Prognostic Value of Tumor Necrosis Factor-Alpha in Patients With ST-Segment Elevation Acute Myocardial Infarction

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Introduction and objectives. Tumor necrosis factor-alpha (TNFα) is implicated in a variety of inflammatory processes, including cardiovascular disease. Little is known about the prognostic value of TNFα in patients with ST-segment elevation myocardial infarction (STEMI). The aim of this study was to determine the prognostic value of TNFα in this clinical setting at 6-month follow-up.

Methods. The levels of TNFα, C-reactive protein (CRP), interleukin 6, and type 1 soluble intercellular adhesion molecules measured within the first 10 h of symptom onset and at 48 h in 74 consecutive patients admitted with STEMI. The relationships between these levels and the incidence of ischemic events (ie, angina, reinfarction, and death), heart failure (HF), or both (ie, all cardiovascular events) were studied.

Results. Overall, TNFα levels were significantly higher in patients who had an ischemic event or HF than in those who did not (P<0.02 for both). At 48 h, the adjusted odds ratios of those in the highest TNFα quartile (2.92 pg/mL) for the development of ischemic events, HF, and all cardiovascular events combined were 13.1, 9.59, and 9.75, respectively. A TNFα level of 2.04 pg/mL at 48 h had a sensitivity of 78% and a specificity of 72.5% in predicting a cardiovascular event of any form. The CRP level, but not the TNFα level, at admission was found to be an independent predictor of the development of a cardiovascular events.

Conclusions. In patients with STEMI, the plasma TNFα level 48 h after symptom onset and the CRP level at admission were independent predictors of cardiovascular events.

Key words: Myocardial infarction. Prognosis. Inflammation. Interleukins. Tumor necrosis factor alpha.
so son predictores independientes de eventos cardiovasculares.

**Palabras clave:** Infarto de miocardio. Pronóstico. Inflamación. Interleucinas. Factor de necrosis tumoral alfa.

**ABBREVIATIONS**

CRP: C-reactive protein  
IL-6: interleukin 6  
LVEF: left ventricular ejection fraction  
PCI: percutaneous coronary intervention  
sICAM-1: soluble intercellular adhesion molecule-1  
TNFα: tumor necrosis factor alpha

**INTRODUCTION**

Inflammation plays a key role in the pathogenesis of atherosclerosis, and is involved, on the one hand, in the genesis, development, rupture, and repair of atherosclerotic plaque and, on the other, in post-reperfusion damage, remodeling, and scarring of myocardial tissue. It is also known that an exacerbated inflammatory state plays a role in the development and progression of heart failure.

Tumor necrosis factor alpha (TNFα) is an inflammatory cytokine synthesized in various blood, endothelial and smooth muscle cells, and in cardiac myocytes. The ubiquity and function of its 2 receptors provide it with the capacity to modulate a diversity of inflammatory processes which are strongly involved in acute coronary syndrome (ACS) and in the development of heart failure due to its negative inotropic action, among others. Several lines of research have indicated that it is an independent predictor of mortality in patients with heart failure and advanced functional class, as well as in the chronic phase of myocardial infarction (MI). The synthesis of TNFα increases in the myocardium during acute myocardial ischemia and, although it is known that its concentrations in blood increase rapidly, little information is available concerning its prognostic value.

The aim of the study was to determine if early concentrations of TNFα, at admission and 48 h, together with those of C-reactive protein (CRP), interleukin 6 (IL-6) and soluble intercellular adhesion molecule-1 (sICAM-1) were predictors of ischemic events or heart failure in patients with ST segment elevation myocardial infarction (STEMI) during 6-month follow-up.

**METHODS**

**Patients**

Between June 2001 and January 2003, 74 consecutive patients admitted to a single center were enrolled in the study. They were aged between 36 and 86 years old, and were diagnosed with STEMI (prolonged precordial pain for more than 30 min accompanied by persistent ECG ST-segment elevation ≥1 mm in at least 2 contiguous limb leads or ≥2 mm in at least 2 precordial leads, together with double the upper limit of creatine kinase and increased concentrations of CK-MB or troponin I). The study was approved by the hospital’s ethics committee and all the participants gave signed informed consent.

