

ORIGINAL PAPER

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Unidentified virus-like particles are detected in plasmas with elevated ALT levels: are they significant of etiological agent(s) of non-B, non-C hepatitis?

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Abstract GB virus C (GBV-C) and hepatitis G virus (HGV) have been proposed as new viruses etiologically implicated in non-B, non-C hepatitis, but the morphology of these particular virus particles is still unknown, and most cases of non-A to E hepatitis do not relate to their infections. We tried to visualize virus-like particles (VLPs) in plasma samples from hepatitis B surface antigen- and antibody to hepatitis C virus (HCV)-negative blood donors with elevated alanine aminotransferase (ALT), and examined the association of the virus-like particles and the genomes of parenterally transmissible GBV-C/HGV. Twenty-three plasma samples, 13 with elevated ALT levels and 10 with normal ALT values, from blood donors without infections of hepatitis B virus (HBV) and HCV, were subjected to a 20%–60% sucrose density gradient centrifugation, and virus-like particles were observed by electron microscopy. GBV-C/HGV RNAs in the plasmas were tested. Virus-like particles were found in the fractions with densities of 1.15–1.16 g/ml from 12 of 13 (92.3%) plasmas with elevated ALT levels and 1 of 10 (10%) normal controls. The ultrastructural morphology of visualized VLPs was pleomorphic in size and appearance; the majority of the VLPs were 50- to 80-nm spherical particles with a 35- to 45-nm inner core and 9- to 12-nm-long surface spikelike projections. Rodlike VLPs 50–70 nm in diameter with a length of 110–160 nm were also observed in the same samples. The incidence of detection of the circulating VLPs was significantly ($P < 0.001$) related to elevated ALT levels, but GBV-C/HGV RNAs were detected in none of the plasmas containing the virus-like particles. Spherical VLPs are detected in HBV- and HCV-

negative plasmas significantly correlated with the elevation of ALT, suggesting that they are implicated in non-B, non-C hepatitis.

Key words Non-B, non-C hepatitis · Virus-like particle · Hepatitis C virus · GB virus C · Electron microscopy

Introduction

The genomes of hepatitis C virus (HCV), GB virus C (GBV-C), and hepatitis G virus (HGV) have been successfully cloned without isolation of the virus particles.^{1–3} The causative role of HCV in bloodborne acute and chronic hepatitis has been well established. Although GBV-C/HGV can be transmitted parenterally, most of their infections are not associated with acute and chronic non-B, non-C hepatitis, and there is some doubt whether GBV-C/HGV replicates in the liver and causes hepatitis.^{4,5} During immunogold electron microscopy^{6–9} of HBV and HCV particles, we have noticed that some plasma samples from blood donors with elevated alanine aminotransferase (ALT) levels contained virus-like particles (VLPs) that did not react positively with antibodies specific to the HCV envelope protein. The VLPs, thus immunologically distinguished from HCV virion, were also different in morphology from the latter, and their etiological implications were not clear. In this article, we have tried to visualize VLPs in hepatitis B surface antigen (HBsAg)- and anti-HCV-negative plasmas and evaluated whether the circulating VLPs were detected with or without a relationship to elevated plasma ALT levels or to GBV-C/HGV RNAs.

Materials and methods

Twenty-three blood donor plasma samples were the subjects in this study. Clinical characteristics of the blood donors are summarized in Table 1. These samples were negative for HBsAg (AUSRIA II-125; Dainabot, Tokyo,

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Table 1. Summarized data of detection of virus-like particles and nucleic acids of known hepatitis viruses in plasma samples negative for HBsAg and anti-HCV

Plasma no.	ALT (IU/l)	Virus-like particles ^a		HBV DNA ^b	HCV RNA ^c	GBV-C RNA ^d	HGV RNA ^e
		Spherical	Rod-like				
1	91	–	–	–	–	–	–
2	81	2+	–	–	–	ND	ND
3	87	2+	–	–	–	–	–
4	70	3+	2+	–	–	–	–
5	82	3+	2+	–	–	–	–
6	103	3+	1+	–	–	–	–
7	121	3+	3+	–	–	–	–
8	67	2+	1+	–	–	–	–
9	117	2+	–	–	–	–	–
10	72	2+	1+	–	–	–	–
11	103	2+	–	–	–	–	–
12	78	3+	1+	–	–	ND	ND
13	77	1+	–	–	–	–	–
14	4	1+	–	–	–	–	–
15	28	–	–	–	–	–	–
16	6	–	–	–	–	–	–
17	10	–	–	–	–	–	–
18	7	–	–	–	–	–	–
19	11	–	–	–	–	–	–
20	4	–	–	–	–	–	–
21	6	–	–	–	–	–	–
22	6	–	–	–	–	–	–
23	8	–	–	–	–	–	–

