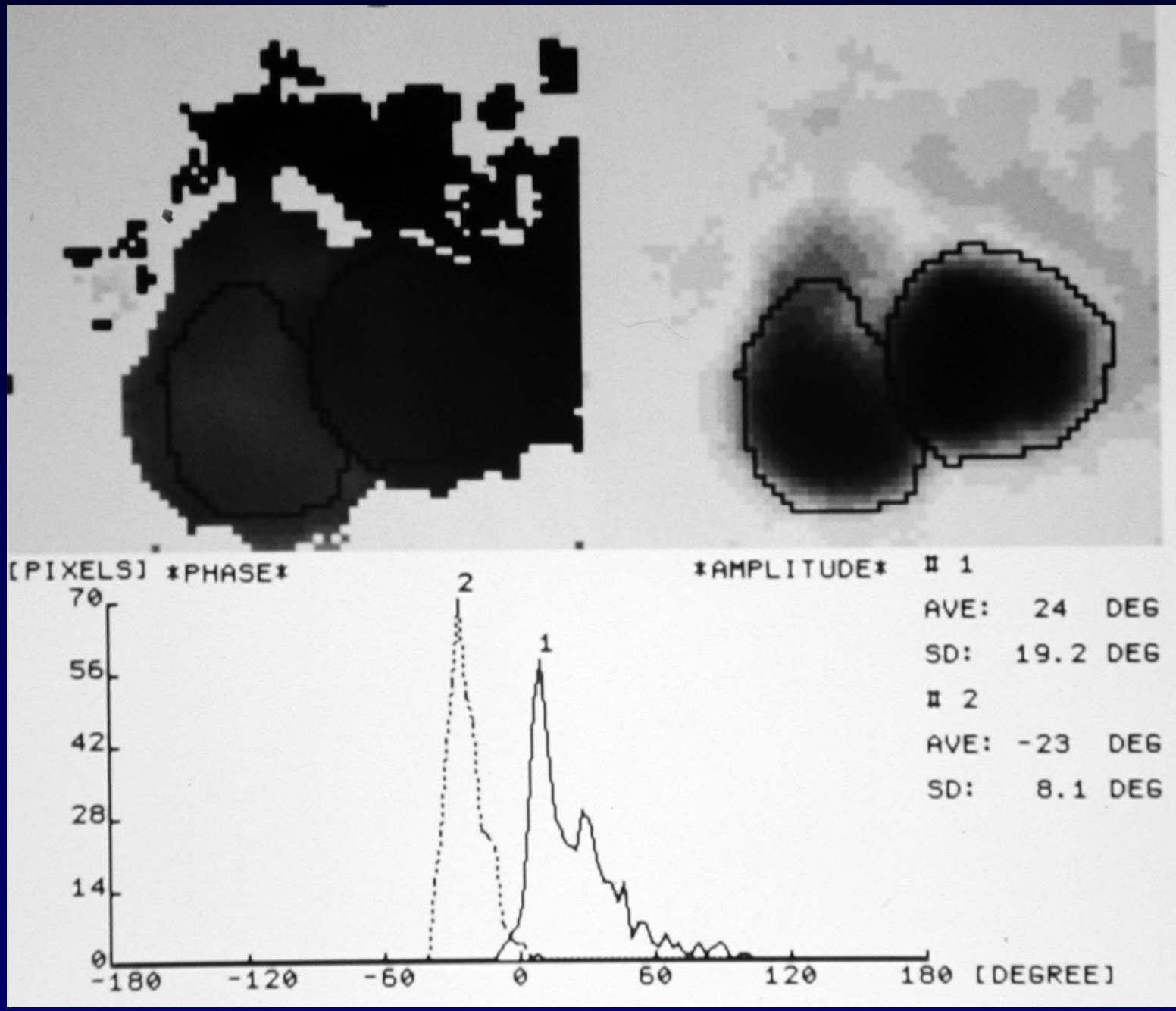

285
W
1
[PIXELS] *PHASE*
AMPLITUDE
1
AVE: 33 DEG
SD: 26.0 DEG
50
40
30
20
10
0
1
-180
-120
-60
0
60
120
180 [DEGREE]


PHASE
AMPLITUDE


2
1
[PIXELS] *PHASE*
AMPLITUDE
1
AVE: -5 DEG
SD: 12.7 DEG
2
AVE: 103 DEG
SD: 12.5 DEG
60
48
36
24
12
0
-180
-120
-60
0
60
120
180 [DEGREE]


PHASE
AMPLITUDE


PHASE
AMPLITUDE


[PIXELS] *PHASE*
AMPLITUDE
1
AVE: 24 DEG
SD: 19.2 DEG
2
AVE: -23 DEG
SD: 8.1 DEG
70
56
42
28
14
0
-180
-120
-60
0
60
120
180 [DEGREE]
1
2

The Impact of Diabetes on Left Ventricular Filling Pattern in Normotensive and Hypertensive Adults: The Strong Heart Study

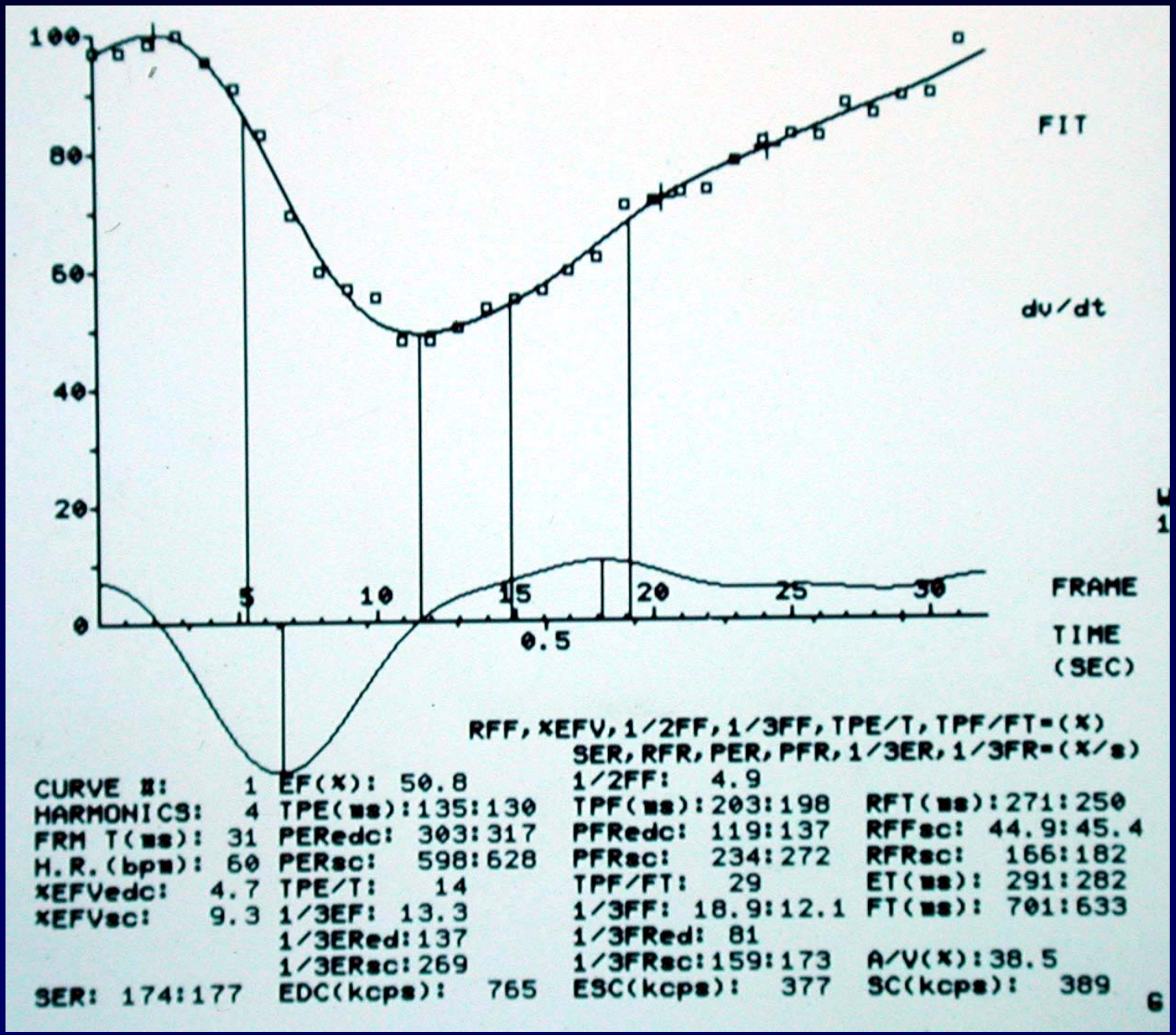
Table 2. Diastolic Filling Parameters in Groups Defined by the Presence or Absence of Hypertension or Diabetes

Variable	No HTN or DM n = 719	HTN n = 390	DM n = 602	HTN + DM 656
E velocity (cm/s)	61 ± 18*	59 ± 16*	57 ± 16†‡	56 ± 17†‡
A velocity (cm/s)	68 ± 15*‡	73 ± 17†	71 ± 15†	76 ± 16*†
E/A ratio	0.92 ± 0.27*‡	0.83 ± 0.23†	0.83 ± 0.24†	0.76 ± 0.22*†‡
Deceleration time (ms)	195 ± 59‡	204 ± 66†	202 ± 64	215 ± 71*†‡
Atrial filling fraction	0.38 ± 0.08*	0.40 ± 0.09†	0.40 ± 0.08†	0.42 ± 0.10†‡
First-half filling fraction	0.53 ± 0.07*‡	0.51 ± 0.07†	0.50 ± 0.08†	0.49 ± 0.08*†‡

*$p < 0.05$ compared to DM by ANOVA followed by the Scheffé post-hoc test; †$p < 0.05$ compared to no HTN or DM by ANOVA followed by the Scheffé post-hoc test; ‡$p < 0.05$ compared to HTN by ANOVA followed by the Scheffé post-hoc test.

