UNIVERSITÀ
DEGLI STUDI
FIRENZE

FLORE

Repository istituzionale dell'Università degli Studi di Firenze

Evaluation of the influence of age and gender on the relationships between infarct size, infarct severity, and left ventricular ejection

Questa è la Versione finale referata (Post print/Accepted manuscript) della seguente pubblicazione:

Original Citation:

Evaluation of the influence of age and gender on the relationships between infarct size, infarct severity, and left ventricular ejection fraction in patients successfully treated with primary percutaneous coronary intervention / R.Sciagra'; G.Parodi; A.Migliorini; G.Memisha; D.Antoniucci; A.Pupi.. - In: JOURNAL OF NUCLEAR CARDIOLOGY. - ISSN 1071-3581. - STAMPA. - 17:(2010), pp. 444-449. [10.1007/s12350-010-9213-7]

Availability:

This version is available at: 2158/386240 since: 2019-10-09T13:34:13Z

Published version:

DOI: 10.1007/s12350-010-9213-7

Terms of use:

Open Access

La pubblicazione è resa disponibile sotto le norme e i termini della licenza di deposito, secondo quanto stabilito dalla Policy per l'accesso aperto dell'Università degli Studi di Firenze (<https://www.sba.unifi.it/upload/policy-oa-2016-1.pdf>)

Publisher copyright claim:

(Article begins on next page)

Evaluation of the influence of age and gender on the relationships between infarct size, infarct severity, and left ventricular ejection fraction in patients successfully treated with primary percutaneous coronary intervention

Roberto Sciagrà, MD,^a Guido Parodi, MD,^b Angela Migliorini, MD,^b
Gentian Memisha, MD,^b David Antoniucci, MD,^b and Alberto Pupi, MD^a

Background. Female sex and advanced age have adverse prognostic meaning in acute myocardial infarction. Whether gender and/or age influence the relationship between infarct size, infarct severity, and left ventricular ejection fraction (LVEF) is unclear.

Methods. We examined 460 patients (359 men) with acute myocardial infarction submitted to successful primary percutaneous coronary intervention. Infarct size, infarct severity, and LVEF were evaluated with perfusion gated SPECT at one month of index infarction.

Results. There were no significant correlations between age and infarct size or infarct severity, and between age and LVEF. Moreover, elderly age (≥ 75 years) did not influence the relationship between LVEF and infarct size or infarct severity. Conversely, there was a significant gender-related difference in the relationship between LVEF and infarct size ($F = 20.5$, $P < .00001$), and between LVEF and infarct severity ($F = 8.6$, $P < .005$). In practice, there was a steeper decrease in LVEF in case of moderate to large infarct size in women than in men.

Conclusion. With increasing infarct size, LVEF decreases more sharply in women than in men. Conversely, age does not influence the relationship between infarct dimensions and LVEF. (J Nucl Cardiol 2010)

Key Words: Age • gated SPECT • gender • infarct size • infarct severity • left ventricular ejection fraction

INTRODUCTION

Age is an independent adverse prognostic factor in patients with acute myocardial infarction.¹⁻³ The use of primary percutaneous coronary intervention (PCI) has improved the prognosis in elderly patients, but age remains an unfavorable predictor also in this setting.⁴⁻⁹ The mechanisms through which age influences the prog-

nosis are still uncertain. Risk factor profile, angiographic variables and the rate of PCI success do not completely explain the worse prognosis of older patients.^{6,7} Whether a larger final infarct size could play a role is unclear. Previous echocardiographic data suggested that elderly patients had a larger infarct zone.¹⁰ However, studies using Tc-99m-sestamibi imaging in the thrombolytic era suggested that older patients did not show larger infarct size nor a significantly lower left ventricular ejection fraction (LVEF), although their prognosis was worse than in their younger counterparts.^{11,12}

As regards gender, it is known that women show a worse prognosis than men, but this is seemingly related to older age, high-risk factor profile, and unfavorable angiographic features and not to an intrinsic adverse prognostic meaning of female sex.^{13,14} Furthermore, previous data suggest that female sex is associated with a smaller infarct size.^{15,16} However, the interaction between gender, infarct size, and LVEF has not been established.

