심장핵의학 분석 응용 프로그램의 원리와 특징

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내 용

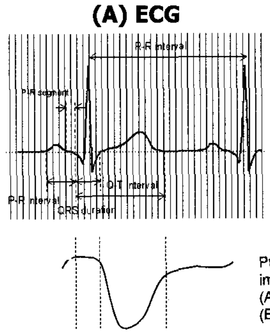
- 심장 핵의학 영상검사의 원리
- 분석용 프로그램의 종류
- 심장 기능 정량화 기법
- 응용 프로그램의 임상적평가

심장핵의학 영상검사의 원리

Nuclear Cardiology

- To detect disease – CAD
- To define the extent of disease which is usually synonymous with risk stratification and prognosis
- To predict the outcome of therapeutic procedures
- To monitoring response to treatment, usually revascularization

(A) ECG

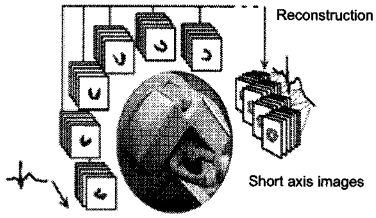


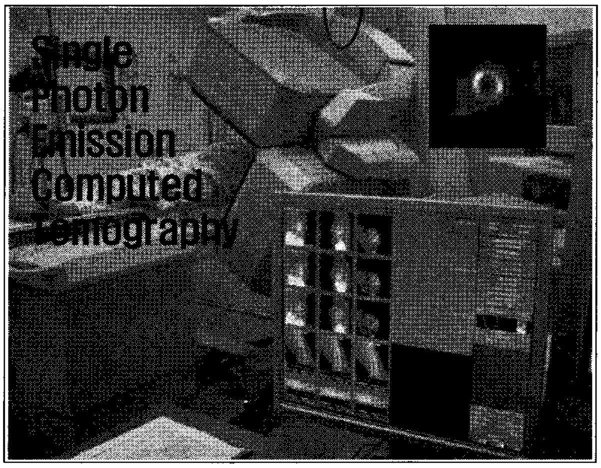
(B) Volume curve

- **Scan time: 15min ~ 30min**
- **Angle:180° - 360°**
- **Reconstruction: FBP**
- **ECG: R-R interval**
- **Rest & Stress image**

Principle of gated myocardial SPECT imaging.
(A) Electrocardiography
(B) Volume curve of left ventricle

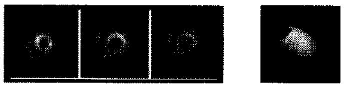
Image Acquisition





Myocardial SPECT

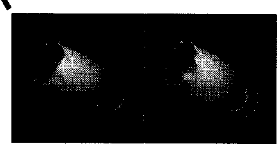
- Gated Myocardial SPECT
  - Analysis of anatomical, biological states
  - Functional nuclear medicine imaging tool
- Perfusion of myocardium
  - Ischemia, Infarction



분석용 프로그램의 종류

Gated Heart Software

Visualization (Usefulness)



Quantification (Automation)

Software for Cardiac Study

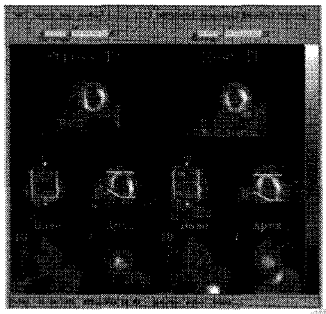
- **QGS**
  - Quantitative Gated SPECT
  - Cedars-Sinai Medical Center
  - Los Angeles, CA
- **ECT**
  - Emory Cardiac Toolbox
  - Emory University
  - Atlanta, GA
- **4D-MSPECT**
  - University of Michigan Medical Center
  - Ann Arbor, MI
- **pFAST**
  - Perfusion and Functional Analysis for Gated SPECT
  - Sapporo Medical University
  - Sapporo, Japan

QGS, QPS

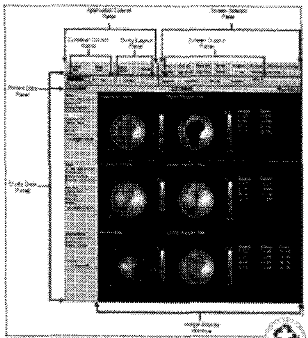
•QGS (Quantitative Gated SPECT)
•Interactive standalone application for the automatic segmentation, quantification, and analysis and display of static and gated short axis myocardial perfusion.

