Movements of Magnesium, Zinc, Calcium, Potassium, Cholesterols and Creatine Kinase in Men and Women during the twelve Days following acute myocardial Infarction. Correlation and regression Studies

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Zusammenfassung

Da beim akuten Myocardinfarkt biologische Beziehungen zwischen verschiedenen Variablen vermutet werden, bestimmten wir bei 34 Männern und 8 Frauen bei Krankenhausaufnahme und dann an den Tagen: 2, 3, 6, 10 und 12 die folgenden Parameter in Plasma (P) und/oder Erythrocyten (E): Magnesium (P-Mg; E-Mg) Zink (P-Zn; E-Zn); Calcium (P-Ca), Kalium (E-K), Gesamt- und HDL-Cholesterin sowie die Gesamt-Creatin-Kinase. Die Gruppen wurden untereinander (Tag 1) sowie mit Werten von 58 bzw. 53 gesunden Männern und Frauen verglichen.
Veränderungen der verschiedenen Variablen (Tag 1 – 12) wurden mittels Varianzanalyse, wiederholten Vergleichen oder dem Test nach *Friedman* analysiert. Bei den Männern mit Myocardinfarkt waren in der Zeit vom 1. bis 12. Tag alle Variablen signifikant verändert; bei den Frauen blieben P-Ca, E-Zn sowie Gesamt- und HDL-Cholesterin unverändert.
Auf Grund zwischen diesen Variablen vermuteter Beziehungen wurden einfache, Spearman und multiple Korrelationskoeffizienten berechnet sowie schrittweise Regressionen mit P-Mg oder E-Mg als abhängige Variablen überprüft. Die schrittweisen Regressionsberechnungen ergaben erhebliche Unterschiede für beide Patientenkollektive während der Tage 1 bis 12 und sind Ausdruck der durch den Streß des Infarktes verursachten metabolischen und hormonellen Veränderungen.

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Summary

The supposed biological relations between different variables in acute myocardial infarction (MI) led us to determine plasma (P) and/or erythrocyte (E) concentrations of magnesium (P-Mg; E-Mg), zinc (P-Zn; E-Zn), calcium (P-Ca), potassium (E-K), total- and HDL-cholesterols and total creatine kinase in 34 men and 8 women upon admission to hospital and then on days 2, 3, 6, 10 and 12. On day 1, these two groups were compared with each other and then with 58 reference men or 53 reference women.
The changes in the different variables from day 1 to day 12 were analyzed by one-way ANOVA, with repeated measurements or by the *Friedman* test. In MI men, from day 1 to day 12, all variables were significantly modified. In MI women, P-Ca, E-Zn, total- and HDL-cholesterols remained unchanged.
In view of the probable relationships between these different variables we calculated simple, Spearman, and multiple correlation coefficients and stepwise regression equations with P-Mg or E-Mg as dependent variables. These stepwise regression equations differed greatly in both groups of patients from day 1 to day 12 as a result of metabolic and hormonal changes in response to stress caused by MI.

Résumé

Après un infarctus aigu du myocarde (IM), les relations biologiques supposées entre différentes variables nous ont conduits à déterminer les concentrations plasmatiques (P) et/ou érythrocytaires (E) du magnésium (Mg-P; Mg-E), du zinc (Zn-P; Zn-E), du calcium (Ca-P), du potassium (K-E), des cholestérols total et HDL et de la créatine-kinase de 32 hommes et 8 femmes, dès l'arrivée à l'hopital, puis aux jours 2, 3, 6, 10 et 12. Au jour 1, ces deux groupes ont été comparés entre eux puis à 58 hommes ou 53 femmes de référence.
Les changements des différentes variables du jour 1 au jour 12 ont été analysés par l'ANOVA à un facteur, mesures répétées ou selon le test de *Friedman*. Chez les hommes IM, du jour 1 au jour 12, toutes les variables évoluaient significativement. Chez les femmes IM, le Ca-P, le Zn-E et les cholestérols total et HDL demeurèrent inchangés.
Compte tenu des relations probables entre ces différentes variables, nous avons calculé les coefficients de corrélation simple, de Spearman et multiple ainsi que les équations de régression pas à pas, Mg-P ou Mg-E représentant les variables dépendantes. Ces équations de régression pas à pas différaient beaucoup, dans les deux groupes de malades, du jour 1 au jour 12, du fait de perturbations métaboliques et hormonales consécutives au stress de l'IM.