From the Nuclear Medicine Unit, Department of Clinical Physiopathology,^a University of Florence, Florence, Italy; Division of Cardiology,^b Careggi Hospital, Florence, Italy.

Received for publication Aug 6, 2009; final revision accepted Feb 28, 2010.

Reprint requests: Roberto Sciagrà, MD, Nuclear Medicine Unit, Department of Clinical Physiopathology, University of Florence, Viale Morgagni 85, 50134 Florence, Italy; r.sciagra@dfc.unifi.it. 1071-3581/\$34.00

Copyright © 2010 by the American Society of Nuclear Cardiology. doi:10.1007/s12350-010-9213-7

Currently, gated SPECT is the state-of-the-art modality for myocardial perfusion scintigraphy.¹⁷ This method allows the assessment of left ventricular (LV) function during a perfusion scan, and has been reported to be accurate and reproducible.¹⁸⁻²³ In a previous study, we had demonstrated that the relationship between infarct size, infarct severity, and LV functional parameters, all simultaneously derived from a single gated SPECT, is significantly related to the infarct location.²⁴ Aim of the present study was to evaluate whether the relationships of infarct size and severity vs. LVEF were somehow influenced by age and/or gender in patients submitted to successful primary PCI for acute myocardial infarction.

MATERIALS AND METHODS

Patient Population and Study Protocol

The patient population included consecutively the patients admitted from January 2001 until May 2008 to our Cardiology Department because of their first acute myocardial infarction within 6 hours of symptom onset who were submitted to successful primary percutaneous coronary intervention with stenting of the infarct-related vessel, and who were then referred to our Nuclear Medicine laboratory for the assessment of infarct size at one-month. The diagnosis of acute myocardial infarction required the presence of typical chest pain lasting more than 30 minutes together with >0.1 mV ST segment elevation in at least two contiguous electrocardiographic leads. Successful primary percutaneous coronary intervention was defined as Thrombolysis In Myocardial Infarction (TIMI) grade 3 coronary flow in the treated vessel with a residual stenosis $<20\%$.²⁵ ST-segment elevation resolution was evaluated at 30 minutes after PCI.²⁶ All patients underwent a control angiography at least one-month after index infarction to exclude the occurrence of restenosis of the infarct-related artery. Six-month follow up data were obtained by outpatient visit or telephone interview, and the occurrence of hard events (cardiac death, nonfatal myocardial infarction, hospitalization for congestive heart failure) was registered.

Gated SPECT

Gated SPECT acquisition began 60 minutes after resting ^{99m}Tc -sestamibi injection (740 MBq), using a double-head camera (either Picker Irix, Philips Medical System, Andover, MA, USA or SKYlight, Philips Medical Systems, Milpitas, CA, USA) equipped with high-resolution collimators, 180° rotation arc, 34 projections, 60 seconds/projection, 8-frames/heart cycle, 64×64 matrices. The studies were reconstructed using filtered backprojection without attenuation or scatter correction and realigned along the heart axis. Infarct size was measured from representative short-axis circumferential count profile curves, with the defect threshold set at 60% of peak uptake.^{24,27} Perfusion defects were identified as infarcted

myocardium and expressed as a percentage of the LV.^{24,27} In case of detectable perfusion defects, infarct severity was defined as the lowest minimal/maximal counts ratio in the short-axis slices examined for infarct size evaluation; therefore, the lower the ratio the more severe the defect.^{24,27-30} The measurement of LVEF was performed by an automated and validated method.¹⁸

Statistical Analysis

Variables are expressed as mean value $\pm$ standard deviation or as median (25th, 75th percentile) as appropriate. The correlation between continuous variables was calculated using the Pearson's correlation coefficient. The comparisons between groups were performed by the Student *t* test for unpaired samples with the Bonferroni correction or the Mann-Whitney *U* test as appropriate. The comparison of proportions was made with the Fisher exact test. The relationships between gender, age, infarct size, infarct severity, and LVEF were analyzed with stepwise multiple linear regression analysis and the analysis of covariance (ANCOVA). The predictors of events at follow up were evaluated using the Cox proportional hazard model. Survival curves were constructed using the Kaplan-Meier method and compared with the log-rank test. A *P* value <0.05 was considered statistically significant.