•QPS (Quantitative Perfusion SPECT)
•Automatic generation of optimal perfusion normal limits from a normal, a prospective and a pilot patient population.

ECToolbox

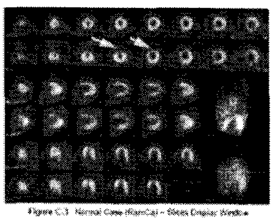


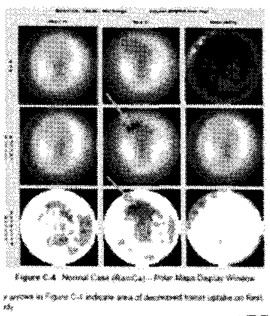
4D-MSPECT



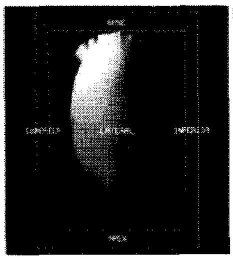
심장기능 정량화 기법

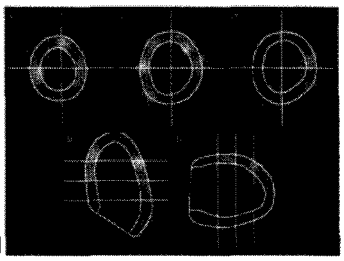
Perfusion image





Function image





Cardiac Index

- Global LV Functions
  - Ejection Fraction
  - Volume of End-systolic and End-diastolic phase
  - LVM
- Regional LV Functions
  - Wall Motion
  - Wall Thickening
- Developing Functions
  - LV Diastolic Phase Analysis
  - RV Estimation

[redacted]

LV Segmentation(1)

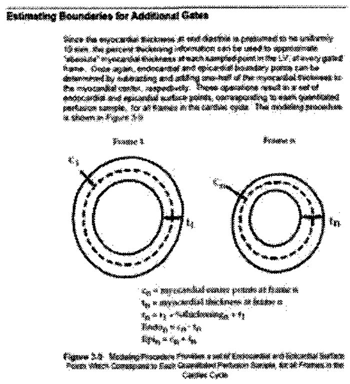
- Threshold Based
  - LV Dynamic Thresholding
  - Thresholding based on discriminant analysis
- Edge-Based Techniques
  - Wavelet-Based LV Edge Detection
  - Gradient Based
  - Statistical-Based Matched Filtering
  - LV Detection Based on AI
- Mathematical Morphology-based Techniques

LV Segmentation(2)

- Germano
  - Threshold to 50% of C_{max}
  - Binary clustering
  - Hough transform extension(local maxima of summed slice)

$$w_i = 1 - 2\left|\frac{i - \frac{N}{2}}{N}\right|$$

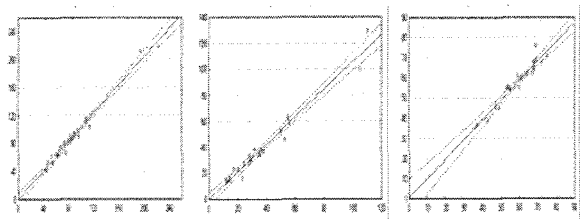
  - 50% threshold inside the cylinder and 3-D scan from COM(10°)
  - An asymmetric Gaussian is fitted to each profile



응용프로그램의 임상적평가

Reproducibility of Gated Myocardial SPECT

Repeated SPECT in situ



EDV ESV EF

Reproducibility & Repeatability

Table 4.5
Reproducibility and Repeatability of Quantitative Gated Perfusion SPECT Measurements