Introduction

Magnesium, zinc, calcium, potassium and various lipidic fractions are involved in cardiovascular pathology [1 – 3]. In previous studies our team noted a generalized significant lowering of magnesium level in the heart ventricles after myocardial infarction (MI) [4] as well as a rise in plasma and erythrocyte magnesium on the twelfth day after the attack [5]. However, the nature of the changes between the first and twelfth day, and the relations between magnesium and other variables, remained unclear. The purpose of the present study was to investigate changes in the concentrations of certain variables after MI and to carry out multivariant analysis. Accordingly, plasma (P) and/or erythrocyte (E) levels of magnesium (P-Mg; E-Mg), zinc (P-Zn; E-Zn), calcium (P-Ca), potassium (E-K), total- and HDL-cholesterols and creatine kinase (CK, EC 2.7.3.2) were measured in two groups of patients admitted to hospital with MI on days (D) 1, 2, 3, 6, 10 and 12. On D1, groups of men and women patients were compared with each other and then with reference groups of men and women. Owing to the recognized importance of Mg in coronary artery diseases [6 – 8], and in view of possible relationships between the variables, simple, Spearman and multiple correlations were computed as well as stepwise regression equations, with P-Mg or E-Mg as dependent variable.

Populations and Methods

Populations

Samples were obtained from 153 white subjects (42 patients with acute myocardial infarction and 111 reference subjects), all residents of the Nantes area in France, a region supplied with soft tap water. The 42 patients (34 MI men, 32 to 82 years of age and 8 MI women, 62 to 74 years of age were hospitalized in an intensive care unit for MI with clinical, biological and electrical signs. During the 12 days of the study these patients were treated intravenously with heparin and nitroglycerine. Appropriate reference subjects (58 men, 53 women) selected and analyzed at the same time were neither blood donors nor hospitalized patients, were free of metabolic or cardiovascular problems and were not receiving any form of medicine.

Assay Techniques

Blood specimens (5 ml) were drawn into Terumo Venoject Tubes (Ref. T 206 LH, Code VT 050 HL 1) containing lithium heparin (Terumo France, 78181 Saint-Quentin-en-Yvelines, France). On the first day, specimens were always taken from patients upon admission to hospital (1 to 3 hours after the first pains). On subsequent days (2, 3, 6, 10 and 12) blood was collected between 0800 and 0900 from fasting patients (conditions were the same for reference subjects).
Magnesium, Ca and Zn were analyzed by flame atomic absorption spectrometry using a Hitachi 180 – 80 model with Zeeman effect (Skalar Analytique, 75015 Paris, France). Potassium was measured by emission spectrometry using the same apparatus. HDL-cholesterol (Precipitant: phosphotungstic acid and Mg ions) and total cholesterol were determined by the Boehringer enzymatic colorimetric cholesterol C-system, CHOD-PAP method (Boehringer, Mannheim, F.R.G.). Measurement of CK activity was performed using the R CK NAC-activated Merckotest (Ref. 14317), and CK-MB activity on D1 and D2 using the R CK-MB NAC-activated Merckotest (Ref. 14333) (E. MERCK, 6100 Darmstadt, F.R.G.). The details of the operating procedures have been described previously [9].

Statistical Analysis

The normality of the distributions of results was checked by the chi-square test [10] or the *Shapiro* and *Wilk*'s test [11]. The homogeneity of variances was then verified [10]. The difference between two means was subjected to appropriate parametric (Student's t-test) or non parametric, (*Mann* and *Whitney*) tests [10]. The changes in the different variables from D1 to D12 were analyzed by one-way ANOVA, with repeated measurements, or by the *Friedman* test [12]. Individual means from D1 to D12 were compared by using the least-significant-difference (LSD) method when F was significant [10].
Simple and multiple correlation coefficients were estimated between series of normally distributed results; their significance was tested by t- and F-tests [10, 13]. The *Spearman* correlation coefficient was used in case of nonnormality [10]. Stepwise regression equations [13] for reference subjects and patients (from D1 to D12) were also calculated, with P-Mg or E-Mg chosen as dependent variable. Only normally distributed variables common to patients and reference subjects of the same sex were retained as primary representative variables; in women, because of the small number of MI patients, HDL- and total-cholesterols were excluded.