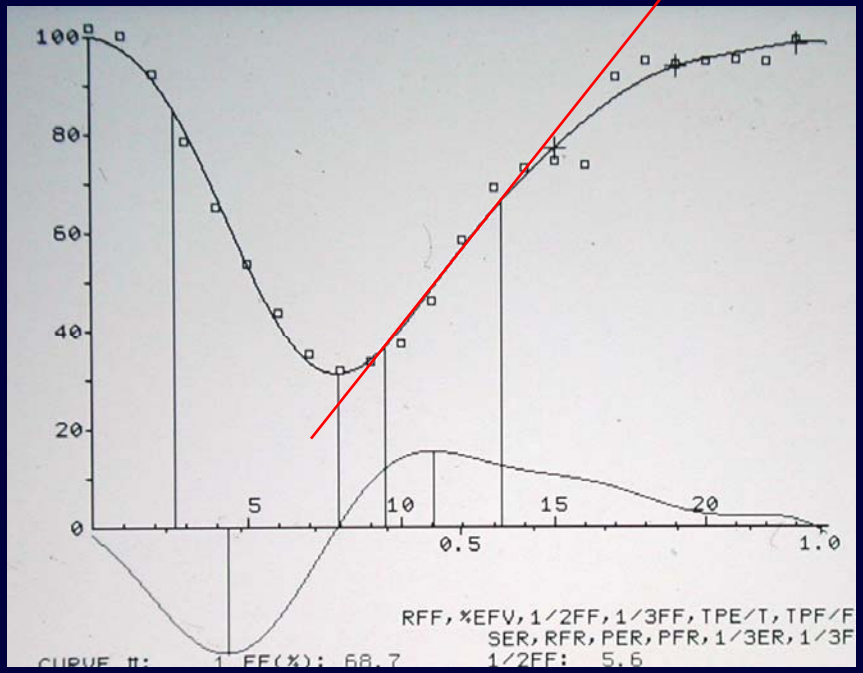
DM = diabetes mellitus; HTN = hypertension.

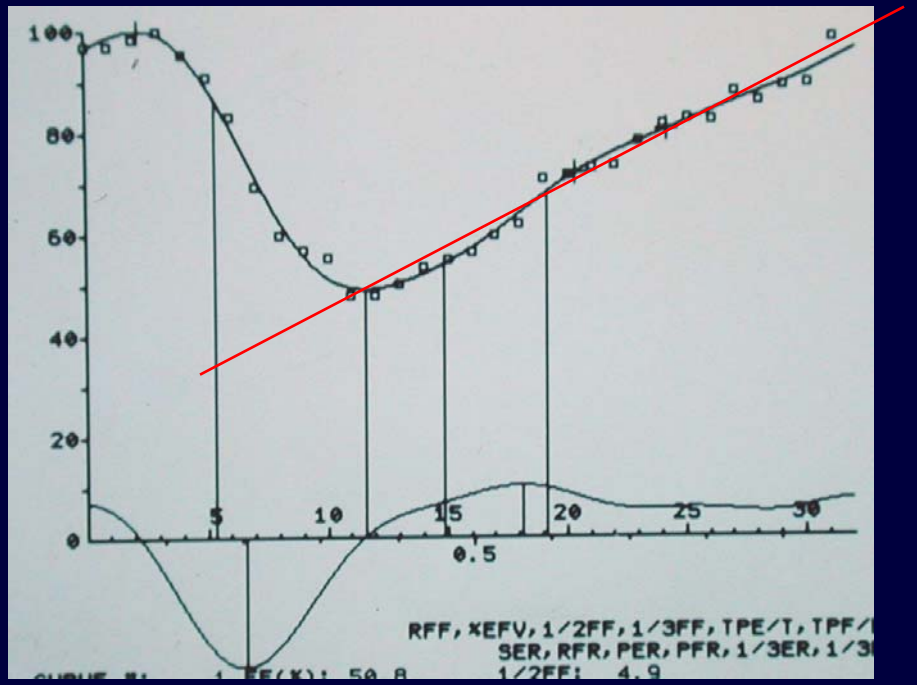
Liu JE et al *JAAC, 2001*

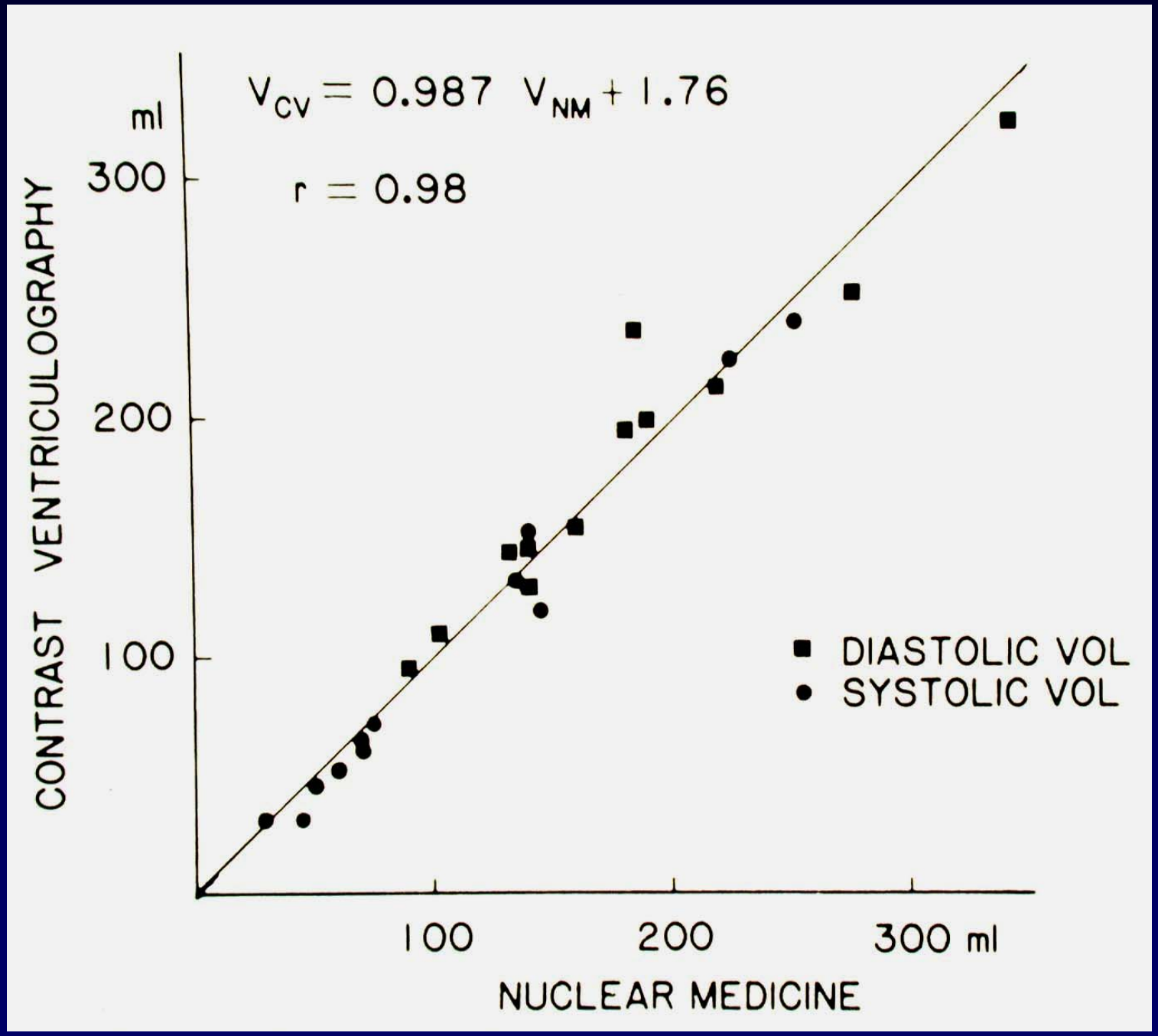


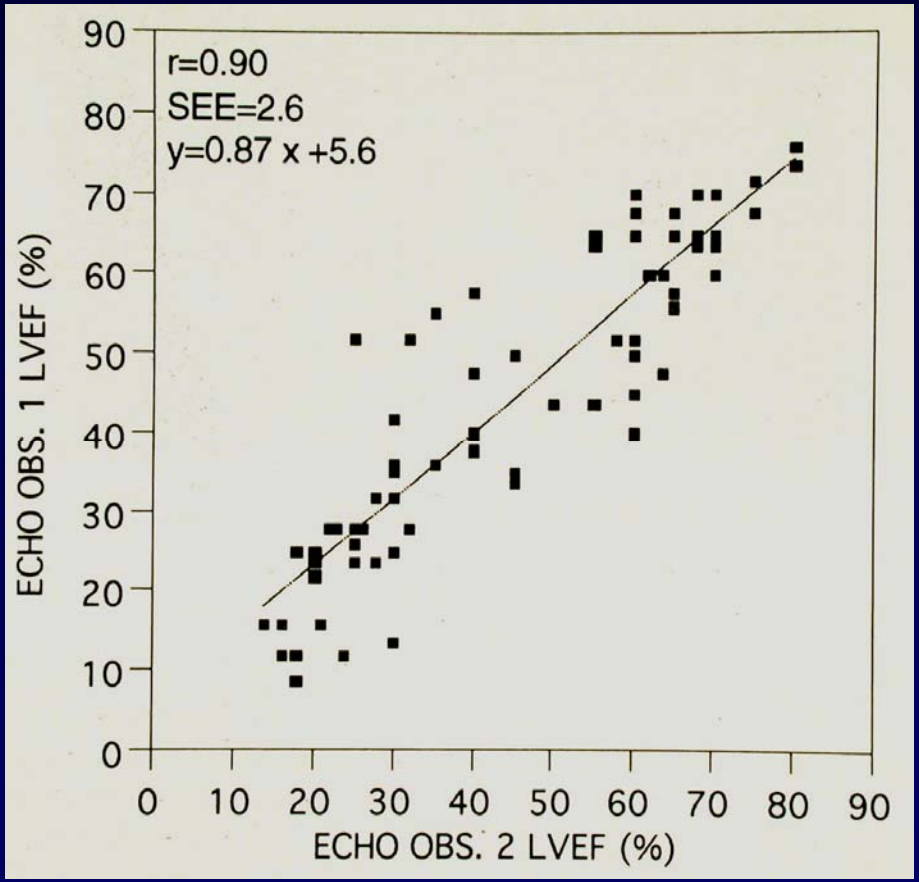
RFF, %EFV, 1/2FF, 1/3FF, TPE/T, TPF/FT=(%)
SER, RFR, PER, PFR, 1/3ER, 1/3FR=(%/s)