ALT, alanine aminotransferase (normal < 35 IU/L); ND; not dated

^a Circulating virus-like particles (VLPs) in a 5-square section of a 300-mesh grid was photographed under electron microscopy. The mean numbers of VLPs in one square was indicated as – (negative), 1+ (0 < + < 10), 2+ (10 ≤ 2+ < 100), and 3+ (100 ≤ 3+)

^b HBV DNA was tested using a Quantiplex HBV-DNA assay kit

^c HCV RNA was tested using an AmpliCor HCV kit

^d GBV-C and ^e HGV RNAs were assayed as described in the text

Japan), antibody to HBV core antigen (CORAB; Dainabot), HBV DNA (Quantiplex HBV-DNA Assay; Chiron, Emeryville, CA, USA), anti-HCV (Ortho HCV Ab IRMA Test III; Ortho-Clinical Diagnostics, Tokyo, Japan), HCV RNA (AmpliCor HCV; Roche Molecular Systems, Branchburg, NJ, USA), and antibodies to human T-cell leukemia virus type I (Determiner HTLV-I Antibody; Kyowa Medex, Tokyo, Japan) and human immunodeficiency virus (GENELAVIA MIXT; Sanofi Diagnostics Pasteur, Marnes la Coquette, France). Thirteen samples were elevated in alanine aminotransferase (ALT) levels (≥35 IU/l), and 10 samples were within a normal level in ALT (<35 IU/l). Total cholesterol and triglyceride levels were normal in all plasma samples.