Patients were excluded if more than 10 h had passed since pain onset, they were undergoing statin therapy, had undergone a previous infarction, were in cardiogenic shock at admission or if they presented some infectious disease, immune disease, or neoplasm. Five patients under study presented chronic ischemic heart disease, although none had undergone previous revascularization. The control group consisted of 38 subjects adjusted for age and sex (63 [11] years; 28 men) and none presented acute disease, chronic disease, or were under medication; their case history, physical exploration and ECG were normal at the time of inclusion.

**Blood Analysis**

A venous blood sample was taken from the 74 patients at admission (within the first 10 h after symptom onset) and at 48 h, and a single sample from the control group. The serum was frozen at –80°C for later analysis. The concentrations of TNFα, IL-6, and sICAM-1 were measured using ELISA kits according to the manufacturer’s instructions (R&D Systems, Minneapolis, USA) as well as CRP concentrations (Generic Assays, Dahlewitz, Germany). The sensitivities and intrasample variation and intersample variation of TNFα, IL-6, sICAM-1, and CRP were 0.12 pg/mL, <8.8%, and <12.6%; 0.7 pg/mL, <4.2%, and <6.4%; 0.35 ng/mL, 4.8%, and 10.1%; 0.56 mg/L, 5.7%, and 13.6%, respectively. Concentrations of TNFα were also determined at discharge (seventh day). Events were allocated by the researchers who were blinded to the results of the blood analysis.

**Cardiovascular Events**

The cardiovascular events were divided into 2 groups: ischemic events (angina, reinfarction, and death) and heart failure. Cardiovascular events refers to the set of combined ischemic and heart failure events, in which case the first one that occurred was recorded if both were present. Angina was defined as oppressive precordial pain associated with electrocardiographic changes occurring at admission or follow-up, excluding inducible angina during risk stratification tests. Infarction was defined at follow-up as prolonged clinical angina with
an increase of double or more than double the upper limit of
CK and concomitant CK-MB or troponin I elevation. Death was classified in all cases as death of cardiac origin
(as no other cause of death occurred during the study period). The ischemic events that occurred during coronary
intervention were not recorded as clinical events. Finally,
heart failure was diagnosed if the patient presented Killip
class II-IV.

Statistical Analysis

Continuous variables were expressed as mean and
standard deviation and discrete variables as percentages.
Non-normally distributed variables were expressed as
interquartile range (IQR), represented as the difference
between the 25th and 75th percentiles. The Student $t$
 test was used to compare the means between continuous
variables and the Mann-Whitney test for nonparametric
variables. The Friedman test was used to study TNF
samples. Percentages were compared using the $\chi^2$
test. Correlations were analyzed using the Pearson
correlation test for normal distributions or the Spearman
$\rho$ for nonparametric variables. The area under the
receiver-operating characteristic (ROC) curve was
constructed to compare the sensitivity and specificity
of a given TNF$\alpha$ value to predict events. A multivariate
binary logistic regression analysis was conducted; the
dependent variable was the incidence of cardiovascular
events and the independent variables (with logarithmic
transformation) were those with $P<.05$ in the univariate
analysis plus the body mass index (BMI), due to its
known association with the inflammatory state, and
white blood cell count at admission. The severity of
coronary disease was excluded from this analysis as
this datum was not available for all patients. To better
understand the data, 2 models were used in the analysis;
one using continuous variables and another regarding
their presence within the fourth quartile. All analyses
were 2-tailed and a $P$ value $<.05$ was considered
significant. The statistical analysis was conducted using
the SPSS statistical package (version 10.05, SPSS,
Chicago, Ill., USA).

The sample size was calculated setting alpha risk at
.05, beta risk at .20 in a 2-tailed test, a cardiovascular
event rate in the group with TNF$\alpha$ below the fourth
quartile (28%), 10 and a relative risk of events in the group
with TNF$\alpha$ within the fourth quartile (2.5), assuming a
5% loss of patients during follow-up. The calculation
was performed using GRANMO 5.0 for Windows
software (Barcelona, Spain).

RESULTS

Table 1 shows the characteristics of the study population
and the patients with cardiovascular events and those
without events. At admission, 58 (78%) patients underwent
primary percutaneous coronary intervention, and TIMI
III flow was obtained in all cases. Primary PCI was not
performed in 16 patients; of these, coronary angiography
indicated ischemia in 10 and revascularization after the
acute phase.