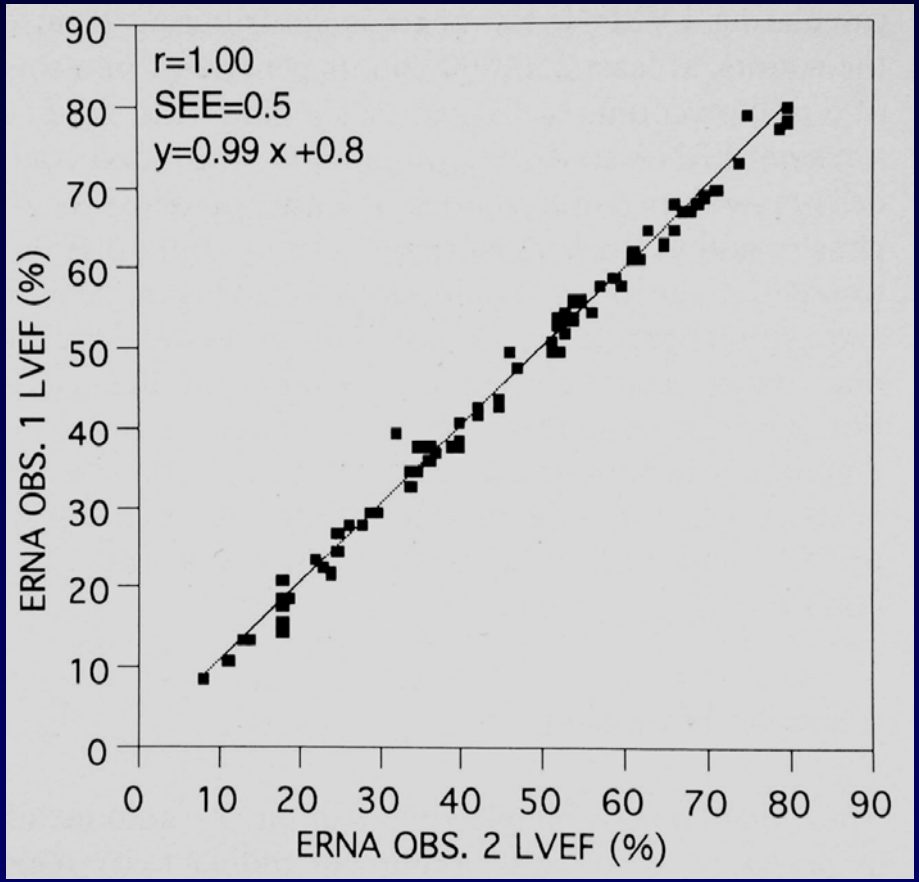
CURVE #:	1	EF(%):	50.8	1/2FF:	4.9		
HARMONICS:	4	TPE(ms):	135:130	TPF(ms):	203:198	RFT(ms):	271:250
FRM T(ms):	31	PERedc:	303:317	PFRedc:	119:137	RFFsc:	44.9:45.4
H.R.(bpm):	60	PERsc:	598:628	PFRsc:	234:272	RFRsc:	166:182
%EFVedc:	4.7	TPE/T:	14	TPF/FT:	29	ET(ms):	291:282
%EFVsc:	9.3	1/3EF:	13.3	1/3FF:	18.9:12.1	FT(ms):	701:633
		1/3ERed:	137	1/3FRed:	81		
		1/3ERsc:	269	1/3FRsc:	159:173	A/V(%):	38.5
SER:	174:177	EDC(kcps):	765	ESC(kcps):	377	SC(kcps):	389


100
80
60
40
20
0
5
10
15
20
0.5
1.0
RFF, %EFV, 1/2FF, 1/3FF, TPE/T, TPF/F
SER, RFR, PER, PFR, 1/3ER, 1/3F
CURVE #: 1 FF(%): 68.7 1/2FF: 5.6


100
80
60
40
20
0
5
10
15
20
25
30
0.5
RFF, %EFV, 1/2FF, 1/3FF, TPE/T, TPF/
SER, RFR, PER, PFR, 1/3ER, 1/3
1/2FF: 4.9


$V_{CV} = 0.987\ V_{NM} + 1.76$
$r = 0.98$
ml
300
200
100
CONTRAST VENTRICULOGRAPHY
DIASTOLIC VOL
SYSTOLIC VOL
100
200
300 ml
NUCLEAR MEDICINE


r=0.90
SEE=2.6
y=0.87 x +5.6
ECHO OBS. 1 LVEF (%)
ECHO OBS. 2 LVEF (%)
0
10
20
30
40
50
60
70
80
90


r=1.00
SEE=0.5
y=0.99 x +0.8
ERNA OBS. 1 LVEF (%)
ERNA OBS. 2 LVEF (%)
0
10
20
30
40
50
60
70
80
90

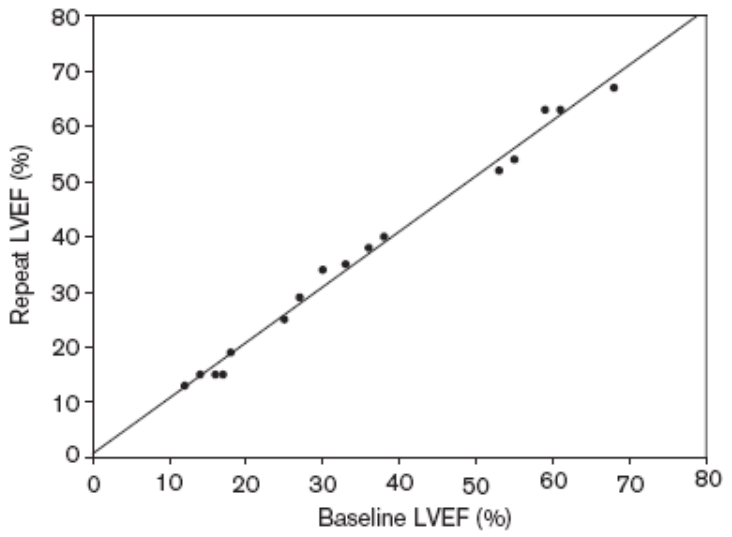
The feasibility of repeated left ventricular ejection fraction analysis with sequential single-dose radionuclide ventriculography

Table 2 Individual results of 16 patients undergoing sequential planar radionuclide ventriculography with a 3 h interval

Patient number	Baseline LVEF	Repeat LVEF	Difference	Difference, in %
1	68	67	−1	−1.5%
2	53	52	−1	−1.9%
3	30	34	4	13.3%
4	59	63	4	6.8%
5	14	15	1	7.1%
6	17	15	−2	−11.8%
7	25	25	0	0.0%
8	61	63	2	3.3%
9	38	40	2	5.3%
10	36	38	2	5.6%
11	16	15	−1	−6.3%
12	18	19	1	5.6%
13	33	35	2	6.1%
14	12	13	1	8.3%
15	55	54	−1	−1.8%
16	27	29	2	7.4%

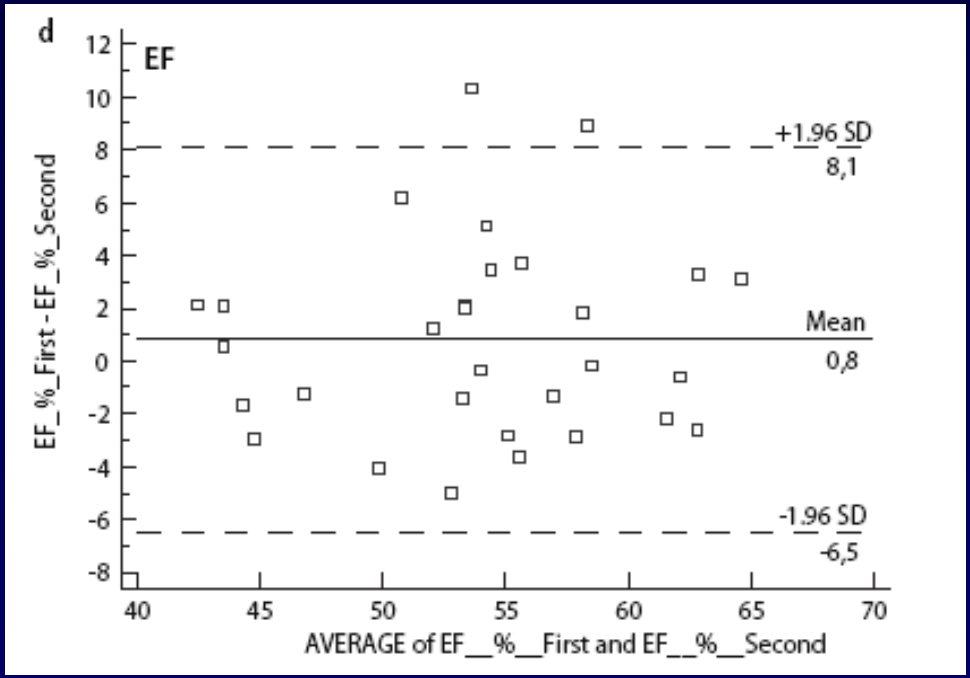
LVEF, left ventricular ejection fraction.