RESULTS

The study cohort included 460 patients (359 men and 101 women, mean age 64 ± 12 years, range 23-93). The mean interval between index infarction and gated SPECT was 35 ± 7 days. At the time of gated SPECT all patients were asymptomatic. Table 1 summarizes the main features of the patient population and compares them in men vs. women. Female patients were significantly older, and more frequently hypertensive. Their infarct size was significantly smaller and infarct significantly less severe than those of male patients, and their LVEF significantly higher.

Table 2 compares the features of elderly (≥ 75 years) patients vs. the other patients. Patients in the older age group were more frequently female, had a more severe risk factor profile as regards hypertension and cholesterol, a more severe coronary artery disease pattern with higher prevalence of multivessel disease, and a more severe clinical presentation as indicated by the incidence of Killip class $> I$. The infarct size and the infarct severity were similar in the two age groups. The LVEF was comparable as well.

In the whole patient population there was a significant inverse correlation between infarct size and LVEF ($r = -.643$, $P < .00001$) and a significant correlation between infarct severity and LVEF ($r = .639$, $P < .00001$). There were no correlations between age

Table 1. Features of the patient population divided according to gender

	Males (n = 359)	Females (n = 101)	P
Age, years, mean $\pm$ SD	62.3 $\pm$ 11.5	71.2 $\pm$ 11.9	<.0001
Family history of coronary artery disease, n (%)	29 (8)	6 (6)	NS
Systemic hypertension, n (%)	137 (38)	56 (55)	<.005
Hypercholesterolemia (total cholesterol >200 mg/dL), n (%)	140 (39)	32 (32)	NS
Recent history of past smoking or current smoker, n (%)	143 (40)	28 (28)	<.05
Diabetes mellitus, n (%)	40 (11)	19 (19)	NS
Time interval symptoms—PCI, min, mean $\pm$ SD	185 $\pm$ 80	202 $\pm$ 87	NS
Anterior infarct location, n (%)	152 (42)	36 (36)	NS
Killip class > I, n (%)	42 (12)	19 (19)	NS
Multivessel coronary artery disease, n (%)	138 (38)	44 (44)	NS
Collateral Rentrop grade $\geq$ 1, n (%)	39 (11)	8 (8)	NS
TIMI grade before PCI, median (25th, 75th percentile)	0 (0,0)	0 (0,1)	NS
Baseline ST-segment elevation, mm, median (25th, 75th percentile)	3 (2,5)	3 (2,4)	<.05
30-minute ST-segment elevation, mm, median (25th, 75th percentile)	1 (0,2)	1 (0,2)	NS
ST-segment elevation resolution, %, mean $\pm$ SD	67.4 $\pm$ 28.1	69.9 $\pm$ 30.8	NS
Infarct size, %, mean $\pm$ SD	18.1 $\pm$ 14	8.8 $\pm$ 10	<.0001
Infarct severity, mean $\pm$ SD	0.43 $\pm$ 0.13	0.50 $\pm$ 0.13	<.0001
LVEF, %, mean $\pm$ SD	46.2 $\pm$ 10.9	54.6 $\pm$ 13.8	<.0001