During 6-month follow-up, 31 (41.9%) patients had a
cardiovascular event (21 at admission and 10 new events
during follow-up); 22 (29.7%) had an ischemic event; of
these, there were 9 (12.2%) deaths, always of cardiac
origin (5 during hospitalization, although not in the first
48 h), and there was 3 reinfarctions (4%) and 10 cases
of angina (13.5%); 19 (25.7%) presented heart failure
during hospitalization (61% of the women and 14.3% of
the men), 9 (12.2%) were in Killip class II, 8 (10.8%) in
Killip class III, and 2 (2.7%) cases of Killip class IV
developed after admission; 7 continued in NYHA
functional class II, but there were no new cases of heart
failure during follow-up.

Table 2 shows the concentrations of cytokines (TNF$\alpha$
and IL-6), sICAM-1, and CRP in the control group and
patients. These values were higher in the patients than
in the control group for all the variables under study
except in the case of TNF$\alpha$ at admission. Its concentrations
on the seventh day were 2.52 (1.81-3.40) pg/mL. These
concentrations were different in the 3 study samples
(P<.001), the highest levels being recorded on the
seventh day.

With the exception of sICAM-1 concentrations, all
levels were greater in patients with cardiovascular events
than in those without events, as shown in Table 3 and,
more specifically, in Table 4, which shows the
concentrations of these parameters according to the
cardiovascular event. As shown, TNF$\alpha$ concentrations
were greater in the patients with ischemic events or heart
failure both at admission and at 48 h. Specifically, TNF$\alpha$
concentrations were analyzed in the group of 9 patients
who died. At admission, these values were not significantly
greater in this group compared to those in the surviving
patients (2.74 [1.1-3.78] pg/mL and 1.64 [0.79-2.16]
pg/mL, respectively; $P=.11$). Nevertheless, at 48 h, TNF$\alpha$
concentrations were indeed significantly greater in the
patients who died than in surviving patients (3.69 [2.61-
4.39] and 1.87 [1.33-2.47] pg/mL; $P=.002$) with a
univariate risk of death 4.5 (95% confidence interval
[CI], 2.41-8.73; $P<.0001$) if TNF$\alpha$ values were in the
fourth quartile ($>2.92$ pg/mL).

In a multivariate analysis (adjusted for age, sex,
diabetes, blood pressure, smoking, creatinine, white
blood cell count, BMI, previous treatment with
acetylsalicylic acid, left ventricular ejection fraction
(LVEF) and CRP, TNF$\alpha$, and IL-6 concentrations at
admission and 48 h), only TNF$\alpha$ concentrations at 48
h and CRP concentrations at admission were independent
predictors of ischemic events, heart failure, or both (Table
5). The white blood cell count at admission was a
predictor of ischemic events, and LVEF, diabetes, and
female sex were clinical predictors of heart failure. Table
6 shows that only CRP concentrations at admission and
TABLE 1. Characteristics of the Population and the Patients With or Without Cardiovascular Events