Fig. 2



Pieter A. van der Vleutena Nucl Med Commun 26:711–715 c 2005

Is Magnetic Resonance Imaging the 'Reference Standard' for Cardiac Functional Assessment? Factors Influencing Measurement of Left Ventricular Mass and Volumes



Steen H et al. Clinical Research in Cardiology, Volume 96, Number 10 (2007)

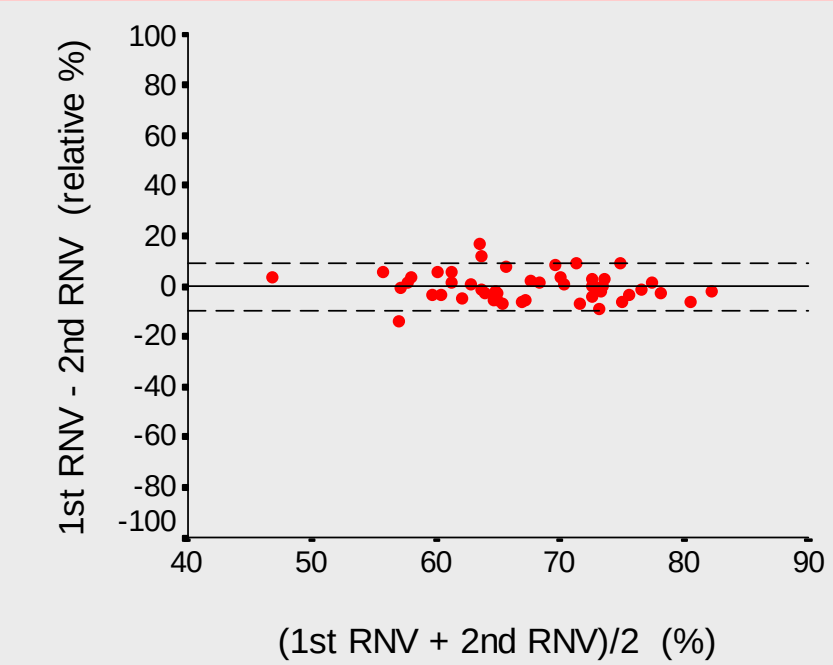
Arsos Et al, EJNM 2004

	$(1^{st}+2^{nd})/2$	$1^{st} - 2^{nd}$	↑ (%)	↓ (%)
EF (%)	67.3±7.2	-0.2±3.8	6.2 (9.2)	6.5 (9.6)
PFR (SV/sec)	4.8±1.2	0.3±0.9	1.8 (38.8)	1.2 (25.0)
1/3 FF (%SV)	44.0±15.7	-1.4±11.5	17.7 (42.1)	20.4 (48.6)
rTPF (%)	17.9±4.3	0.9±5.2	9.4 (52.7)	7.8 (42.3)
TPF (msec)	144.4±35.1	6.4±44.4	79.5 (55.1)	66.8 (46.3)
A/V (%SV)	24.9±9.5	0.2±7.7	13.0 (52.0)	12.5 (50.3)

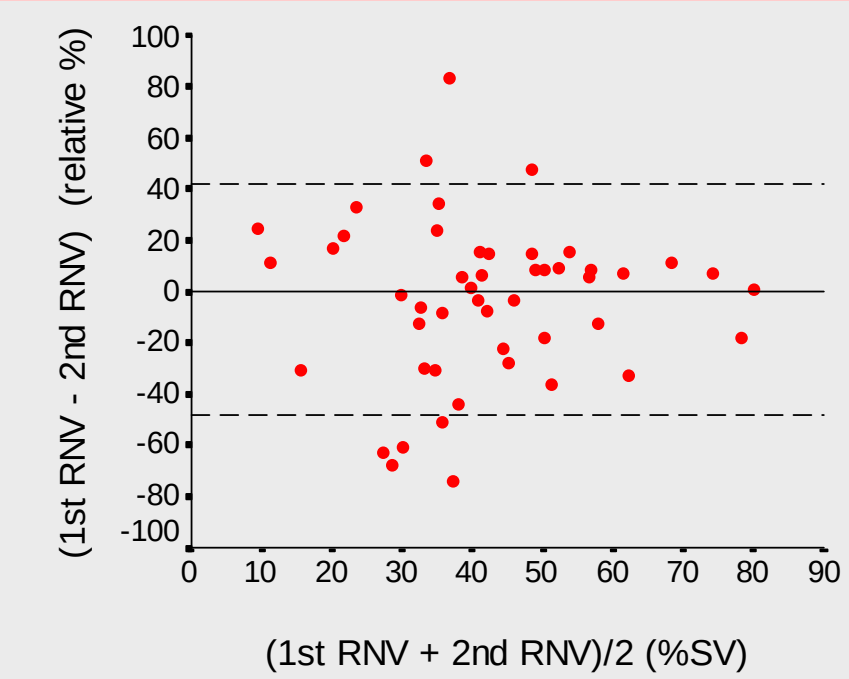
The minimum change of a parameter [↑(%) or ↓ (%), percent in parentheses] that could be considered as true at the 95% level of certainty provided an estimate of reliability. The lower the change required, the better the reliability. Note, that in contrast to EF where a <10% change is adequate, approx. 25-50% change is required for diastolic parameters before they can be confidently considered true

