Infection of Peripheral Blood Mononuclear Cells by Hepatitis C Virus in Mixed Cryoglobulinemia

By Clodoveo Ferri, Monica Monti, Luca La Civita, Giovanni Longombo, Francesco Greco, Giampiero Pasero, Paolo Gentilini, Stefano Bombardieri, and Anna Linda Zignego

A striking association between hepatitis C virus (HCV) infection and mixed cryoglobulinemia (MC) has been shown; thus, HCV seems to play an important etiopathogenetic role in this lymphoproliferative disorder. Because HCV is both a hepatotropic and lymphotropic virus, this study aimed to investigate the prevalence of HCV infection of peripheral blood mononuclear cells (PBMCs) in a series of 16 patients with type II (IgMk) MC. Antibodies against HCV were detected by commercially available kits (Second Generation Chiron enzyme-linked immunosorbent assay [ELISA]) and recombinant-based immunoblot assay [RIBA]), and the presence of HCV RNA was evaluated in both sera and isolated PBMCs using the polymerase chain reaction technique. A previous exposure to HCV was shown by ELISA and confirmed by RIBA in all cases (100%). Moreover, HCV RNA was present in the sera of 8 of 16 patients (50%), whereas its frequency markedly increased (13 of 16 [81%]) when genomic sequences were detected in peripheral lymphocytes. HCV RNA was never detected in the PBMCs of 20 control subjects. These findings showed that HCV infection, alone or in combination with other factors, may be responsible for the clonal B-cell expansion underlying the systemic manifestations of MC, and may explain the appearance of a malignant non-Hodgkin’s lymphoma in some subjects.

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MIXED CRYOGLOBULINEMIA (MC) is a lymphoproliferative disorder characterized clinically by purpura, arthralgias, weakness, and various organ involvement such as peripheral neuropathy, chronic hepatitis, glomerulonephritis, and generalized vasculitis.1 The typical pathologic lesions involving small- and medium-sized vessels are due to deposition of circulating immune-complexes (CIC) and complement.1,2 In MC patients, a monoclonal rheumatoid factor in the cryoprecipitates,3 a clonal expansion of IgMk-bearing B cell in peripheral blood,3 lymphoid aggregates in bone marrow biopsics, and lymphocytic infiltration of liver, spleen, or kidneys have been reported.3 Together, these findings raised the possibility that a malignant lymphoproliferative disorder is responsible for the disease.3,5 However, B-cell lymphomas develop in only a small number of cases, generally after a long follow-up period.1 More recently, evidence of hepatitis C virus (HCV) infection in the majority of patients has suggested that this virus could be the main etiologic factor of MC.4,6 HCV is responsible for different chronic liver diseases, ie, posttransfusion non-A, non-B chronic hepatitis4,6 and autoimmune chronic hepatitis7,12; in this respect, liver involvement present in two-thirds of MC could be regarded as a clinical variant of HCV-related chronic hepatitis. However, in almost 30% of MC patients, HCV infection has also been found without any clinical evidence of liver damage.7,9 This observation suggests that MC is not simply an extrahaematogenic infection of HCV liver infection, but primarily a systemic lymphoproliferative disorder. More recently, it has been shown that HCV is both a hepatotropic and lymphotropic virus13; on this basis, we can suppose that, in MC patients, chronic HCV infection could be responsible for the lymphoproliferative disorder underlying clinical manifestations of the disease. To better define the role of this virus in the pathogenesis of the MC, HCV infection of peripheral lymphocytes was investigated in a series of patients.

PATIENTS AND METHODS

Sixteen consecutive MC patients (mean age, 59 ± 8 years; mean disease duration, 10 ± 5 years) were included in the study. In all cases, diagnosis of MC was based on the presence of the typical syndrome (purpura, arthralgias, and weakness) and of circulating mixed cryoglobulins, and on the exclusion of other neoplastic or systemic disorders. All patients were Italian-born heterosexuals and had no history of contact with hepatitis or parenteral exposure to blood products, or of drug or alcohol abuse. The presence of visceral complications, ie, peripheral neuropathy and liver and renal involvement, were evaluated as previously described.2,6,14 Routine blood chemistry studies were performed by standard methods. Cryocrit, ie, the percentage of packed cryoglobulins, hemolytic complement activity, and C3-C4 fractions were measured as previously described.2,6,14 Mixed cryoglobulins were classified as type II or type III according to the presence of monoclonal or polyclonal IgM rheumatoid factor (RF).