<table>
<thead>
<tr>
<th>Variables</th>
<th>All Variables (n=74)</th>
<th>Cardiovascular Events (n=31)</th>
<th>Without Cardiovascular Events (n=43)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), years</td>
<td>65 (11)</td>
<td>70 (7)</td>
<td>62 (11)</td>
<td>.001</td>
</tr>
<tr>
<td>Men, n (%)</td>
<td>56 (76)</td>
<td>20 (64)</td>
<td>36 (84)</td>
<td>.05</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>23 (31)</td>
<td>15 (48)</td>
<td>8 (19)</td>
<td>.006</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>31 (42)</td>
<td>16 (52)</td>
<td>15 (35)</td>
<td>.15</td>
</tr>
<tr>
<td>Smokers, n (%)</td>
<td>33 (45)</td>
<td>7 (22)</td>
<td>26 (60)</td>
<td>.002</td>
</tr>
<tr>
<td>Hypercholesterolemia, n (%)</td>
<td>18 (24)</td>
<td>5 (16)</td>
<td>13 (30)</td>
<td>.17</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>27 (3)</td>
<td>27 (4)</td>
<td>28 (3)</td>
<td>.63</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>125.4 (26.1)</td>
<td>120.1 (22.2)</td>
<td>129.8 (28.2)</td>
<td>.13</td>
</tr>
<tr>
<td>Heart rate, beats/min</td>
<td>81.8 (16.3)</td>
<td>82.2 (19.7)</td>
<td>81.5 (13.8)</td>
<td>.8</td>
</tr>
<tr>
<td>LVEF (%) at admission, mean (%)</td>
<td>47 (7)</td>
<td>44 (7)</td>
<td>50 (10)</td>
<td>.001</td>
</tr>
<tr>
<td>LVEF (%) at 6 months, mean (SD)</td>
<td>52 (8)</td>
<td>49 (6)</td>
<td>54 (7)</td>
<td>.032</td>
</tr>
<tr>
<td>Diseased vessels, n/N (%)</td>
<td>39/67 (58.2)</td>
<td>8 (29.6)</td>
<td>31 (77.5)</td>
<td>.001</td>
</tr>
<tr>
<td>Preinfarction angina, n (%)</td>
<td>29 (39.2)</td>
<td>16 (51.6)</td>
<td>13 (30.2)</td>
<td>.09</td>
</tr>
<tr>
<td>Anterior infarction, n (%)</td>
<td>33 (44.6)</td>
<td>15 (49)</td>
<td>18 (42)</td>
<td>.57</td>
</tr>
<tr>
<td>Maximum CK-MB, mean (SD), mU/L</td>
<td>302.6 (189.2)</td>
<td>335.8 (190.5)</td>
<td>278.7 (186.7)</td>
<td>.2</td>
</tr>
<tr>
<td>Blood glucose, mean (SD), mg/dL</td>
<td>127.6 (55.23)</td>
<td>138.3 (59.1)</td>
<td>119.8 (51.6)</td>
<td>.15</td>
</tr>
<tr>
<td>White blood cells/mL, mean (SD)</td>
<td>11 311 (3270)</td>
<td>11 154 (3194)</td>
<td>11 424 (3337)</td>
<td>.72</td>
</tr>
<tr>
<td>Hemoglobin, mean (SD), g/L</td>
<td>12.8 (1.9)</td>
<td>12.6 (2.1)</td>
<td>12.8 (1.8)</td>
<td>.66</td>
</tr>
<tr>
<td>LDL-C, mean (SD), mg/dL</td>
<td>105 (32.5)</td>
<td>106.4 (37.6)</td>
<td>105.1 (28.9)</td>
<td>.86</td>
</tr>
<tr>
<td>Creatinine, mean (SD), mg/dL</td>
<td>1.1 (0.4)</td>
<td>1.22 (0.5)</td>
<td>1.02 (0.21)</td>
<td>.02</td>
</tr>
</tbody>
</table>

*CK-MB indicates creatine kinase-MB fraction; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; LVEF, left ventricular ejection fraction; ACE inhibitors, angiotensin-converting enzyme inhibitors; BMI, body mass index.
*Data referring to 92% (n=67) of the patients with coronary angiography (lesions ≥75%).
*Three vessels and left main coronary artery.
*Blood analysis data at admission.

TABLE 2. Cytokine, sICAM-1, and CRP Concentrations in the Control Group and Study Population (Median and Interquartile Range)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control Group (n=38)</th>
<th>Patients (n=74)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNFα, at admission, pg/mL</td>
<td>1.51 (.97-1.84)</td>
<td>1.72 (.92-2.25)</td>
<td>.271</td>
</tr>
<tr>
<td>TNFα, at 48 h, pg/mL</td>
<td>2.02 (1.39-2.92)</td>
<td></td>
<td>.01</td>
</tr>
<tr>
<td>IL-6, at admission, pg/mL</td>
<td>.92 (.03-7.9)</td>
<td>10.9 (6-18.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>IL-6, at 48 h, pg/mL</td>
<td>18.4 (9.7-36.54)</td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CRP, at admission, mg/L</td>
<td>1.6 (.7-2.5)</td>
<td>2.4 (1.3-6)</td>
<td>.04</td>
</tr>
<tr>
<td>CRP, at 48 h, mg/L</td>
<td>24.3 (20.2-31.6)</td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>sICAM-1, at admission, ng/mL</td>
<td>189.4 (169.6-231.2)</td>
<td>269.4 (228.9-313.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>sICAM-1, at 48 h, ng/mL</td>
<td>279.6 (233.4-323.4)</td>
<td></td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*sICAM-1 indicates type-1 soluble intercellular adhesion molecule; IL-6, interleukin 6; CRP, C-reactive protein; TNFα, tumor necrosis factor alpha.
*Data referring to 92% (n=67) of the patients with coronary angiography (lesions ≥75%).
TNFα concentrations at 48 h were significantly elevated in the patients who had cardiovascular events during admission and follow-up.