Results 6 : Bland-Altman analysis

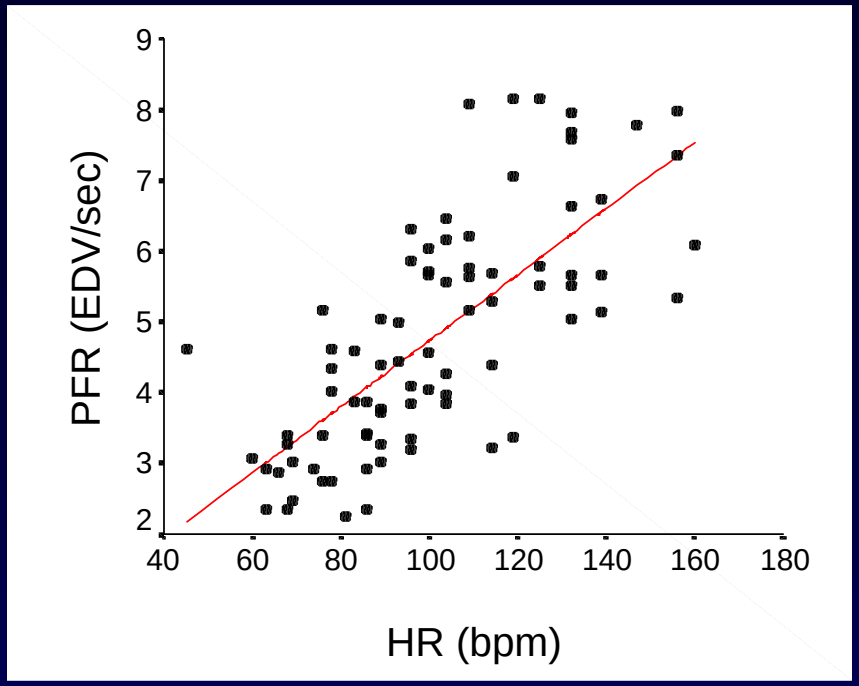
EF



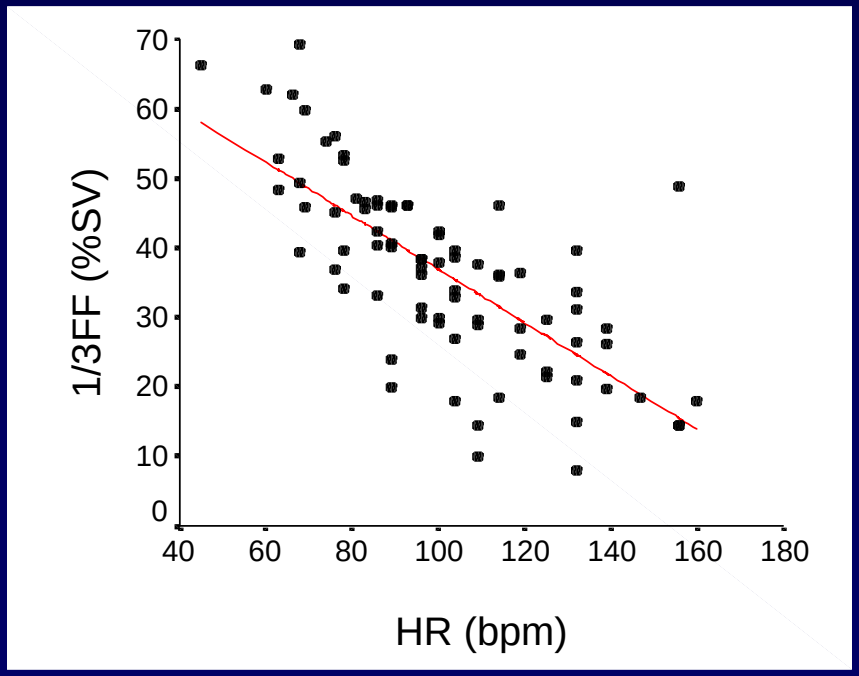
1/3 FF



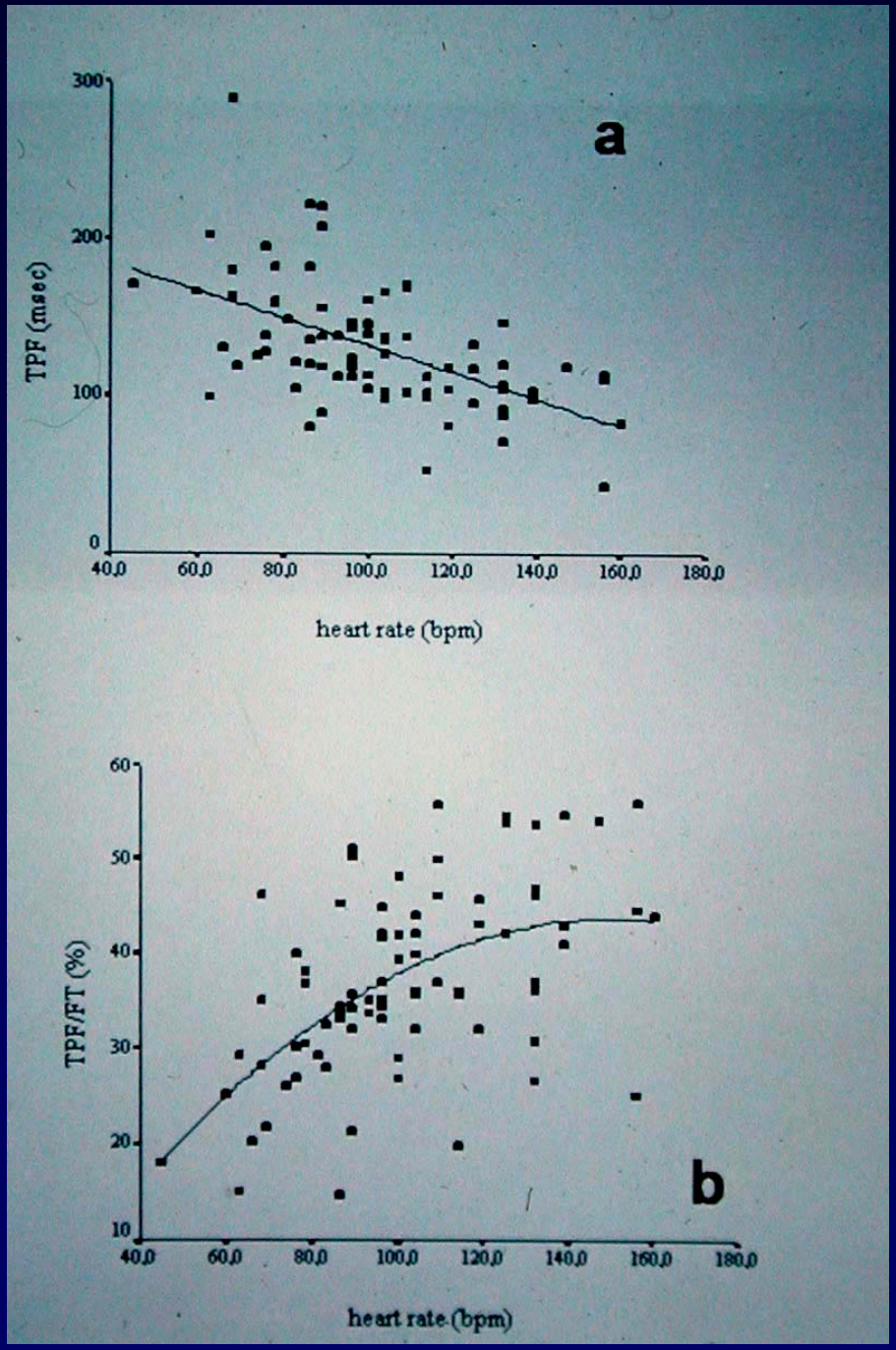
the agreement of the diastolic RNV index 1/3 FF between the RNV sessions was unsatisfactory,indicating limited reliability, in contrast to the ejection fraction



Diastolic function



Relations between HR-PFR, & HR-1/3FF in normal children


a
TPF (msec)
300
200
100
0
40,0
60,0
80,0
100,0
120,0
140,0
160,0
180,0
heart rate (bpm)
b
TPF/FT (%)
60
50
40
30
20
10
40,0
60,0
80,0
100,0
120,0
140,0
160,0
180,0
heart rate (bpm)

Cardiac Abnormalities in Diabetic Patients With Neuropathy

Effects of aldose reductase inhibitor administration

Table 2—*Radionuclide ventriculography measures at rest*

	Baseline	Week 52	Change	*P* value
Ejection fraction (%)				
Placebo	56.7 ± 1.8	57.9 ± 1.7	1.60 ± 1.52	NS
Zopolrestat	59.7 ± 1.2	61.4 ± 1.2	1.69 ± 0.68	<0.02
Cardiac output (l/min)				
Placebo	7.0 ± 0.6	6.5 ± 0.4	−0.54 ± 0.68	NS
Zopolrestat	5.8 ± 0.3	6.2 ± 0.3	0.46 ± 0.20	<0.03
Stroke volume (ml)				
Placebo	87 ± 8	86 ± 6	−3.6 ± 7.7	NS
Zopolrestat	76 ± 3	84 ± 3	8.5 ± 2.7	<0.004
Heart rate (bpm)				
Placebo	82 ± 4	77 ± 3	−4.5 ± 2.1	NS
Zopolrestat	77 ± 2	75 ± 2	−2.2 ± 1.8	NS
End diastolic volume (ml)				
Placebo	153 ± 14	150 ± 12	−7.3 ± 15.1	NS
Zopolrestat	127 ± 5	136 ± 5	8.3 ± 4.9	NS
PFR (EDV/s)				
Placebo	2.36 ± 0.11	2.56 ± 0.18	0.27 ± 0.18	NS
Zopolrestat	2.61 ± 0.10	2.66 ± 0.09	0.05 ± 0.09	NS

Data are means ± SD unless otherwise indicated. NS, not significant.

Table 3—*Radionuclide ventriculography measures at exercise*

Variable treatment	Baseline	Week 52	Change	*P* value
Ejection fraction (%)				
Placebo	67.0 ± 1.7	64.6 ± 2.1	−2.65 ± 2.02	NS
Zopolrestat	65.6 ± 1.2	69.2 ± 1.1	3.70 ± 0.83	<0.001
Cardiac output (l/min)				
Placebo	13.1 ± 0.9	11.2 ± 0.8	−2.29 ± 0.95	<0.03
Zopolrestat	11.3 ± 0.5	12.0 ± 0.6	0.85 ± 0.59	NS
Stroke volume (ml)				
Placebo	108 ± 9	89 ± 6	−18.8 ± 7.3	<0.02
Zopolrestat	89 ± 3	96 ± 5	8.1 ± 4.9	NS
Heart rate (bpm)				
Placebo	138 ± 5	135 ± 4	−1.7 ± 4.2	NS
Zopolrestat	136 ± 3	125 ± 3	−10.4 ± 2.6	<0.001
EDV (ml)				
Placebo	157 ± 11	136 ± 8	−19.5 ± 8.7	<0.04
Zopolrestat	136 ± 4	140 ± 7	6.4 ± 6.5	NS

Data are means ± SD unless otherwise indicated. NS, not significant.

Johnson B et al. Diabetes Care, 2004

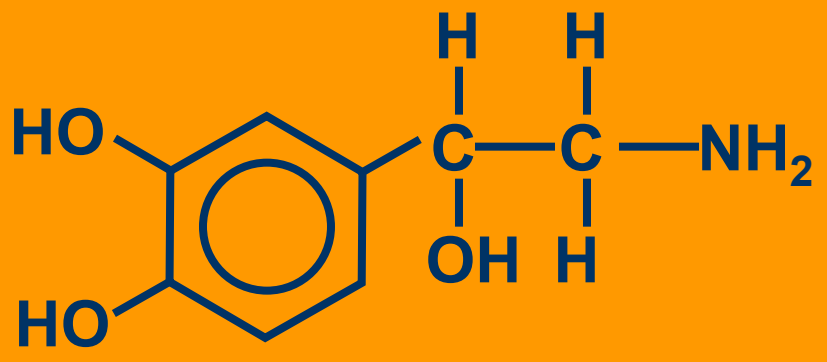
Left Ventricular Systolic and Diastolic Function in Normotensive Type 1 Diabetic Patients With or Without Autonomic Neuropathy

A radionuclide ventriculography study

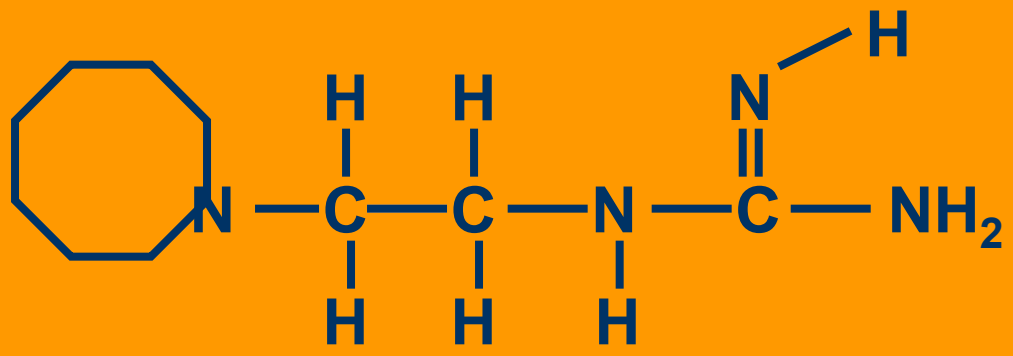
Table 3—*Systolic, diastolic, and volumetric RNV parameters in the two groups of patients as defined by the presence or absence of DAN*