Results

The different results are given in Tables I to VII. In MI men, from D1 to D12, all variables were significantly changed. In MI women, P-Ca, E-Zn and total- and HDL-cholesterols remained unchanged. The individual comparison of means by LSD indicated the dates of significant changes in concentrations. The vertical square brackets in Tables I and II mark the days of significant variation ($p < 0.05$) in the levels of the different variables. Thus, in men, for P-Mg a first variation occurred on D3 and then, as of D6, the level remained constant.
Sex and MI were significant factors in certain results (Table III).
Only significant ($p \leq 0.05$) simple (r) *Spearman* (r_s) and multiple (R) correlation coefficients are given in Tables IV and V. It is necessary, in MI men, to add

certain results for r_s correlations not shown in table IV between CK and CK-MB ($p < 0.001$) on D1 ($r_s = + 0.872$) and D2 ($r_s = + 0.874$), and between CK-MB and E-Mg ($r_s = + 0.409$; $p < 0.02$), CK-MB and P-Ca ($r_s = - 0.480$; $p < 0.01$), CK-MB and P-Zn ($r_s = - 0.429$; $p < 0.02$), CK-MB and E-K ($r_s = - 0.377$; $p < 0.05$) on D2. In MI women, r_s correlations were significant between CK and CK-MB ($r_s = 0.904$; $p < 0.01$) on D1 and D2 ($r_s = 0.944$; $p < 0.001$), and

Tab. I: Means and standard deviations of the populations for results in 58 reference men and 34 men patients hospitalized after acute myocardial infarction (MI) at days 1, 2, 3, 6, 10 and 12

	Plasma magnesium mmol/l (1)	Erythrocyte magnesium mmol/l (2)	Plasma calcium mmol/l (3)	Plasma zinc µmol/l (4)	Erythrocyte zinc µmol/l (5)	Erythrocyte potassium mmol/l (6)	Total cholesterol mmol/l (7)	HDL-cholesterol mmol/l (8)	Total creatine kinase I.U./l (9)
Reference men (n = 58)	0.77 (0.06)	2.12 (0.25)	2.20 (0.12)	10.8 (2.09)	157 (20.4)	86.7 (9.63)[a]	5.23 (1.08)	1.21 (0.28)	
Myocardial Infarcted men (n = 34)									
day 1	0.76 (0.09)[c]	2.19 (0.25)	2.08 (0.13)	8.07 (1.67)	162 (20.6)	86.3 (5.96)	5.43 (1.07)	1.07 (0.31)	364 (260)
day 2	0.77 (0.09)	2.20 (0.24)	2.08 (0.13)	7.82 (1.77)	162 (19.4)	88.7 (8.17)	5.23 (0.91)	1.09 (0.30)	336 (336)[a]
day 3	0.80 (0.08)	2.21 (0.25)	2.07 (0.16)	7.80 (1.56)	162 (19.6)	88.3 (10.6)	5.03 (0.89)	1.11 (0.28)	129 (108)[a]
day 6	0.86 (0.09)	2.28 (0.27)	2.11 (0.14)	9.29 (1.38)	163 (18.6)	89.4 (7.47)	5.06 (0.78)	0.99 (0.29)	38.8 (22.0)[a]
day 10	0.85 (0.09)	2.36 (0.30)	2.12 (0.15)	10.6 (1.62)	168 (19.6)	88.0 (7.37)	5.21 (0.88)	0.97 (0.32)	27.8 (21.2)[a]
day 12	0.84 (0.08)	2.40 (0.27)	2.15 (0.13)	10.7 (1.36)	168 (19.0)	90.1 (7.83)[a]	5.20 (0.78)	0.98 (0.26)	24.1 (13.1)[a]
ANOVA[b])	$p<0.001$	$p<0.001$	$p<0.01$	$p<0.001$	$p<0.05$		$p<0.05$	$p<0.001$	
Friedman test						$p<0.05$			$p<0.001$

[a] Nonnormal distribution.
[b] One-way analysis of variance, repeated measurements, from day 1 to day 12.
[c] Individual comparison of means by the least significant difference (days with significant variation: $p<0.05$).