Receiver operating characteristic analysis of TNFα concentrations at admission and 48 h showed a greater area under the curve (95% CI) in the sample taken at 48 h than that at admission (80 (68.7-89.6) and 67.7 [55.2-80.1]). A cutoff value for TNFα of 2.04 pg/mL at 48 h had a sensitivity of 78% and a specificity of 72.5% in predicting cardiovascular events at follow-up (Figure 1). If the cutoff value was 2.92 pg/mL, corresponding to the beginning of the last quartile, specificity was 93% although diagnostic sensitivity was lost (53.8%). Figure 2 shows the distribution of TNFα concentrations at 48 h in relation to whether there were cardiovascular events or not.

### TABLE 3. Cytokine, sICAM-1, and CRP Concentrations in Patients With and Without Cardiovascular Events (Median and Interquartile Range)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Cardiovascular Events (n=31)</th>
<th>Without Cardiovascular Events (n=43)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNFα, at admission, pg/mL</td>
<td>2.05 (1.07-2.95)</td>
<td>1.49 (0.65-2.1)</td>
<td>.01</td>
</tr>
<tr>
<td>TNFα, at 48 h, pg/mL</td>
<td>2.91 (2.05-3.88)</td>
<td>1.62 (1.19-2.11)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>IL-6, at admission, pg/mL</td>
<td>15.9 (10.1-31.2)</td>
<td>7.7 (4.4-13.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>IL-6, at 48 h, pg/mL</td>
<td>25.1 (14.7-56)</td>
<td>15 (8.1-28.1)</td>
<td>.013</td>
</tr>
<tr>
<td>CRP, at admission, mg/L</td>
<td>6 (1.8-10.8)</td>
<td>1.5 (1.1-3.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CRP, at 48 h, mg/L</td>
<td>27.1 (22.1-27.1)</td>
<td>23.1 (16.3-3)</td>
<td>.016</td>
</tr>
<tr>
<td>sICAM-1, at admission, ng/mL</td>
<td>281.9 (242.5-504)</td>
<td>265.3 (215.3-318.2)</td>
<td>.63</td>
</tr>
<tr>
<td>sICAM-1, at 48 h, ng/mL</td>
<td>289.3 (256.2-341.1)</td>
<td>265.6 (216.9-322.8)</td>
<td>.09</td>
</tr>
</tbody>
</table>

*sICAM-1 indicates type-1 soluble intercellular adhesion molecule; IL-6, interleukin 6; CRP, C-reactive protein; TNFα, tumor necrosis factor alpha.

### TABLE 4. Cytokine, sICAM-1, and CRP Concentrations in the Presence/Absence of Ischemic Events or Heart Failure (Median and Interquartile Range)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Ischemic Events (n=22)</th>
<th>Without Ischemic Events (n=52)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNFα, at admission, pg/mL</td>
<td>2.19 (1.05-3.63)</td>
<td>1.56 (0.73-2.1)</td>
<td>.016</td>
</tr>
<tr>
<td>TNFα, at 48 h, pg/mL</td>
<td>3.12 (2.19-3.99)</td>
<td>1.68 (1.24-2.19)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CRP, at admission, mg/L</td>
<td>6.1 (1.5-10.1)</td>
<td>1.9 (1.2-4.6)</td>
<td>.009</td>
</tr>
<tr>
<td>CRP, at 48 h, mg/L</td>
<td>27.7 (22.8-33)</td>
<td>23.1 (16.3-30.8)</td>
<td>.02</td>
</tr>
<tr>
<td>IL-6, at admission, pg/mL</td>
<td>17.4 (10.4-36)</td>
<td>8.5 (5.6-15.8)</td>
<td>.003</td>
</tr>
<tr>
<td>IL-6, at 48 h, pg/mL</td>
<td>18.3 (14.1-59.7)</td>
<td>19 (8.2-31.9)</td>
<td>.17</td>
</tr>
<tr>
<td>sICAM-1, at admission, ng/mL</td>
<td>263.8 (235.6-301.3)</td>
<td>269.4 (223.5-333.1)</td>
<td>.67</td>
</tr>
<tr>
<td>sICAM-1, at 48 h, ng/mL</td>
<td>284 (243.9-330.9)</td>
<td>276.1 (231.5-323.7)</td>
<td>.51</td>
</tr>
</tbody>
</table>

*Variables compared using nonparametric tests.