Table 2. Features of the patient population divided according to age

	Age < 75 years (n = 362)	Age $\geq$ 75 years (n = 98)	P
Female sex, n (%)	56 (15)	45 (45)	<.00001
Family history of coronary artery disease, n (%)	34 (9)	1 (1)	<.005
Systemic hypertension, n (%)	138 (38)	55 (56)	<.003
Hypercholesterolemia (total cholesterol >200 mg/dL), n (%)	148 (41)	24 (24)	<.005
Recent history of past smoking or current smoker, n (%)	164 (45)	7 (7)	<.00001
Diabetes mellitus, n (%)	42 (12)	17 (17)	NS
Time interval symptoms—PCI, min, mean $\pm$ SD	186 $\pm$ 82	199 $\pm$ 82	NS
Anterior infarct location, n (%)	152 (42)	36 (37)	NS
Killip class > I, n (%)	38 (10)	23 (23)	<.002
Multivessel coronary artery disease, n (%)	130 (36)	52 (53)	<.005
Collateral Rentrop grade $\geq$ 1, n (%)	41 (11)	6 (6)	NS
TIMI grade before PCI, median (25th, 75th percentile)	0 (0,0)	0 (0,2)	NS
Baseline ST-segment elevation, mm, median (25th, 75th percentile)	3 (2,5)	3 (2,4.125)	NS
30-minute ST-segment elevation, mm, median (25th, 75th percentile)	1 (0,2)	1 (0,2)	NS
ST-segment elevation resolution, %, mean $\pm$ SD	69.4 $\pm$ 27.7	62.7 $\pm$ 31.8	NS
Infarct size, %, mean $\pm$ SD	16.7 $\pm$ 14.1	13.8 $\pm$ 12.6	NS
Infarct severity, mean $\pm$ SD	0.44 $\pm$ 0.13	0.46 $\pm$ 0.13	NS
LVEF, %, mean $\pm$ SD	47.5 $\pm$ 11.6	50 $\pm$ 13.6	NS

and infarct size or infarct severity, and between age and LVEF.

According to stepwise multiple regression analysis examining gender and all other parameters listed in Table 1 that were significantly different between the gender groups, the significant predictors of LVEF were infarct severity, infarct size, gender, and baseline ST segment elevation, with a final model adjusted $R^2 = .470$ (Table 3). ANCOVA demonstrated a significant effect of gender on the relationship between LVEF, infarct size, and infarct severity: $F = 12.4$ ($P < .0005$) when both covariates were considered together, $F = 10$ ($P < .002$), and $F = 19$ ($P < .00002$), respectively, for infarct size and infarct severity examined separately. The ANCOVA test for parallelism showed a significant difference in the relationship between LVEF, infarct size, and infarct severity between males and females: $F = 7$ ($P < .001$). The difference was larger for the relationship between LVEF and infarct size than for that between LVEF and infarct severity: $F = 20.5$ ($P < .00001$) and $F = 8.6$ ($P < .005$), respectively. These data indicate that the relationship between LVEF and infarct size, and to a minor degree that between LVEF and infarct severity, are modulated by gender. As shown in Figure 1, the relationship between infarct size and LVEF appears clearly steeper in women than in men, with small infarcts showing higher LVEF and larger ones lower LVEF in female than in male patients.

As regards age, including in stepwise multiple regression analysis the age group and all variables listed in Table 2 that were significantly different between elderly and other patients, the significant predictors of LVEF were infarct severity, infarct size, Killip class > 1 , and gender, with a final model adjusted $R^2 = .480$ (Table 4). ANCOVA did not demonstrate age-related differences in the relationship between LVEF, and infarct size and infarct severity, neither examined together nor separately.

During follow up (192 ± 49 days) 10 hard events (5 cardiac death, 3 non-fatal myocardial infarctions, and 2 hospitalizations for congestive heart failure) were

Table 3. Significant predictors of LVEF selected by multivariate analysis from the variables that were significantly different between men and women

	F value	P
Infarct severity size	324	<.00001
Infarct size	28	<.00001
Gender	12	<.00001
Baseline ST elevation	9	<.005
Adjusted R^2 of the model = .470

Figure 1. Scatter plot of infarct size vs. LVEF. Open circles indicate men, and closed circles women. The lines represent the slopes of linear regression for men (dashed line), and women (solid line).

Table 4. Significant predictors of LVEF selected by multivariate analysis from the variables that were significantly different between young and elderly patients

	F value	P
Infarct severity size	324	<.00001
Infarct size	28	<.00001
Killip class > 1	14	<.00001
Gender	16	<.00001
Adjusted R^2 of the model = .480		

registered. As expected because of the small number of events, there were no differences in the Kaplan-Meier survival curves when the patient population was divided according to gender or to age group. In the Cox proportional hazard model including age, gender, LVEF, infarct size, and infarct severity, LVEF was selected as the sole significant event predictor ($\chi^2 = 11.9$, $P < .001$).