Tab. II: Means and standard deviations of the populations for results in 53 reference women and 8 women patients hospitalized after acute myocardial infarction at days 1, 2, 3, 6, 10 and 12

	Plasma magnesium mmol/l (1)	Erythrocyte magnesium mmol/l (2)	Plasma calcium mmol/l (3)	Plasma zinc µmol/l (4)	Erythrocyte zinc µmol/l (5)	Erythrocyte potassium mmol/l (6)	Total cholesterol mmol/l (7)	HDL-cholesterol mmol/l (8)	Total creatine kinase I.U./l (9)
Reference women (n = 53)	0.77 (0.05)	2.03 (0.23)	2.18 (0.10)	9.80 (1.17)	154 (15.4)	90.7 (7.27)[a]	5.06 (0.97)	1.43 (0.28)	
Myocardial Infarcted women (n = 8)									
day 1	0.72 (0.05)[c]	2.27 (0.11)	2.14 (0.18)	7.76 (1.54)	185 (26.3)	85.6 (11.0)	6.55 (1.58)	1.42 (0.31)	449 (299)
day 2	0.73 (0.06)	2.19 (0.22)	2.09 (0.17)	7.65 (1.78)	182 (24.4)	92.6 (4.31)	5.87 (1.43)	1.37 (0.35)	278 (190)
day 3	0.79 (0.09)	2.32 (0.12)	2.11 (0.16)	7.53 (1.38)	185 (25.1)	91.0 (5.84)	5.53 (1.51)	1.35 (0.30)	123 (75.3)
day 6	0.88 (0.13)	2.34 (0.20)	2.13 (0.15)	9.62 (1.86)	183 (25.4)	92.1 (3.94)	5.55 (1.62)	1.35 (0.34)	35.1 (18.0)
day 10	0.85 (0.07)	2.43 (0.17)	2.13 (0.17)	10.7 (0.87)	188 (23.5)	92.9 (4.59)	5.50 (1.59)	1.28 (0.35)	16.1 (8.85)
day 12	0.86 (0.14)	2.43 (0.20)	2.12 (0.12)	10.6 (1.22)	184 (21.6)	92.4 (5.43)	5.47 (0.94)	1.42 (0.42)	18.8 (11.3)
ANOVA[b]	$p<0.001$	$p<0.001$	NS[c]	$p<0.001$	NS	$p<0.05$	NS	NS	$p<0.001$

[a] Nonnormal distribution.
[b] One-way analysis of variance, repeated measurements, from day 1 to day 12.
[c] Individual comparison of means by the least significant difference (days with significant variation: $p<0.05$).

between CK-MB and E-Mg ($r_s = + 0.777$; $p < 0.05$) on D1 and CK-MB and P-Mg on D2 ($r_s = + 0.819$; $p < 0.02$).

The stepwise regression equations (Tables VI and VII) provided evidence in reference men of the major influence of P-Ca, P-Zn and E-Mg on the P-Mg level and of p-Mg and E-Zn on the E-Mg level. In reference women, the mainly representative variables for P-Mg were P-Zn, E-Zn and E-Mg and for E-Mg, P-Zn, E-Zn and P-Mg. In patients, the stepwise regression equations differed from D1 to D12.

Tab. III: Comparison of results between men and women and between patiens[a] and controls

— Reference subjects 58 men/53 women	E-Mg $p<0.05$	P-Zn $p<0.01$	E-K[b] $p<0.001$	HDL-cholesterol $p<0.001$	
— Patients 34 men/8 women	E-Zn $p<0.025$	Total-cholesterol $p<0.025$	HDL-cholesterol $p<0.01$		
— 34 MI men/ 58 reference men	P-Ca $p<0.001$	P-Zn $p<0.001$	HDL-cholesterol $p<0.05$		
— 8 MI women/ 53 reference women	P-Mg $p<0.025$	E-Mg $p<0.005$	P-Zn $p<0.001$	E-Zn $p<0.001$	Total cholesterol $p<0.001$

[a] Patients on day 1. [b] Mann and Whitney test.