### TABLE 5. Variables Associated With the Development of Ischemic Events, Heart Failure, or Both (Cardiovascular Events) Using Multivariate Analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>OR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TNFα at 48 h (&gt;2.92 pg/mL)</td>
<td>13.1 (3.15-54.39)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TNFα at 48 h (&gt;6.04 mg/L)</td>
<td>4.21 (1.03-17.12)</td>
<td>.045</td>
</tr>
<tr>
<td>White blood cells at admission (&gt;13 300/mL)</td>
<td>4.16 (1.08-17.23)</td>
<td>.049</td>
</tr>
<tr>
<td>Heart failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TNFα at 48 h</td>
<td>9.59 (1.83-50.1)</td>
<td>.007</td>
</tr>
<tr>
<td>CRP at admission (&gt;13 300/mL)</td>
<td>12.67 (2.65-60.99)</td>
<td>.001</td>
</tr>
<tr>
<td>Women</td>
<td>9.87 (1.83-50)</td>
<td>.007</td>
</tr>
<tr>
<td>Diabete</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cardiovascular events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TNFα at 48 h</td>
<td>9.75 (2.17-43.8)</td>
<td>.003</td>
</tr>
<tr>
<td>CRP at admission</td>
<td>17.68 (3.34-93.58)</td>
<td>.001</td>
</tr>
</tbody>
</table>

*LVEF indicates left ventricular ejection fraction; CI, confidence interval; OR, odds ratio; CRP, C-reactive protein; TNFα, tumor necrosis factor alpha.
The TNFα concentrations recorded at 48 h were significantly negatively correlated with LVEF ($\rho=–0.416; P<.001$); this correlation was maintained at 6 months among the 65 surviving patients ($\rho=–0.256; P=.039$). In addition, there was a positive correlation between TNFα concentrations and IL-6, sICAM-1, and CRP concentrations at admission ($\rho=0.269, P=.02; \rho=0.444, P<.001$; and $\rho=0.286, P=.01$, respectively), and after 48 h ($\rho=0.309, P=.007; \rho=0.163, P=.1$; and $\rho=0.418, P=.001$, respectively).

**DISCUSSION**

Tumor necrosis factor alpha is an inflammatory cytokine present in the peripheral blood of patients with chronic ischemic heart disease$^6$ and ACS.$^9,11$ Its negative inotropic action$^6$ and the association between its concentrations and the grade of heart failure$^7$ are well known. It is synthesized not only in the inflammatory cells of the arterial wall and circulating blood, in the infarction area and its vicinity, but also in healthy myocardium,$^3$ which indicates that it is involved in some way in cardiac remodeling after MI.$^{12}$

It has also been directly associated with myocardial damage after ischemia/reperfusion,$^{13}$ oxidative stress in patients with STEMI,$^{11}$ myocardial rupture and chronic ventricular dysfunction,$^{14}$ apoptosis,$^{15}$ and peripheral endothelial dysfunction.$^{16}$ Taking these data into account, the prognostic value of TNFα concentrations measured at admission and 48 h was analyzed in a group of patients with STEMI using a sample extraction protocol that had not been studied previously.