DISCUSSION

LVEF is certainly a major prognostic factor in acute myocardial infarction patients.³¹ Infarct dimensions are major determinants of the functional impairment after acute myocardial infarction, as shown by their close (inverse) relationship with the post-infarction LVEF.³¹ This relationship is certainly influenced by other

variables, as for instance infarct location.²⁴ If a parameter causes a more severe decrease in LVEF for the same degree of infarct size or infarct severity this could be a contributory mechanism for its adverse prognostic meaning. Both female sex and old age have been related to worse prognosis after acute myocardial infarction.¹⁻¹⁴ As regards gender, various data suggest that it is not an independent adverse prognosticator, but that it is frequently related to high-risk profile and worse coronary angiographic pattern.^{13,14} On the other hand, the reasons why elderly patients have a worse prognosis even after successful reperfusion are not completely clear, and apparently neither larger infarct size nor lower LVEF are involved as causative mechanisms.^{11,12} On these premises, we tried to verify whether gender and older age influence the relationship between infarct dimensions and LVEF.

Our results confirm that in patients successfully reperfused with primary PCI advanced age is not related to differences in infarct size, infarct severity, and LVEF. Moreover, there are no differences in the relationships between indicators of infarct dimensions and LVEF based on age as a continuous variable or on advanced age as a dichotomous parameter.

In the same clinical setting, women as a group are confirmed to have significantly smaller and less severe infarctions and higher LVEF than men. However, in our series gender emerges as a significant predictor of LVEF even after correcting for infarct size, infarct severity and the other variables that are different between women and men. In particular, gender modulates the relationship between infarct size (and to a more limited degree, infarct severity) and LVEF. Apparently, females have a steeper decrease of LVEF with increasing infarct size. In part, this can be explained by the high LVEF values registered in women with negligible or small infarctions, a circumstance possibly related also to gated SPECT overestimation of LVEF in small hearts.³² However, for infarcts of moderate to large extent (as shown in Figure 1, infarct size > approximately 20%) in women there is a trend to a more severe impairment of LVEF than in men. Because of the essential prognostic role of LVEF in acute myocardial infarction patients, which is confirmed also in our small cohort, this could be a contributing factor for explaining the worse prognosis of women after acute myocardial infarction. Naturally, studies on much larger patient populations are needed to confirm this hypothetic connection among gender, infarct size, LVEF, and prognosis.

The results of the present study must be evaluated taking into account its limitations. Our patient population was selected because included only patients with successful early primary PCI. Therefore, different results could be possible in patients submitted to less

effective reperfusion strategies. Furthermore, the very low event rate obtained because of the aggressive treatment, and the short-term follow up preclude a reliable analysis of the prognostic factors. The lack of follow up data with regard to ventricular volumes and function is another major limitation. Certainly the demonstration of more frequent and extensive left ventricular remodeling in women would add a most important link between gender and adverse prognosis.

CONCLUSION

Our data suggest that age has no influence on the relationship between post-infarction myocardial damage and left ventricular function. Conversely, this relationship is influenced by gender, with women showing the trend to a worse functional response with increasing infarct size.