Method	Type of Analysis	Parameter	Agreement	No. of Patients	Reference
Gaussian fit	Reproducibility	LVEF	r = 1, SEE = 0%	65	Germano et al.[7]
"	"	EDV	r = 1, SEE = 0 mL	"	"
"	"	ESV	r = 1, SEE = 0 mL	"	"
"	"	WM	% agreement = 100%	79	Germano et al. [illegible]
"	"	WT	% agreement = 100%	"	"
"	Repeatability	LVEF	[illegible]	15	Johnson et al. [illegible]
"	Repeatability [illegible]	LVEF	[illegible]	180	Berman et al. [illegible]
"	"	EDV	[illegible]	"	"
"	"	ESV	[illegible]	"	"
"	[illegible]	[illegible]	[illegible]	[illegible]	Germano et al. [illegible]
[illegible]	Cross-algorithm reproducibility	LVEF	[illegible]	40	Everaert et al. [illegible]
"	"	EDV	[illegible]	"	"
"	"	ESV	[illegible]	"	"
Moment	Intraobserver reproducibility	LVEF	[illegible]	[illegible]	Everaert et al. [illegible]
"	Interobserver reproducibility	LVEF	[illegible]	"	"
"	Reproducibility	LVEF	[illegible]	[illegible]	Schwartz et al. [illegible]
Threshold (I)	Intraobserver reproducibility	LVEF	[illegible]	[illegible]	Nichols et al. [illegible]
"	"	EDV	[illegible]	"	"
"	"	ESV	[illegible]	"	"
"	Interobserver reproducibility	LVEF	[illegible]	140	"
"	"	EDV	[illegible]	"	"
"	"	ESV	[illegible]	"	"
"	Intraobserver reproducibility	LVEF	[illegible]	[illegible]	Nichols et al. [illegible]
"	"	EDV	[illegible]	"	"
"	"	ESV	[illegible]	"	"
Threshold (II)	Intraobserver reproducibility	LVEF	[illegible]	[illegible]	Yang et al. [illegible]
"	Interobserver reproducibility	LVEF	[illegible]	"	"
Partial volume	Intraobserver reproducibility	LVEF	r = 0.97	[illegible]	Calnon et al. [illegible]
"	Interobserver reproducibility	LVEF	r = 0.97	"	"
"	Intraobserver reproducibility	WT	r = 0.97	"	"
"	Interobserver reproducibility	WT	[illegible]	10	[illegible]
"	Intraobserver reproducibility	WT	[illegible]	"	"
Image inversion	Intraobserver reproducibility	LVEF	[illegible]	14	Williams et al. [illegible]
"	Interobserver reproducibility	LVEF	[illegible]	"	"