	Patients with <2 measures of DAN	Patients with ≥2 measures of DAN	*P*
n	33	24	—
Systolic			
Ejection fraction (%) (normal values >55%)	66.9 ± 5.4	68.8 ± 7.9	NS
Peak emptying rate (EDV/s)	3.81 ± 0.65	3.89 ± 0.65	NS
Diastolic			
Atrial contribution (%SV)	17.3 ± 7.1	26.0 ± 11.9	0.002
Peak filling rate (EDV/s)	3.44 ± 0.71	3.43 ± 1.04	NS
First third filling fraction (%SV)	52.7 ± 16.5	32.8 ± 11.9	<0.001
Time to peak filling (ms)	138.6 ± 29.3	153.6 ± 38.7	NS
Volumetric			
EDV (ml)	138.2 ± 29.8	116.3 ± 28.8	0.015
EDV index (ml/m^2)	72.1 ± 13.3	65.2 ± 16.5	NS
ESV (ml)	45.9 ± 12.8	36.5 ± 13.8	0.007
ESV index (ml/m^2)	24.5 ± 6.6	20.4 ± 7.6	0.017
SV (ml)	92.3 ± 20.4	79.8 ± 21.2	0.034
SV index (ml/m^2)	49.4 ± 10.3	44.9 ± 12.7	NS
Cardiac output (ml/min)	6,700 ± 1,654	6,623 ± 1,986	NS
Cardiac index (ml · min^{-1} · m^{-2})	3,586 ± 879	3,735 ± 1,211	NS

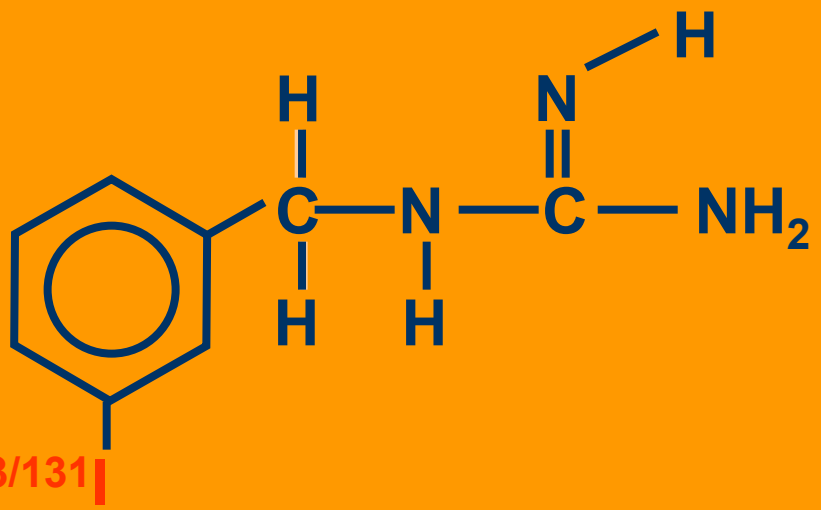
Didangelos et al. Diabetes Care 2003



norepinephrine

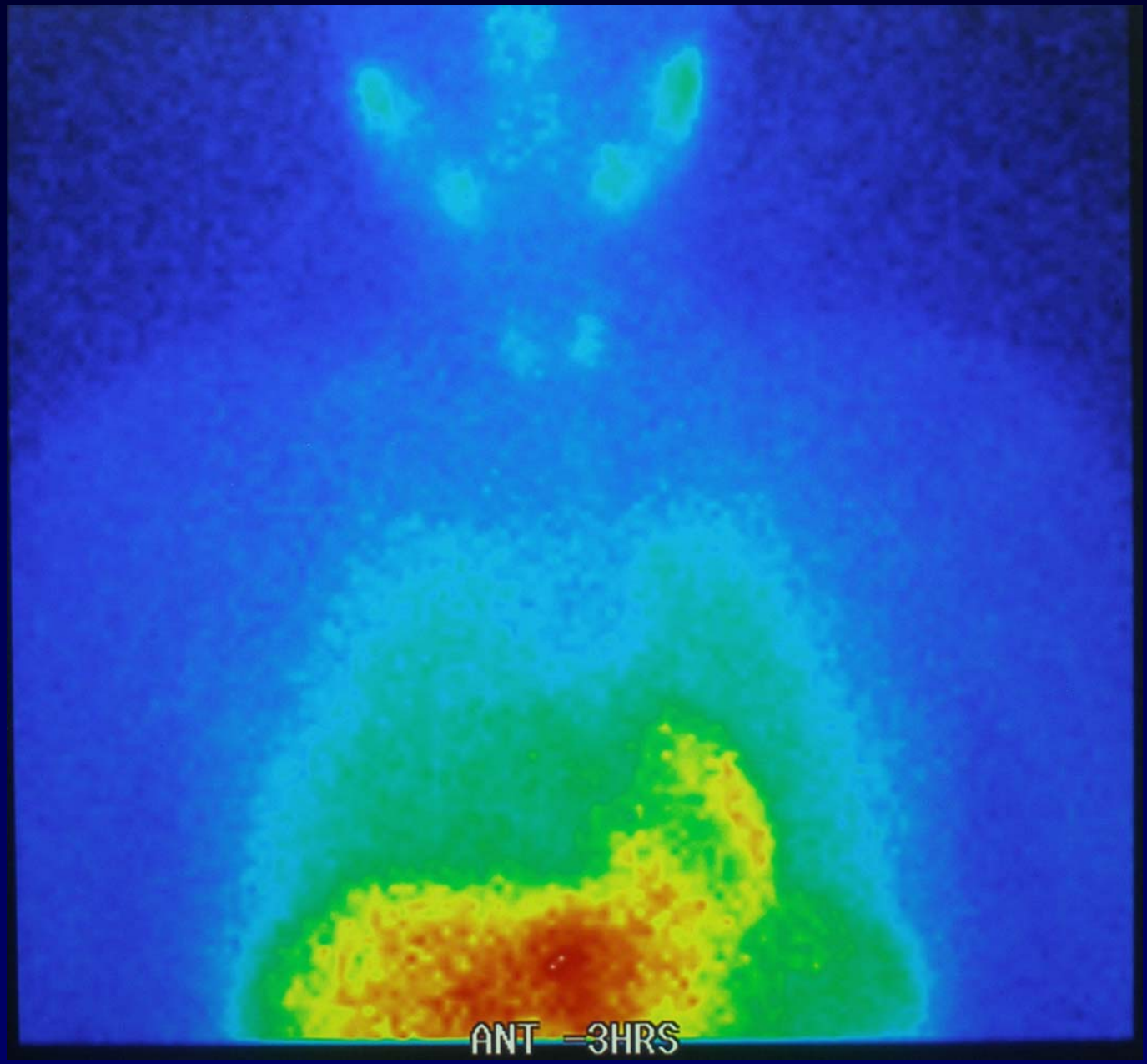


guanethidine
(Ismelin)