The presence in the sera of HCV RNA, anti-HCV, hepatitis B surface antigen (HBsAg), anti-HBc (anti-HBsAb, -HBc, -HBe), and anti-human immunodeficiency virus antibody (anti-HIV) was detected on serum and centrifuged at 37°C and stored at −80°C. Anti-HCV were detected by enzyme-linked immunosorbent assays (Chiron ELISA HCV, Second Generation; Emeryville CA), and confirmed in all cases by recombinant-based immunoblot assay (Chiron RIBA HCV, Second Generation Assay). HBV and HIV markers were detected by ELISA using commercially available kits (Hepanostika, Vironostika anti-HTLV III; Organon Teknika, Boxtel, The Netherlands). In the same blood samples, the presence of HCV RNA in the serum and in peripheral blood mononuclear cells (PBMCs) was investigated. PBMCs were prepared from heparinized venous blood samples by centrifugation on Ficoll-Hyphaque density gradient (Ficoll-Hyphaque; Pharmacia, Uppsala, Sweden), and may explain the appearance of a malignant non-Hodgkin’s lymphoma in some subjects.

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and were tested for the presence of HCV RNA.\textsuperscript{13} Briefly, three to four aliquots of $2 \times 10^6$ cells were obtained from each patient and washed three to five times by centrifugation with RNase-free phosphate-buffered saline (PBS).

HCV RNA was also detected in both sera and PBMCs of the following control groups: (1) 10 healthy subjects, and (2) 10 anti-HCV-negative patients with type B or $\delta$ chronic active hepatitis (HBsAg, IgM anti-HBc positive or IgM anti-HD, serum HDV RNA positive, respectively).

Total RNA was extracted according to a previously described technique.\textsuperscript{13,15} Briefly, sera were digested in 4 vol of a lysis buffer containing 10 mmol/L EDTA, 1 mmol/L Tris-HCl (pH 7.5), 1% sodium dodecyl sulfate (SDS), and 500 $\mu$g/mL proteinase K. Proteins were then extracted with phenol-chloroform and total RNA was precipitated overnight at $-20^\circ$C after the addition of sodium acetate 0.2 mol/L, transfection RNA, and 2 vol of ice-cold ethanol. The precipitated nucleic acids were recovered by centrifugation (14,000 rpm for 30 minutes at $4^\circ$C), washed in 70% ethanol (500 $\mu$L), evaporated to dryness, dissolved in 30 $\mu$L of sterile diethylpyrocarbonate-treated water (DEPC H$_2$O), and stored at $-80^\circ$C.

HCV RNA sequences were determined using a "one-tube nested" polymerase chain reaction (PCR) assay as previously described.\textsuperscript{13,16} HCV PCR was performed using primers (Table 1) corresponding to the well-conserved 5' noncoding region of the HCV genome as described.\textsuperscript{13,16,17}

Amplification products were detected by ethidium bromide staining. Fifteen microliters of each reaction mix was applied to a 1.9% agarose slab gel in a Tris-borate buffer (pH 8). PCR products were also analyzed by Southern blot hybridization using $^{32}$P-labeled 40 oligonucleotide sequence probes corresponding to HCV sequences inside the primers used. The membrane (Gene Screen Plus; New England Nuclear, Boston, MA) was washed twice with 0.2X SSC/1% SDS at 20°C for 15 minutes, and twice with 0.2X SSC/1% SDS at 55°C for 20 minutes, and exposed to a Kodak X-AR film at $-80^\circ$C for 24 and 72 hours using an intensifying screen (Eastman Kodak, Rochester, NY).