Table 4.2
Validations of Quantitative Measurements of LVEF from Gated Perfusion

Method	Gold Standard	No. of Patients	Spearman's r (LVEF)	Isotope	Reference
Gaussian fit	first pass	65	0.91	99mTc-sestamibi	Germano et al.[7]
"	first pass	15	0.87	99mTc-sestamibi	He et al.[13]
"	first pass	15	0.82	201-Tl	He et al.[13]
"	MUGA	50	0.92	99mTc-sestamibi	Moriel et al.[14]
"	MUGA	36	0.87–0.92	201-Tl	Bateman et al.[16]
"	MUGA	40	0.93	99mTc-tetrofosmin	Everaert et al.[15]
"	2-D echo	35	0.79	99mTc-sestamibi	Zanger et al.[17]
"	2-D echo	52	0.82	201-Tl	Bateman et al.[18]
"	2-D echo	49	0.77	unspecified	Cwajg et al.[19]
"	2-D echo	50	0.90	99mTc-sestamibi	Mathew et al.[20]
"	2-D echo	57	0.85	99mTc-tetrofosmin	Di Leo et al.[21]
"	3-D echo	18	0.80	201-Tl	Akinboboye et al.[22]
"	contrast ventricul.	12	0.85	99mTc-tetrofosmin	Di Leo et al.[21]
"	MRI	17	0.93	99mTc-tetrofosmin	He et al.[23]
"	thermodilution	21	0.84	99mTc-sestamibi	Germano et al.[24]
Threshold (I)	first pass	65	0.87	99mTc-sestamibi	Nichols et al.[3]
"	first pass	22	0.87	99mTc-sestamibi	Nichols et al.[43]
"	MUGA	75	0.87	99mTc-sestamibi	Nichols et al.[3]
"	contrast ventricul.	58	0.88	99mTc-sestamibi	Nichols et al.[26]
"	MRI	21	0.86	99mTc-tetrofosmin	Stollfuss et al.[27]
Threshold (II)	MUGA	21	0.87	99mTc-sestamibi	Yang et al.[38]
Moment	first pass	20	0.86	99mTc-sestamibi	Schwartz et al.[28]
"	MUGA	50	0.93	99mTc-tetrofosmin	Everaert et al.[3]
"	MUGA	40	0.94	99mTc-tetrofosmin	Everaert et al.[15]
"	2-D echo	49	0.73	99mTc-sestamibi	Schwartz et al.[29]
Gradient	contrast ventricul.	27	0.93	unspecified	Adiseshan et al.[30]
Partial volume	MUGA	23	0.91	99mTc-sestamibi	Calnon et al.[31]
Image inversion	first pass	38	0.83	99mTc-sestamibi	Williams et al.[12]
"	contrast ventricul.	54	0.90–0.93	99mTc-sestamibi	Williams et al.[12]
Total		1,095	0.87		

Table 4.2
Validations of Quantitative Measurements of Volumes from Gated Perfusion SPECT

Method	Gold Standard	No. of Patients	Spearman's r (EDV)	Spearman's r (ESV)	Isotope	Reference
Gaussian fit	2-D echo	35	0.88	0.91	99mTc-sestamibi	Zanger et al.[17]
"	2-D echo	52	0.70	0.71	201-Tl	Bateman et al.[18]
"	2-D echo	49	0.79	0.82	unspecified	Cwajg et al.[19]
"	2-D echo	50	0.87	0.90	99mTc-sestamibi	Mathew et al.[20]
"	3-D echo	18	0.94	0.97	201-Tl	Akinboboye et al.[2]
"	MRI	17	0.81	0.90	99mTc-tetrofosmin	He et al.[23]
"	thermodilution	21	0.86	0.94	99mTc-sestamibi	Germano et al.[24]
	thermodilution	24	0.89	0.94	99mTc-sestamibi	Iskandrian et al.[25]
Threshold	contrast ventricul.	58	0.87	0.91	99mTc-sestamibi	Nichols et al.[26]
Moment	first pass	20	0.93	0.92	99mTc-sestamibi	Schwartz et al.[28]
Gradient	contrast ventricul.	27	0.95	0.95	unspecified	Adiseshan et al.[30]
Total		**371**	**0.86**	**0.90**		

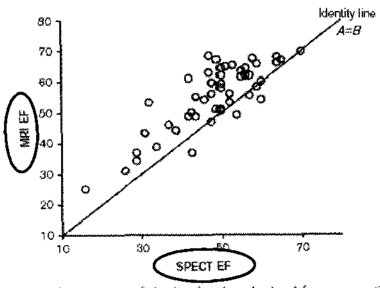


Fig. 2. Comparison of ejection fraction obtained from magnetic resonance imaging and from gated SPECT. The line of identity is also shown.

Comparison of quantification software

Table 1. Correlation matrix.

	QGS	4DM	ECT
Ejection fraction			
QGS	1	0.928	0.929
4DM	0.928	1	0.910
ECT	0.929	0.910	1
End diastolic volume			
QGS	1	0.986	0.984
4DM	0.986	1	0.982
ECT	0.984	0.982	1

QGS, 4DM and ECT are software programs. See text for details.