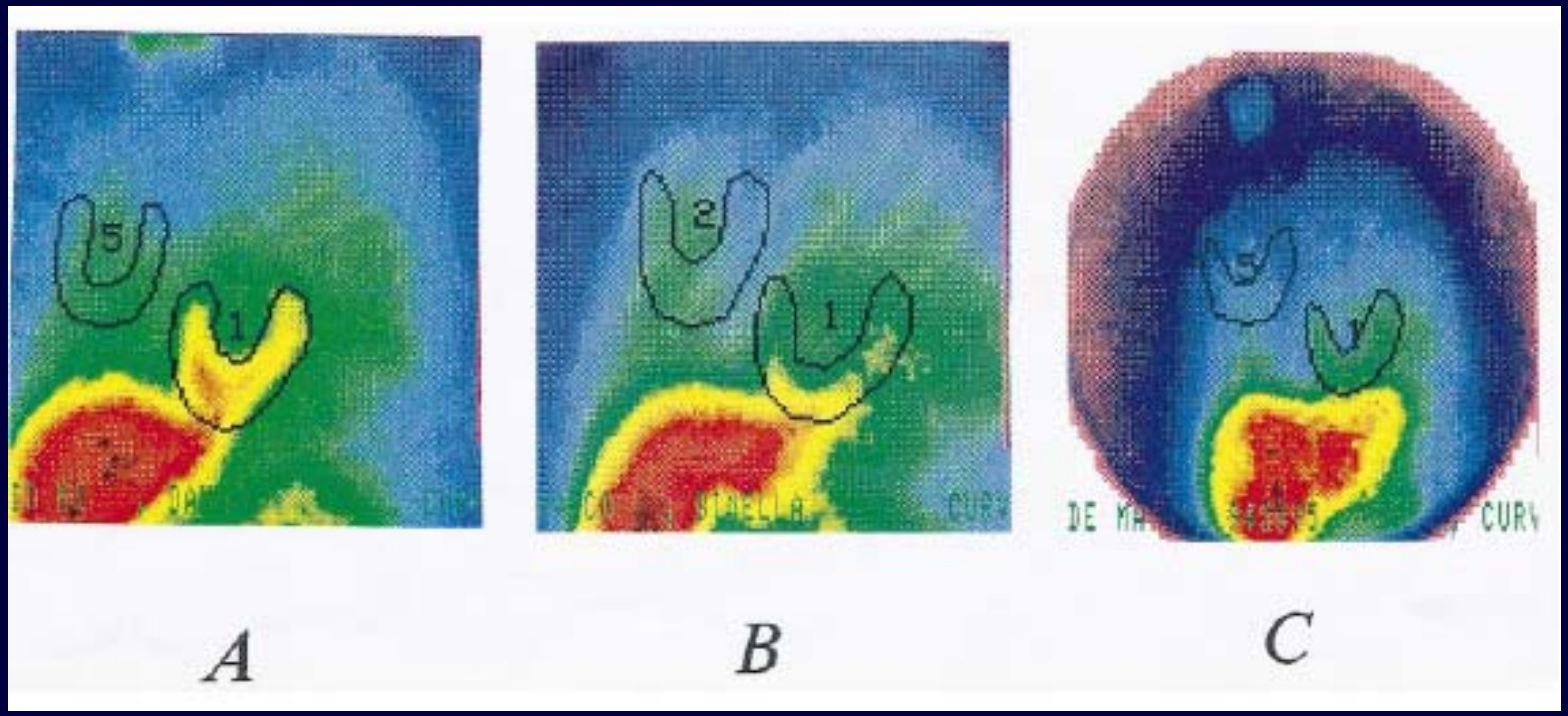


mIBG

123/131

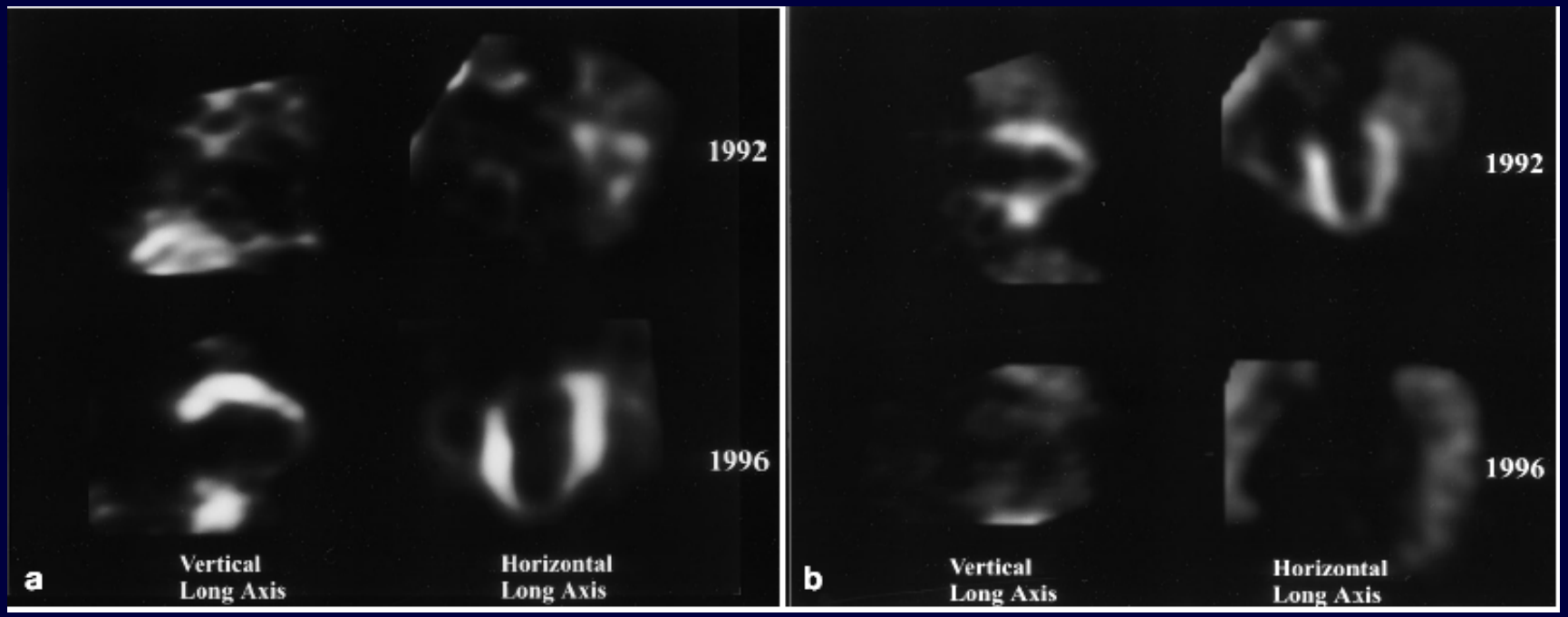

ANT -3HRS

Myocardial Dysfunction and Adrenergic Cardiac Innervation in Patients with Insulin-Dependent Diabetes Mellitus



Scognamiglio R et al *JACC, 1998*

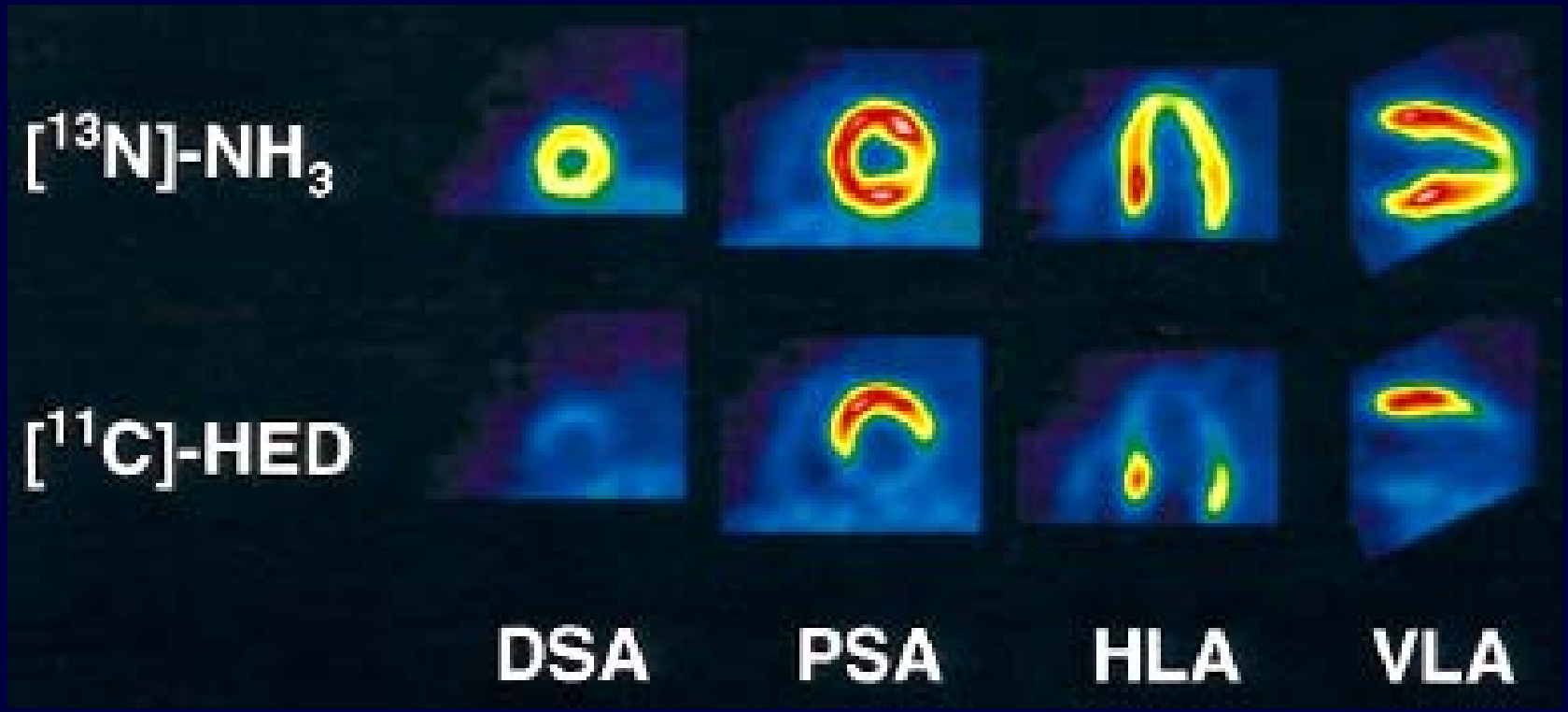
Effect of glycaemic control on myocardial sympathetic innervation assessed by [123I]metaiodobenzylguanidine scintigraphy: a 4-year prospective study in IDDM patients