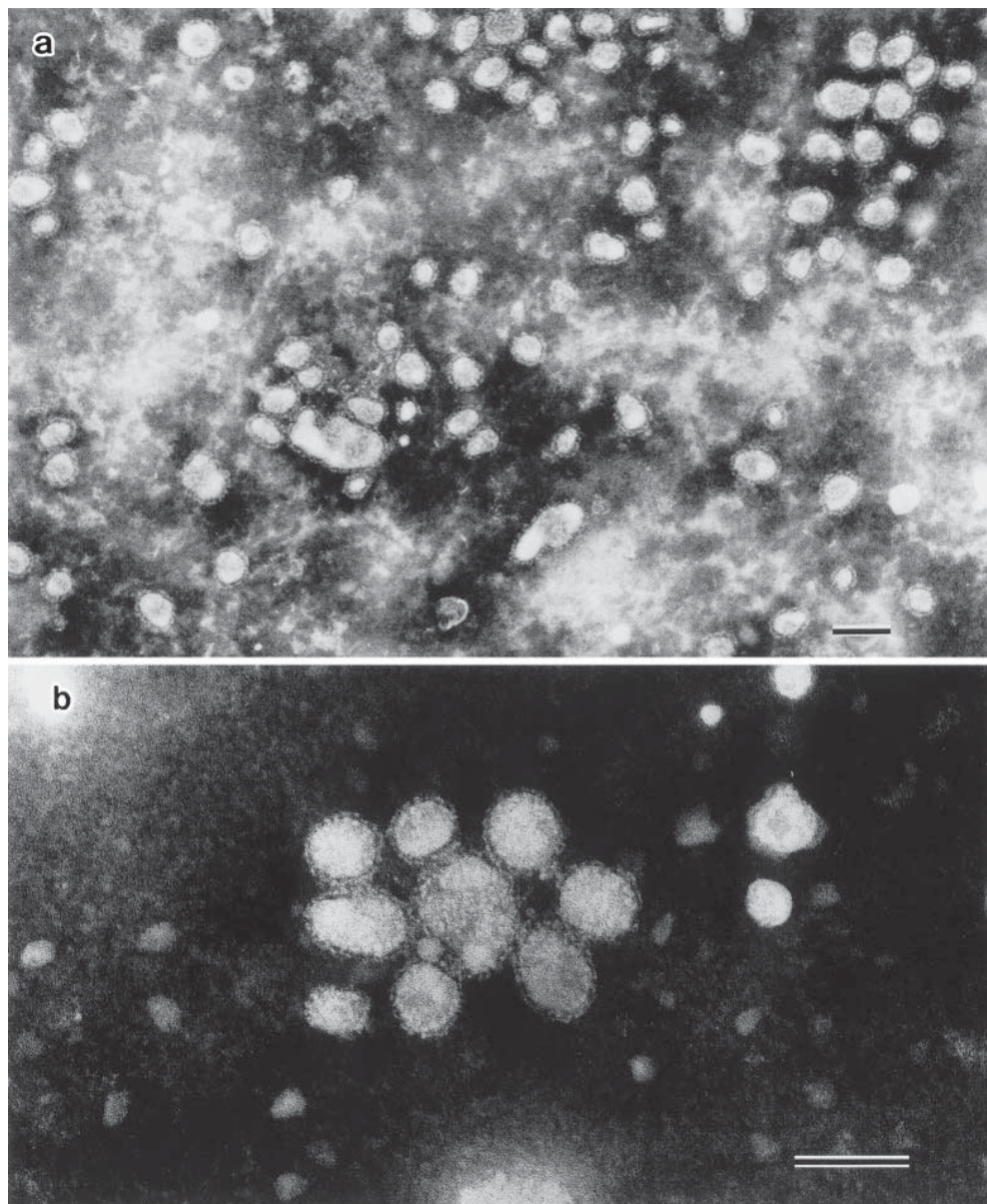
One hundred milliliters of each plasma sample was diluted with two volumes of TEN [100 mM Tris-HCl, pH 8.0, 1 mM ethylenediaminetetraacetic acid (EDTA), 100 mM NaCl] and centrifuged at 75 000 g for 6 h at 4°C. A suspension of the pellet in TEN was centrifuged again at 150 000 g for 2.5 h at 4°C. An approximately 1000-fold-concentrated suspension of the sample in TEN was layered on a 20%–60% (W/W) linear sucrose density gradient in TE (100 mM Tris-HCl, pH 8.0, 1 mM EDTA) and centrifuged at 100 000 g for 16 h at 4°C, which was followed by fractionation from the bottom of the tube. After measurement of the sucrose concentration of every fraction, each sucrose fraction was

diluted in phosphate-buffered saline (PBS, pH 7.4) and then centrifuged at 150 000 g for 2.5 h at 4°C. The resulting pellet was suspended in 100 ml PBS, equivalent to 1:1000 of the original plasma volume, for observing VLPs, and stored at –80°C until use. Two to three microliters of the concentrated specimen was mounted on a Formvar-coated and carbon-vaporized copper grid and examined under a Hitachi H-800 electron microscope operated at 100 kV after staining with 2% phosphotungstic acid (pH 6.5). To observe the nucleic acid-containing virus core structure, the specimen was subjected to repeated freezing and thawing several times, and then stained with 0.2% uranyl acetate (pH 4.4).

The GBV-C genome was assayed by reverse transcription-nested polymerase chain reaction (PCR) using primers derived from the NS3/helicase region of GBV-C genome reported by Simons et al.,² and this assay was performed as described elsewhere.¹⁰ The genome of HGV, provisionally designated by Linnen et al.,³ was assayed by using the kit of Boehringer Mannheim (Mannheim, Germany), which contained one primer pair for the NS5A region and a second primer pair for the 5'-untranslated region as well as the corresponding capture probes, according to the manufacturer's instructions.

Fisher's exact probability test was used to assess the significance of differences between the sample groups with or without elevated ALT levels.

Fig. 1. Electron micrograph of negatively stained 50- to 80-nm spherical virus-like particles (VLPs) in hepatitis B surface antigen (HBsAg)- and anti-hepatitis C virus (HCV)-negative plasma with an elevated alanine aminotransferase (ALT) level. VLPs from sample no. 6 (**a**) and sample no. 3 (**b**) are shown. Bar 100 nm



Results

Spherical VLPs were detected in 12 of 13 (92.3%) plasma samples with elevated ALT levels and 1 of 10 (10%) plasma samples with normal ALT values. The incidence of detection of the virus-like particles was significantly ($P < 0.001$) related to the elevation of plasma ALT levels (see Table 1).