### TABLE 6. Cytokine, sICAM-1, and CRP Concentrations at the Time of the Event (Median and Interquartile Range)$^a$

| Variables | Events | Without Events | $P$ | Events | Without Events | $P$
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>In-Hospital</td>
<td>At Follow-Up</td>
<td></td>
<td>In-Hospital</td>
<td>At Follow-Up</td>
<td></td>
</tr>
<tr>
<td>TNFα, at admission, pg/mL</td>
<td>2.14 (1.14-3.02)</td>
<td>1.6 (0.72-2.12)</td>
<td>.22</td>
<td>1.95 (0.98-3.68)</td>
<td>1.64 (0.78-2.14)</td>
<td>.11</td>
</tr>
<tr>
<td>TNFα, at 48 h, pg/mL</td>
<td>3.01 (1.9-3.99)</td>
<td>1.76 (1.26-2.31)</td>
<td>&lt;.001</td>
<td>2.39 (1.84-3.73)</td>
<td>1.74 (1.31-2.3)</td>
<td>.01</td>
</tr>
<tr>
<td>CRP, at admission, mg/L</td>
<td>6.9 (2.12-15.65)</td>
<td>1.9 (1.15-4.39)</td>
<td>.001</td>
<td>5.73 (1.84-9.5)</td>
<td>1.96 (1.34-4.8)</td>
<td>.03</td>
</tr>
<tr>
<td>CRP, at 48 h, mg/L</td>
<td>28.5 (21.29-33.55)</td>
<td>23.48 (18.52-31.27)</td>
<td>.16</td>
<td>27.01 (22.79-30.86)</td>
<td>23.36 (16.43-31.47)</td>
<td>.19</td>
</tr>
<tr>
<td>IL-6, at admission, pg/mL</td>
<td>25 (11.06-39.69)</td>
<td>8.38 (4.26-14.21)</td>
<td>&lt;.001</td>
<td>16.47 (7.5-32.16)</td>
<td>9.18 (5.93-15.9)</td>
<td>.08</td>
</tr>
<tr>
<td>IL-6, at 48 h, pg/mL</td>
<td>25.31 (15.65-69)</td>
<td>17.36 (8.1-28.46)</td>
<td>.01</td>
<td>18.17 (12.08-29.03)</td>
<td>18.32 (8.53-32.91)</td>
<td>.86</td>
</tr>
<tr>
<td>sICAM-1, at admission, ng/mL</td>
<td>281.92 (241.88-297.64)</td>
<td>266.7 (224.26-322.87)</td>
<td>.87</td>
<td>263.81 (238.72-315.59)</td>
<td>272.9 (221.55-318.22)</td>
<td>.85</td>
</tr>
<tr>
<td>sICAM-1, at 48 h, ng/mL</td>
<td>305.5 (265.34-340.07)</td>
<td>267.4 (229.39-323.06)</td>
<td>.08</td>
<td>275.45 (227.18-308.38)</td>
<td>279.6 (230.52-323.31)</td>
<td>.88</td>
</tr>
</tbody>
</table>

$^a$sICAM-1 indicates type-1 soluble intercellular adhesion molecule; IL-6, interleukin 6; CRP, C-reactive protein; TNFα, tumor necrosis factor alpha.

$^b$Four patients in this group also had in-hospital events.
The main finding of the study is that TNF-α concentrations 48 h after symptom onset in patients with STEMI is an independent predictor of cardiovascular events at 6-month follow-up. There was also a negative correlation with LVEF and a positive correlation with other inflammatory markers of recognized prognostic value. These results were obtained in a population with a number of events that, although apparently high, are very similar in terms of percentages to those found in other studies.9,10

The results show that TNF-α concentrations were greater in the patients than in the control group at 48 h and at 7 days, but not at admission. There could be 2 reasons for this: the early extraction of the first sample, in the first 10 h of pain onset, which is in line with experimental data that show gradual TNF-α synthesis from the onset of ischemia or necrosis1, and the low incidence of heart failure2 (predominantly Killip class III) plus the exclusion of patients in cardiogenic shock at admission. This information, together with the lack of predictive value of TNF-α concentrations at admission in the patients who died, suggests that such an early sample is unlikely to be of prognostic use. Another study also reports similar results5 regarding the limited predictive value of TNF-α concentrations at admission. There is a later increase in its concentrations, which may be of prognostic value; this increase may indicate that TNF-α is associated with postinfarction ventricular remodeling. However, although data are available on the potential role of TNF-α in remodeling,5,12 it remains to be clarified whether its concentrations are simply a marker or if it has a key role in promoting remodeling. In this regard, it is interesting to consider the possibility that apoptosis may be core to postinfarction remodeling17 and that soluble TNF-α receptor levels may correlate with apoptosis in patients with dilated cardiomyopathy.15