Tab. IV: Study of simple (r), Spearman (r_s) and multiple (R) correlations[a] in men

Reference men	MI-Day 1	MI-Day 2	MI-Day 3	MI-Day 6	MI-Day 10	MI-Day 12
r = +0.390** 1,2[b]	r = +0.535*** 1,4	r = +0.375 3,4	r = +0.493*** 1,7	r = −0.476*** 3,5	r = +0.344 3,4	r = −0.416* 2,6
r = +0.540**** 3,4	r = −0.340 2,6	r = +0.560*** 3,6	r = +0.449** 3,6	r = +0.596**** 3,6	r = −0.403* 3,5	r = −0.348 4,8
r = +0.270 4,7	r = +0.444** 3,4	r = +0.374 3,8	r = +0.359 3,8	r = +0.365 4,7	r = +0.352 3,7	
	r = +0.443** 3,6	r = +0.533*** 4,6	r = +0.432* 5,7	r = +0.473*** 5,7		
	r = +0.449** 3,8	r = +0.422* 7,8	r = +0.429* 6,8			
	r = +0.485*** 4,6					
	r = −0.446** 4,9					
	r = +0.510*** 5,7					
	r = −0.336 6,9					
		r_s = −0.524** 3,9	r_s = −0.460** 3,9	r_s = −0.400 3,9		r_s = −0.425* 6,2
		r_s = −0.471** 4,9	r_s = −0.574**** 4,9			r_s = +0.397 6,3
		r_s = −0.417* 6,9				r = +0.376 6,9
	R = 0.626 total chol.	R = 0.631 total chol.	R = 0.725** total chol.	R = 0.661* total chol.		
R[c] = 0.630**** P-Ca	r = 0.646* P-Ca	R = 0.643* HDL-chol.		R = 0.631* P-Ca	R = 0.649* P-Ca	
R = 0.600**** P-Zn	R = 0.705** P-Zn					
	R = 0.606 E-Zn			R = 0.695** E-Zn		

[a] Only significant correlation coefficients ($p<0.05$) are indicated.
[b] Column number from table 1.
[c] Multiple correlations between normally distributed variables common to reference men and men patients with myocardial infarction: P-Mg, E-Mg, P-Ca, P-Zn, E-Zn, total-, and HDL-cholesterol.
* $p<0.02$; ** $p<0.01$; *** $p<0.005$; **** $p<0.001$

Tab. V: Study of simple (r), Spearman (r_s) and multiple (R) correlations[a] in women

Reference women	NI-Day 1	MI-Day 2	MI-Day 3	MI-Day 6	MI-Day 10	MI-Day 12
r = +0.290 3,7[b]	r = −0.754 1,3	r = −0.736 1,3	r = +0.899*** 3,7	r = +0.746 3,6	r = −0.798* 2,6	r = +0.741 1,2
r = +0.380** 7,8	r = +0.874** 3,7	r = +0.710 1,9		r = +0.744 3,7	r = +0.718 3,7	r = −0.760 1,4
	r = +0.796* 6,7	r = +0.756 3,6				r = −0.787* 1,8
		r = +0,891*** 3,7				r = −0.714 2,8
		r = +0.783 4,5				r = +0.837** 3,7
		r = +0.810* 6,7				
R[c] = 0.520 chol. total						

a Only significant correlation coefficients ($p < 0.05$) are indicated.
b Column number from table 2.
c Multiple correlation between normally distributed variables of reference women.
* $p < 0.02$; ** $p < 0.01$; *** $p < 0.005$

Discussion

Out of all the correlated variables acting on a given phenomenon, the stepwise regression equation selects the most representative ones.

Our stepwise regression equations differed greatly in both groups of patients from D1 to D12, probably as a result of metabolic and hormonal changes in response to MI-induced stress (glycoregulation, lipolysis, catecholamines, hyperaldosteronism) [14, 15]. The heterogenity of the most representative variables of these equations was normal in view of the different changes relative to each variable between D1 and D12.