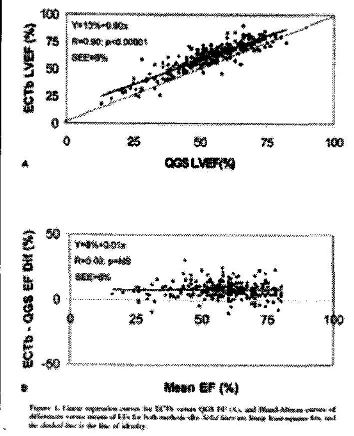
nuclear medicine communicatioins(2003)

Table 2. Results of repeated measures ANOVA.

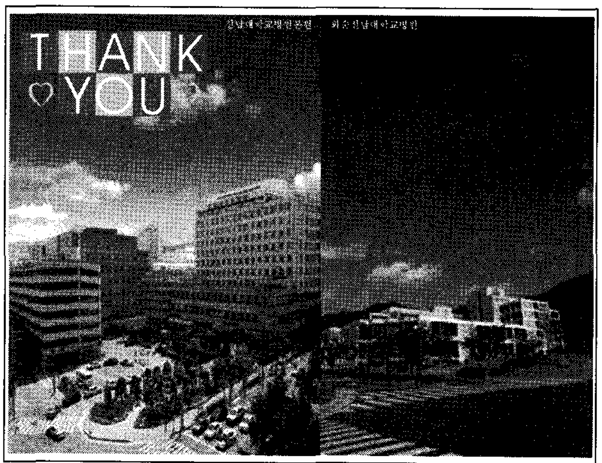
Measured quantity	Group	Comparison	Mean difference	P value	Standard deviation	Range (mean −2SD to mean+2SD)
Ejection fraction	1	QGS vs 4DM	−1.8065	0.276	9.0606	−19.9277~16.3147
	1	QGS vs ECT	−0.871	0.539	7.8091	−16.4860~14.7472
	1	4DM vs ECT	0.9355	0.632	10.7577	−20.5799~22.4509
	2	QGS vs 4DM	−5.9296	<0.001	6.0364	−18.0028~6.1432
	2	QGS vs ECT	−4.3239	<0.001	5.9804	−16.2847~7.6369
	2	4DM vs ECT	1.6056	<0.001	7.1783	−12.751~15.9622
	3	QGS vs 4DM	−4.1931	<0.001	6.5917	−17.3765~9.0503
	3	QGS vs ECT	−4.899	<0.001	6.0351	−16.9692~7.1722
	3	4DM vs ECT	−0.7449	<0.001	6.9465	−14.6379~13.1481
End diastolic volume	1	QGS vs 4DM	−6.8065	<0.001	6.2151	−19.2367~5.6237
	1	QGS vs ECT	−9.5163	<0.001	7.7983	−25.0922~6.0603
	1	4DM vs ECT	−2.7097	0.100	8.8964	−20.5025~15.0831
	2	QGS vs 4DM	−14.0986	<0.001	10.4378	−34.9742~6.777
	2	QGS vs ECT	−10.0423	<0.001	9.5819	−29.2061~9.1215
	2	4DM vs ECT	4.0563	0.003	10.2049	−16.3535~24.4661
	3	QGS vs 4DM	−16.5714	<0.001	14.3592	−45.2898~12.147
	3	QGS vs ECT	−10.2950	<0.001	12.6705	−35.6360~15.0451
	3	4DM vs ECT	6.2755	<0.001	15.6602	−25.0450~37.5764

QGS, 4DM and ECT are software programs. See text for details.