The prognostic value of TNF-α has been studied in patients with heart failure and coronary heart disease. Several studies on heart failure have identified it either as an independent predictor of mortality5,6 or have strongly suggested this role.18 In patients with chronic coronary heart disease, the CARE (Cholesterol And Recurrent Events) study reported an almost 3-fold increase in events if TNF-α concentrations 9 months postinfarction were in the 95th percentile. Interestingly, the mean and median TNF-α values in this study (2.7 pg/mL and 2.5 pg/mL, respectively) are similar to those obtained in our series at day 7 (2.77 pg/mL and 2.52 pg/mL, respectively). This may indicate that “chronic” TNF-α plasma concentrations could already be measured 7 days postinfarction; however, no samples were taken after this point in time. In the acute phase of STEMI, increased TNF-α concentrations were associated with heart failure, arrhythmias and major alterations in left ventricular wall motion and perfusion measured by thallium scintigraphy in a study with 50 patients.19 In another study,4 TNF-α receptor-I values at admission, but not TNF-α itself, were independent predictors of death and heart failure in a group of patients with ACS (151 with STEMI). However, TNF-α values were not analyzed later, unlike in the present study. The prognostic value of TNF-α receptor-I has also been reported in patients with chronic heart failure.5,7

In our series, the values of the 2 samples of TNF-α, CRP, and IL-6 were greater in the patients who had cardiovascular events than those who did not. The multivariate analysis showed that TNF-α concentrations at 48 h were independent predictors of ischemic events and heart failure. As mentioned above, another study9 found that TNF-α concentrations at admission are not independent predictors of death and heart failure; in contrast, CRP concentrations at admission are in fact predictors of these events, as described in the literature.20 The white blood cell count at admission is also an independent predictor of ischemic events when its values are in the fourth quartile (>13 300); similar data have been reported in other series of patients with STEMI.21 The clinical variables female sex, diabetes, and LVEF were predictors of heart failure, but not of ischemic events; these variables have already been identified as indicators of poor prognosis.22,23 At admission and 48 h, IL-6 concentrations were not independent predictors of events despite its known predictive value in patients with non-ST-segment elevation acute coronary syndrome.24 Thus, in line with these results, a practical strategy in the use of biomarkers in this population may be the early measurement of CRP concentrations and TNF-α concentrations at 48 h.

The ROC curves for TNF-α indicate a greater area under the curve for samples taken at 48 h; at this time the sensitivity and specificity in predicting cardiovascular events are moderate (around 75%) if the cutoff point is set at 2.04 pg/mL. Nevertheless, greater TNF-α concentrations, corresponding to the beginning of the fourth quartile (2.92 pg/mL), are of greater clinical interest, since they have high specificity (93%), thereby reducing the number of false positives at diagnosis. Similar results have been reported for TNF-α receptor type-I at admission in patients with STEMI.9 In addition, our results are in line with those for markers of hemodynamic stress, such as B-type natriuretic peptide (BNP) in patients with STEMI. In one study,25 the relative risk for the last quartile of BNP of death, reinfarction and heart failure, and ROC curves (sensitivity 75% and specificity for a cutoff point of 40 pg/mL) are very similar to the results for TNF-α in our series. Further studies should clarify with greater accuracy the prognostic value of the two groups of biomarkers.

Finally, it is difficult to define the significance of increased TNF-α concentrations in this population. In the context of predicting heart failure, TNF-α concentrations at 48 h could be a reflection of myocardial
damage in the ischemic territory and cardiac remodeling, as indicated by its negative correlation with LVEF and the findings of several lines of research.\textsuperscript{3,12,13} As a predictor of ischemic events, similar to high CRP concentrations, it may reflect a concomitant exacerbated inflammatory state and positively correlate with other markers (IL-6, CRP and sICAM-1), all of which are involved in the inflammatory cascade and that pathophysiologically induce the development and progression of atherosclerotic disease.\textsuperscript{1}

**Limitations**

Our results, and in particular the multivariate analysis, should be interpreted with caution due to the sample size. On the other hand, although multivessel disease was a predictor of events in the univariate analysis, the fact of not knowing the coronary anatomy of all the patients hinders understanding the association between multivessel disease, biomarkers, and cardiovascular events. Nevertheless, a multivariate analysis that only included these patients (n=67) showed that multivessel disease is another predictor of ischemic events and total cardiovascular events ($P<.001$).

**CONCLUSIONS**

In the patients with STEMI, our results indicate that peripheral blood TNF\alpha concentrations 48 h from pain onset, together CRP concentrations at admission, are independent predictors of ischemic events and heart failure at 6-month follow-up. At this time, TNF\alpha concentrations correlate with LVEF and other inflammatory markers with known prognostic value.

**REFERENCES**