In our previous work [5, 6], as well as in recent articles [1, 7, 16], the role and results of Mg in cardiac diseases have been reviewed. Our present results are not in disagreement with our earlier studies [5, 6] but confirm increases in P-Mg and E-Mg between D1 and D12. Our observation that Mg after MI was released not only by the infarcted left ventricle but also by the nonnecrotic left ventricle and the right ventricle had led us to suppose that it entered into the extracellular compartment [4, 5]. The significant positive r_s correlations in MI men between CK-MB and E-Mg on D2, and in MI women between CK-MB and E-Mg on D1 and between CK-MB and P-Mg on D2, are of considerable interest in this respect.

It is also of interest to note that changes close to ours in Mg serum and erythrocyte levels after MI have been recently reported [16−18].

Moreover, in 26 men (46 to 82 years of age) and 11 women (53 to 78 years of age) with unstable angina pectoris (UA) sampled and analyzed by us at the same

Tab. VI: Stepwise regression equations[a] in men

Reference men:

P-Mg: 0.828 − 0.126 P-Ca + 0.005 P-Zn + 0.078 E-Mg ($R = 0.412$; $F = 3.67$; $p < 0.05$)
E-Mg: 0.731 + 1.421 P-Mg + 0.002 E-Zn ($R = 0.395$; $F = 5.08$; $p < 0.01$)

Myocardial infarction men:

Day 1: P-Mg = 0.518 + 0.030 P-Zn ($R = 0.535$; $F = 12.8$; $p < 0.01$)
E-Mg = 1.984 + 0.067 total-chol. − 0.149 HDL-chol. ($R = 0.338$; $F = 2.00$)

Day 2: P-Mg = 0.377 + 0.127 P-Ca + 0.025 total-chol. ($R = 0.312$; $F = 1.67$)
E-Mg = nothing

Day 3: P-Mg = 0.580 + 0.044 total-chol. ($R = 0.493$; $F = 10.3$; $p < 0.01$)
E-Mg = 2.112 − 0.047 P-Zn + 0.091 total-chol. ($R = 0.356$; $F = 2.26$)

Day 6: P-Mg = 0.700 + 0.072 E-Mg ($R = 0.203$; $F = 1.39$)
E-Mg = 1.782 + 0.581 P-Mg ($R = 0.204$; $F = 1.39$)

Day 10: P-Mg = 0.715 + 0.010 P-Zn − 0.001 E-Zn + 0.076 E-Mg ($R = 0.357$; $F = 1.46$)
E-Mg = 2.753 − 0.434 P-Ca − 0.189 HDL-chol. + 0.815 P-Mg ($R = 0.418$; $F = 2.12$)

Day 12: P-Mg = 0.964 − 0.024 total-chol. ($R = 0.230$; $F = 1,80$)
E-Mg = 3.500 − 0.566 P-Ca + 0.061 P-Zn − 0.003 E-Zn ($R = 0.402$; $F = 1.93$)

a P-Mg (mmol/l) or E-Mg (mmol/l): dependent variables; P-Ca (mmol/l), P-Zn (μmol/l), E-Zn (μmol/l), total- and HDL-cholesterols (mmol/l), P-Mg or E-Mg: mainly representative variables.

time, on the first day of hospitalization, UA men showed an increase in E-Mg ($p < 0.005$) in comparison with 58 reference men. UA women, in comparison with 53 reference women, showed a rise in P-Mg ($p < 0.02$) and E-Mg ($p < 0.001$) as well as a positive correlation ($r_s = 0.70$; $p < 0.05$) between CK (normal levels) and P-Mg [19]. It may thus be supposed that hypoxia without necrosis or with rudimentary necrosis is also associated with a rise in P-Mg and/or E-Mg, which may account for the much greater decrease in myocardial Mg in a reported group of men with prior history of angina who died suddenly of ischemic heart disease [20]. However, before manifestation of UA or MI, it is probable that these subjects presented a Mg deficiency with decreased P-Mg and/or E-Mg levels. It has also been recently reported that Ca and Mg contents of hair samples from infarction patients were significantly lower than in control subjects, indicating a decrease of these electrolytes in serum prior to infarction [17]. Likewise, reported results of a lower quadriceps lateralis muscle biopsy have indicated Mg deficiency [21].