Group 1: small heart (n=31)
Group 2: normal perfusion scan (n=71)
Group 3: Perfusion defects (n=98)



	Surface Models					
	Reference	Model	Potential	Reported	Type of Input	Type of Feature
Continuous	Taratorin [98, 99]	Stacked curves	BA	BA	M2DP	manual contours
	Young [60, 100]	Bicubic Hermite patches	BA	BA	PS	coronary bifurcation points
	Spinale [101]	Stacked hemiellipses	BA	BA	M2DP	manual contours
	Pentland [102]	FE and modal analysis	NS	X	M2DP	optic flow
	Cauvin [103]	Truncated bullet	NS	SPECT	3DV	thresh. + morphol. skeleton
	Czegledy [104]	Stack of concentric outlines	NS	CT	3DV	linear measurements
	Gustavsson [105]	Cubic B-spline curves' mesh	US	US	MO2DS	manual contours
	Sacks [106]	Biquadric surface patches	NS	MR	3DV	manual contours
	Chen [107]	Superquadrics + spher. harmon.	NS	BA	PS	coronary bifurcation points
	Denslow [108]	Ellipsoidal shell	NS	MR	3DV	linear measurements
	Mashio [28]	Bicubic spline surface patches	NS	US	MO2DS	edge detection + manual correction
	Chen [109]	Voxel repres. / superquadric	NS	DSR	3DV	shape & grey-level properties
	Coppini [27]	Spherical elastic surface	NS	US	MO2DS	NN edge detector
	[illegible] [110]	Rational Gaussian surface	NS	MR	3DV	zero-crossings Laplacian
	Matheny [111]	2-D/3-D harmonic surfaces	NS	DSR/BA	PS	iso-surface, coronary bifurcation points
	Staib [112]	Bayesian Fourier surface	NS	MR/DSR	3DV	Gaussian gradient
	Park [8]	Superquadrics + par. functions	MR-tag	MR-tag	PS	MR tagging-derived mid-wall motion field [88]
	Bardinet [6, 113]	Superquadrics + FFD	NS	DSR/SPECT	PS	iso-surfaces
	Declerck [114]	Planispheric transformation	NS	SPECT	3DV	normalized radial gradient
	Sato [115]	B-spline surface	BA	BA	M2DP	apparent/occluding contours
Discrete	Geiser [116, 117]	12-sided stacked polygons	US	US	MO2DS	manual contours
	Faber [118]	4-D discrete template	NS	MR/SPECT	3DV	normalized radial gradient
	Gopal [95]	Polyhedral mesh	NS	US	MO2DS	manual contours
	[illegible] [119]	Triangulated mesh	NS	MR	PS	manual contours
	Huang [120]	Adaptive-size mesh	NS	DSR	PS	[illegible] distance + [illegible]
	Faber [121]	3D discrete template	SPECT	SPECT	3DV	radioactive distrib. profile
	Germano [122, 123]	Ellipsoid + local refinement	SPECT	SPECT	3DV	radioactive distrib. profile
	McInerney [124]	FE deformable balloon	NS	DSR	3DV	Gauss/Monga-Deriche grad.
	Ranganath [125]	2D snakes + propagation	MR	MR	3DV	intensity profile matching
	Tu [126]	Spherical template	NS	DSR	3DV	spatio-temporal gradient
	Nastar [127]	Mass-spring mesh	NS	DSR	3DV	edge distance map
	Rueckert [128]	Geom. Def. Template	NS	MR	3DV	zero-crossings Laplacian
	Shi [129, 130]	Delaunay triangulation	NS	MR/DSR	PS	bending energy
	Leggett [96]	Piecewise subdivision surface	NS	US	MO2DS	manual contours
	Montagnat [131]	Simplex meshes	US	US	MO2DS	edges in cylindrical coord.
	[illegible] [132]	Bullet-like elastic mesh	SPECT	SPECT	3DV	radioactive distrib. profile
Implicit	Yezzi [133, 134]	Implicit snakes	NS	MR	3DV	Gaussian gradient
	[illegible] [135]	Cont. Dist. Transf. NN	NS	US	MO2DS	manual contours
	Niessen [136]	Implicit snakes	NS	MR/DSR	3DV	Gaussian gradient



MEMO

MEMO