Ziegler D et al *Diabetologia ,1998*

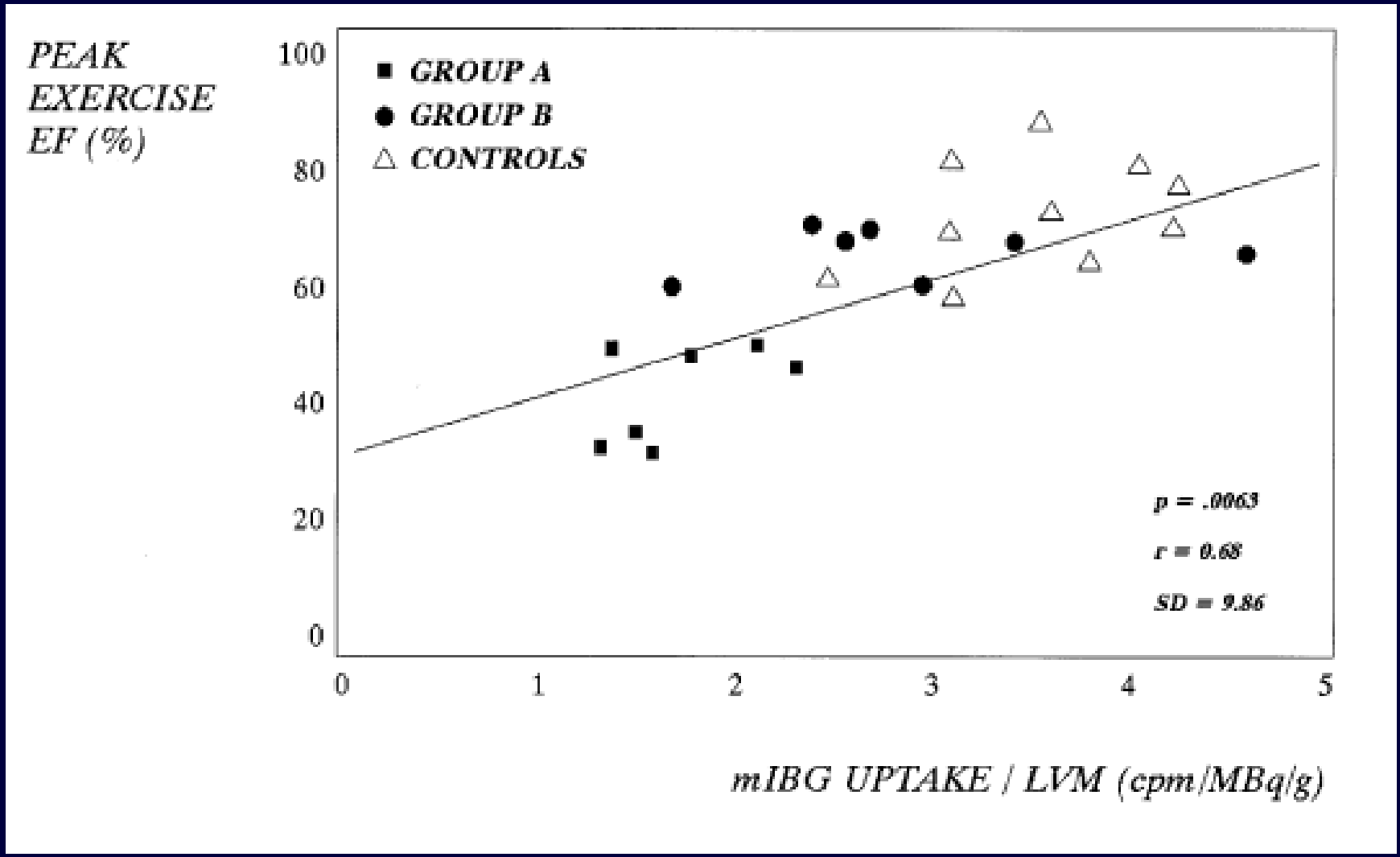
Scintigraphic Assessment of Regionalized Defects in Myocardial Sympathetic Innervation and Blood Flow Regulation in Diabetic Patients

With Autonomic Neuropathy



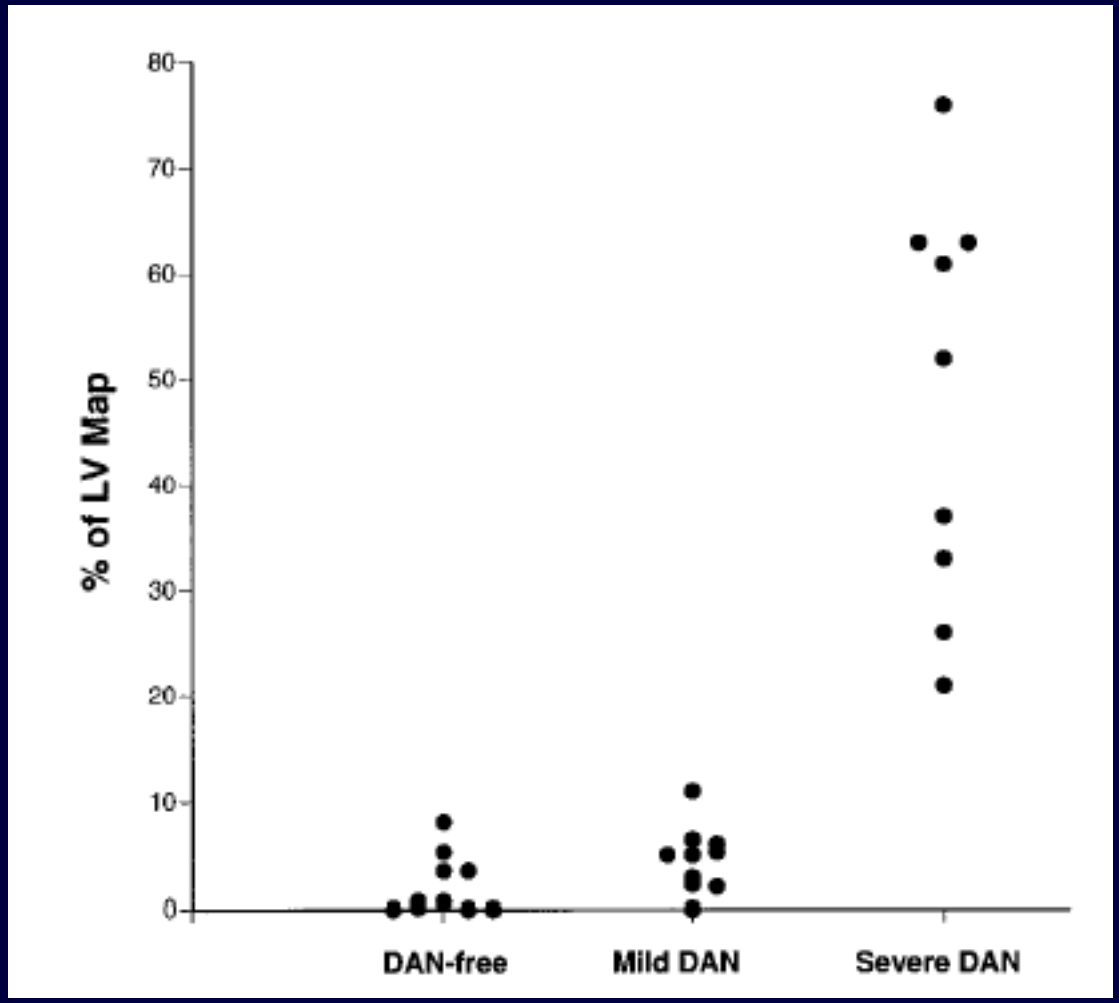
Stevens MJ et al *JACC, 1998*

Myocardial Dysfunction and Adrenergic Cardiac Innervation in Patients With Insulin-Dependent Diabetes Mellitus

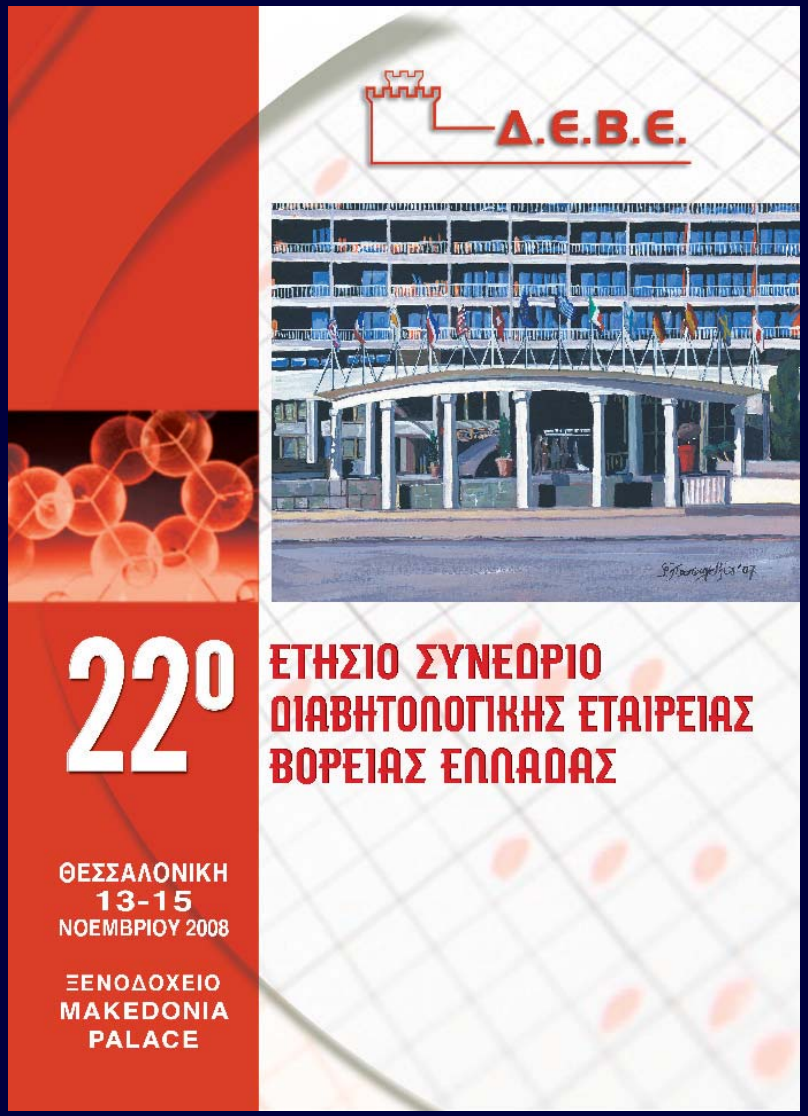


Scognamiglio Ret al *JACC, 1998*

Cardiac Sympathetic Dysinnervation in Diabetes. Implications for Enhanced Cardiovascular Risk



Stevens MJ et al *Circulation, 1998*



Ευχαριστώ

για την

προσοχή σας!