As for our MI men, a decrease in serum Ca level in patients after acute MI as compared to control subjects has also been reported [17, 22, 23]. A decrease ($p < 0.001$) in P-Ca was similarly noted in our study of UA men, which may account for the accumulation of Ca in the infarcted left ventricle or the ischemic myocardium. It has been shown very recently in female SD-rats that high doses of adrenaline in stress reactions increase serum Mg by depleting tissue stores, whereas adrenaline induces a strong Ca overload in the heart [15]. Stress increases the membrane permeability of catecholamine-sensitive cells which in turn raises Ca influx into cells

Tab. VII: Stepwise regression equations[a] in women

Reference women:	
P-Mg: 0.633 + 0.010 P-Zn − 0.001 E-Zn + 0.068 E-Mg (R = 0.352; F = 2.31)	
E-Mg: 0.984 − 0.039 P-Zn + 0.003 E-Zn + 1.226 P-Mg (R = 0.351; F = 2.30)	
Myocardial infarction women:	
Day 1:	P-Mg = 1.219 − 0.232 P-Ca (R = 0.750; F = 7.90; p < 0.01)
	E-Mg = 1.453 + 1.135 P-Mg (R = 0.557; F = 2.70)
Day 2:	P-Mg = 1.288 − 0.267 P-Ca (R = 0.736; F = 7.08; p < 0.01)
	E-Mg = 0.761 + 1.957 P-Mg (R = 0.549; F = 2.59)
Day 3:	P-Mg = 0.197 − 0.060 P-Zn + 0.003 E-Zn + 0.244 E-Mg (R = 0.864; F = 3.93)
	E-Mg = 3.299 − 0.465 P-Ca (R = 0.604; F = 3.45)
Day 6:	P-Mg = nothing
	E-Mg = 3.991 − 0.771 P-Ca (R = 0.575; F = 2.97)
Day 10:	P-Mg = 0.568 − 0.002 E-Zn + 0.234 E-Mg (R = 0.733; F = 2.91)
	E-Mg = 1.426 − 0.451 P-Ca + 0.003 E-Zn + 1.651 P-Mg (R = 0.768; F = 1.92)
Day 12:	P-Mg = 0.938 + 0.592 P-Ca − 0.060 P-Zn + 0.487 E-Mg (R = 0.942; F = 10.6; p < 0.01)
	E-Mg = 2.723 − 1.021 P-Ca + 0.062 P-Zn + 1.415 P-Mg (R = 0.917; F = 7.07; p < 0.01)

[a] Stepwise regression equations between five normally distributed variables: P-Mg, E-Mg, P-Ca, P-Zn, E-Zn.

and releases intracellular Mg [17].

After MI, a significant decrease in P-Zn or serum Zn has been consistently observed [23–25]. Moreover, in patients with MI a significant inverse correlation has been noted between P-Zn level and the value of plasma enzymes from the heart [24–26]. Several hypotheses have been advanced to account for the drop in P-Zn after MI [24, 25, 27]. Our own results relative to men and women who died after MI indicate that only the Zn level of the necrotic area is decreased ($p < 0.01$) as compared to that of the left ventricle of reference subjects [2]; in the right ventricle and the nonnecrotic left ventricle, Zn levels were even slightly higher than those of control groups. Accordingly, in view of the drop in P-Zn from D1 to D3, the hypothesis would seem feasible that circulating Zn is taken up by nonnecrosed myocardial tissue, in proportion to the extent of the necrotic area, as part of the reparative process. However, the nature of the metabolic route between plasma and the heart remains uncertain. As for our UA women [19], a rise ($p < 0.001$) in E-Zn on D1 was noted in our MI women compared to reference women. Increases in E-Zn have also been reported in atherosclerosis [28].

As indicated in Table III, an elevated ($p < 0.001$) total-cholesterol rate in MI women and a lowered ($p < 0.05$) HDL-cholesterol level in MI men are normal in comparison with reference subjects [22, 23, 29]. Changes close to ours in total- and HDL-cholesterol levels after MI have been previously reported [3, 30, 31].

Acute MI often involves a worsening of ischemic heart diseases. An effort should be made in treatment to normalize the membrane permeability altered after MI [17].

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