A series of technical precautions were used to assure specificity and sensitivity of HCV-RNA determination: (1) the various steps involved in the method (RNA purification, PCR, and product analysis) were physically separated; (2) all pipettes and containers were disposable; (3) only cell preparations whose last wash was HCV PCR negative were examined; (4) RNA extraction and PCR were performed at least three times for each sample (PBMCs, sera, last washes) and a result was considered definitive only when confirmed in different experiments; and (5) positive and negative controls were used, which included RNA and DNA extracted from PBMCs and sera of healthy subjects, RNA extracted from baker's yeast, the reaction mixture without the reverse transcriptase of RNA, distilled water, and RNA extracted from 10 PBMCs and serum samples known to contain HCV RNA sequences. In particular, PCR was able to detect HCV sequences in samples containing as little as $5 \times 10^6$ to $1 \times 10^7$ HCV-infected cells as shown by limit dilution experiments of T-cell lines obtained from HCV chronically infected patients (Zignego et al, in preparation), as well as in $10^{-3}$ to $10^{-7}$ diluted sera obtained from the same patients. Finally, to avoid the risk of contamination caused by double amplification, "nested" HCV PCR was performed in the same reaction tube by separating the reaction mixtures for the first and second PCR with a layer of mineral oil.

\textbf{RESULTS}

The main clinico-epidemiologic data and the results of laboratory parameter investigations are reported in Table 2. Liver involvement and peripheral neuropathy were the most common manifestations of the disease. At the time of the study, a chronic active hepatitis, evaluated on the basis of histologic and/or liver enzyme alterations, was present in 11 of 16 (69%) cases. In 2 patients, a renal involvement was recorded: renal biopsy showed a membranoproliferative glomerulonephritis in 1, and a constant proteinuria was detected in the other. Long-term steroid therapy was used in the majority of cases; its dosage was graduated to control minor symptoms of the MC, ie, purpura episodes, weakness, and arthralgias. In two cases (no. 5 and 6), $\alpha$-interferon treatment was started (9 $\times$ 10$^6$ IU/wk) 12 months before the study. Immunologic parameter investigations showed the presence of monoclonal rheumatoid factor (IgM) in all cryoprecipitates. The cryocrit widely varied from 0.6% to 20% (mean $\pm$ SD, 4.2% $\pm$ 6.3%). Hemolytic complement activity was depressed in 11 of 16 cases (mean $\pm$ SD, 118 $\pm$ 43 hu/mL; normal range, 160 to 220), with constantly marked reduction of C4 component (mean $\pm$ SD, 12 $\pm$ 3; normal range, 20 to 60 mg/dL) and normal C3 levels.

A previous exposure to HCV was shown in all MC patients by ELISA; all seropositives were confirmed by RIBA II (Table 2). The presence of HCV genome was detected in the serum of 8 of 16 MC patients (50%), indicating the ongoing HCV replication in these subjects. The percentage of HCV RNA positivity markedly increased when it was evaluated in isolated PBMCs, in which genomic sequences were detected in 13 of 16 cases (81%). In 1 of 2 patients (case no. 6) undergoing long-term $\alpha$-interferon treatment, HCV RNA was absent in both serum and isolated PBMCs; in this subject, the presence of HCV viremia had been observed before the treatment. HCV RNA was never found in both sera and PBMCs of the healthy controls and patients with B or $\delta$ chronic active hepatitis.

\textbf{DISCUSSION}

This study first showed that HCV infects the peripheral lymphocytes in a relevant number of MC patients. In a previous report, HCV RNA has been shown in the PBMCs of patients with HCV-related chronic hepatitis;\textsuperscript{12} in the same subjects, HCV-RNA–negative stranded molecules, indicative of viral replication, were found in both fresh and cultured PBMCs.\textsuperscript{13} Moreover, an immunogenic activity of HCV viral proteins on peripheral lymphocytes has been reported in patients with chronic hepatitis C by Botarelli et al.
HCV INFECTION OF PBMCs IN CRYOglobulinemia