References

1. Tofler GH, Muller JE, Stone PH, Willich SN, Davis VG, Poole WK, et al. Factors leading to shorter survival after acute myocardial infarction in patients ages 65 to 75 years compared with younger patients. *Am J Cardiol* 1988;62:860-7.
2. Maggioni AP, Maseri A, Fresco C, Franzosi MG, Mauri F, Santoro E, The Investigators of the Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto Miocardico (GISSI-2), et al. Age-related increase in mortality among patients with first myocardial infarction treated with thrombolysis. *N Engl J Med* 1993;329:1442-8.
3. White HD, Barbash GI, Califf RM, Simes RJ, Granger CB, Weaver WD, et al. Age and outcome with contemporary thrombolytic therapy: Results from the GUSTO-I trial: Global Utilization of Streptokinase and TPA for Occluded Coronary Arteries Trial. *Circulation* 1996;94:1826-33.
4. Berger AK, Schulman KA, Gersh BJ, Pizada S, Breall JA, Johnson AE, et al. Primary coronary angioplasty vs thrombolysis for the management of acute myocardial infarction in elderly patients. *JAMA* 1999;282:341-8.
5. Mehta RH, Sadiq I, Goldberg RJ, Gore JM, Avezum A, Spencer F, GRACE Investigators, et al. Effectiveness of primary percutaneous coronary intervention compared with that of thrombolytic therapy in elderly patients with acute myocardial infarction. *Am Heart J* 2004;147:253-9.
6. DeGeare VS, Stone GW, Grines L, Brodie BR, Cox DA, Garcia E, et al. Angiographic and clinical characteristics associated with increased in-hospital mortality in elderly patients with acute myocardial infarction undergoing percutaneous intervention (a pooled analysis of the primary angioplasty in myocardial infarction trials). *Am J Cardiol* 2000;86:30-4.
7. Prasad A, Stone GW, Aymong E, Zimetbaum PJ, McLaughlin M, Mehran R, et al. Impact of ST-segment resolution after primary angioplasty on outcomes after myocardial infarction in elderly patients: An analysis from the CADILLAC trial. *Am Heart J* 2004;147:669-75.
8. Halkin A, Singh M, Nikolsky E, Grines CL, Tchong JE, Garcia E, et al. Prediction of mortality after primary percutaneous coronary intervention for acute myocardial infarction: The CADILLAC risk score. *J Am Coll Cardiol* 2005;45:1397-405.