Table 2. Clinico-Epidemiologic and Laboratory Findings of 16 MC Patients

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (yr)/gender</th>
<th>Disease Duration (yr)</th>
<th>Liver Involvement</th>
<th>ALT (XULN)</th>
<th>Renal Involvement</th>
<th>Neuritis</th>
<th>Cryocrit (X)</th>
<th>Monoclonal Component</th>
<th>Therapy</th>
<th>Anti-HCV RIBA II</th>
<th>Serum-HEV RNA</th>
<th>PBMC HCV RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57/M</td>
<td>2</td>
<td>CAH</td>
<td>1.1</td>
<td>-</td>
<td>+</td>
<td>0.6</td>
<td>IgMk</td>
<td>6-MP (20)</td>
<td>1/0/2/3</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>48/F</td>
<td>11</td>
<td>ND</td>
<td>0.9</td>
<td>-</td>
<td>+</td>
<td>1.8</td>
<td>IgMk</td>
<td>6-MP (4)</td>
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<td>+</td>
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<tr>
<td>3</td>
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<td>0.9</td>
<td>-</td>
<td>-</td>
<td>2.7</td>
<td>IgMk</td>
<td>6-MP (6)</td>
<td>2/2/3/3</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>55/F</td>
<td>5</td>
<td>ND</td>
<td>2.1</td>
<td>-</td>
<td>-</td>
<td>0.7</td>
<td>IgMk</td>
<td>6-MP (4)</td>
<td>2/1/3/4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>58/M</td>
<td>9</td>
<td>CAH</td>
<td>4.5</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>IgMk</td>
<td>α-IFN</td>
<td>0/1/4/3</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>58/F</td>
<td>19</td>
<td>CAH</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>1.9</td>
<td>IgMk</td>
<td>α-IFN</td>
<td>1/1/2/4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>69/F</td>
<td>10</td>
<td>CAH</td>
<td>3.7</td>
<td>-</td>
<td>-</td>
<td>1.4</td>
<td>IgMk</td>
<td>-</td>
<td>2/2/3/3</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>54/M</td>
<td>13</td>
<td>ND</td>
<td>0.9</td>
<td>MPGN</td>
<td>+</td>
<td>0.7</td>
<td>IgMk</td>
<td>4-MP (10)</td>
<td>0/0/2/4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>64/F</td>
<td>11</td>
<td>CAH</td>
<td>3.3</td>
<td>-</td>
<td>+</td>
<td>17</td>
<td>IgMk</td>
<td>6-MP (4)</td>
<td>0/2/3/3</td>
<td>+</td>
<td>+</td>
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<tr>
<td>10</td>
<td>62/M</td>
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<td>0.6</td>
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<td>-</td>
<td>1.4</td>
<td>IgMk</td>
<td>-</td>
<td>2/3/4/4</td>
<td>-</td>
<td>-</td>
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<tr>
<td>11</td>
<td>58/M</td>
<td>10</td>
<td>ND</td>
<td>0.5</td>
<td>-</td>
<td>+</td>
<td>20</td>
<td>IgMk</td>
<td>6-MP (4)</td>
<td>4/4/3/4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>68/F</td>
<td>19</td>
<td>CAH</td>
<td>5.4</td>
<td>-</td>
<td>-</td>
<td>1.5</td>
<td>IgMk</td>
<td>6-MP (6)</td>
<td>4/2/3/4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>13</td>
<td>56/F</td>
<td>13</td>
<td>ND</td>
<td>1.1</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>IgMk</td>
<td>6-MP (8)</td>
<td>1/3/3/3</td>
<td>-</td>
<td>-</td>
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<tr>
<td>14</td>
<td>47/M</td>
<td>11</td>
<td>CAH + C</td>
<td>1.9</td>
<td>+</td>
<td>+</td>
<td>13</td>
<td>IgMk</td>
<td>6-MP (8)</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>15</td>
<td>66/F</td>
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<td>ND</td>
<td>0.7</td>
<td>-</td>
<td>+</td>
<td>2.1</td>
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<td>6-MP (2)</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>1.7</td>
<td>IgMk</td>
<td>6-MP (4)</td>
<td>4/2/4/3</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Abbreviations: ALT (XULN), serum alanine aminotransferase (multiple of upper limit of normal); 6-MP, 6-methylprednisolone (mg/d); α-IFN, α-interferon (9 mega-IU/wk); CAH, chronic active hepatitis; C, cirrhosis; MPGN, membranoproliferative glomerulonephritis; ND, not done; 5.1.1. C100, C33c, C22, antibodies against recombinant HCV-related antigens used in RIBA II (score 0-4).

* Proteinuria.
patients’ subsets, i.e., HCV-related chronic hepatitis, MC, and MC complicated by frank lymphoma. In addition, the detection of HCV RNA in lymphoid aggregates of the bone marrow and/or liver or lymphnodes and the isolation of specific HCV mutants, together with genetic and molecular biology investigations, should clarify this intriguing matter.

REFERENCES


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