9. Parodi G, Memisha G, Valenti R, Trapani M, Migliorini A, Santoro GM, et al. Five year outcome after primary coronary intervention for acute ST elevation myocardial infarction: Results from a single centre experience. *Heart* 2005;91:1541-4.
10. Smart S, Sagar K, Tresch D. Age-related determinants of outcome after acute myocardial infarction: A dobutamine-atropine stress echocardiographic study. *J Am Geriatr Soc* 2002;50:1176-85.
11. Miller TD, Christian TF, Hodge DO, Hopfenspirger MR, Gersh BJ, Gibbons RJ. Comparison of acute myocardial infarct size to two-year mortality in patients < 65 to those ≥ 65 years of age. *Am J Cardiol* 1999;84:1170-5.
12. Miller TD, Piegas LS, Gibbons RJ, Yi C, Yusuf S. Role of infarct size in explaining the higher mortality in older patients with acute myocardial infarction. *Am J Cardiol* 2002;90:1370-4.
13. De Luca G, Suryapranata H, Dambrink JH, Ottervanger JP, van 't Hof AW, Zijlstra F, et al. -related differences in outcome after ST-segment elevation myocardial infarction treated by primary angioplasty: Data from the Zwolle Myocardial Infarction study. *Am Heart J* 2004;148:852-6.
14. Antonucci D, Valenti R, Moschi G, Migliorini A, Trapani M, Santoro GM, et al. Sex-based differences in clinical and angiographic outcomes after primary angioplasty or stenting for acute myocardial infarction. *Am J Cardiol* 2001;87:289-93.
15. Stone GW, Dixon SR, Grines CL, Cox DA, Webb JG, Brodie BR, et al. Predictors of infarct size after primary coronary angioplasty in acute myocardial infarction from pooled analysis from four contemporary trials. *Am J Cardiol* 2007;100:1370-5.
16. Mehilli J, Ndrepepa G, Kastrati A, Nekolla SG, Markwardt C, Bollwein H, et al. Gender and myocardial salvage after reperfusion treatment in acute myocardial infarction. *J Am Coll Cardiol* 2005;45:828-31.
17. ASNC Executive Council. American Society of Nuclear Cardiology position statement on electrocardiographic gating of myocardial perfusion SPECT scintigrams. *J Nucl Cardiol* 1999; 6:470-1.
18. Germano G, Kiat H, Kavanagh PB, Moriel M, Mazzanti M, Su HT, et al. Automatic quantification of ejection fraction from gated myocardial perfusion SPECT. *J Nucl Med* 1995;36:2138-47.
19. Williams KA, Taillon LA. Left ventricular function in patients with coronary artery disease assessed by gated tomographic myocardial perfusion images. Comparison with assessment by contrast ventriculography and first-pass radionuclide angiography. *J Am Coll Cardiol* 1996;27:173-81.
20. Cwajg E, Cwajg J, He ZX, Hwang WS, Keng F, Nagueh SF, et al. Gated myocardial perfusion tomography for the assessment of left ventricular function and volumes: Comparison with echocardiography. *J Nucl Med* 1999;40:1857-65.
21. Nichols K, Lefkowitz D, Faber T, Folks R, Cooke D, Garcia EV, et al. Echocardiographic validation of gated SPECT ventricular function measurements. *J Nucl Med* 2000;41:1308-14.
22. Vaduganathan P, He ZX, Vick GW 3rd, Mahmarian JJ, Verani MS. Evaluation of left ventricular wall motion, volumes and ejection fraction by gated myocardial tomography with technetium 99m-labeled tetrofosmin: A comparison with cine magnetic resonance imaging. *J Nucl Cardiol* 1999;6:3-10.
23. Mansoor MR, Heller GV. Gated SPECT imaging. *Semin Nucl Med* 1999;29:271-8.
24. Sciagrà R, Imperiale A, Antonucci D, Migliorini A, Parodi G, Comis G, et al. Relationship of infarct size and severity versus left ventricular ejection fraction and volumes obtained from 99mTc-sestamibi gated single-photon emission computed tomography in patients treated with primary percutaneous coronary intervention. *Eur J Nucl Med Mol Imaging* 2004;31:969-74.
25. Parodi G, Valenti R, Carrabba N, Memisha G, Moschi G, Migliorini A, et al. Long-term prognostic implications of non-optimal primary angioplasty for acute myocardial infarction. *Cath Cardiovasc Interv* 2006;68:50-5.
26. Santoro GM, Antonucci D, Valenti R, Bolognese L, Buonamici P, Trapani M, et al. Rapid reduction of ST-segment elevation after successful direct angioplasty in acute myocardial infarction. *Am J Cardiol* 1997;80:685-9.
27. O'Connor MK, Hammel T, Gibbons RJ. In vitro validation of a simple tomographic technique for estimation of percentage myocardium at risk using methoxyisobutyl isonitrile technetium 99m (sestamibi). *Eur J Nucl Med* 1990;17:69-76.
28. Christian TF, Schwartz RS, Gibbons RJ. Determinants of infarct size in reperfusion therapy for acute myocardial infarction. *Circulation* 1992;86:81-90.
29. Christian TF, O'Connor MK, Schwartz RS, Gibbons RJ, Ritman EL. Technetium-99m MIBI to assess coronary collateral flow during acute myocardial infarction in two closed-chest animal models. *J Nucl Med* 1997;38:1840-6.
30. Christian TF, Berger PB, O'Connor MK, Hodge DO, Gibbons RJ. Threshold values for preserved viability with a noninvasive measurement of collateral blood flow during acute myocardial infarction treated by direct coronary angioplasty. *Circulation* 1999;100:2392-5.
31. Burns RJ, Gibbons RJ, Yi Q, Roberts RS, Miller TD, Schaer GL, et al. The relationships of left ventricular ejection fraction, end-systolic volume index and infarct size to six-month mortality after hospital discharge following myocardial infarction treated by thrombolysis. *J Am Coll Cardiol* 2002;39:30-6.
32. Khalil MM, Elgazzar A, Khalil W, Omar A, Ziada G. Assessment of left ventricular ejection fraction by four different methods using 99mTc tetrofosmin gated SPECT in patients with small hearts: Correlation with gated blood pool. *Nucl Med Commun* 2005; 26:885-93.