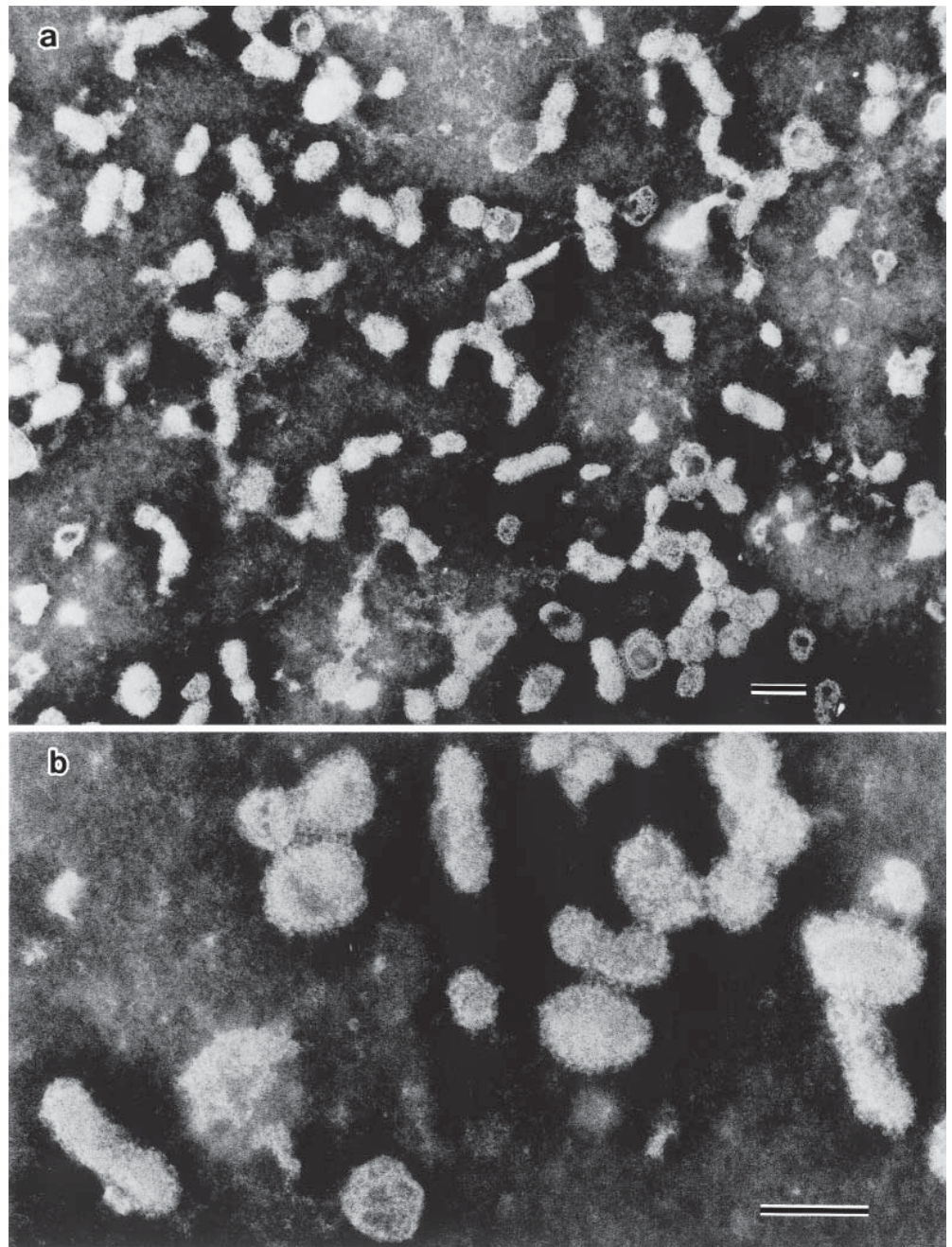
Most the visualized VLPs were spherical particles 50–80 nm in diameter with 9- to 12-nm-long surface spikelike projections (Fig. 1a,b). Some VLPs have a large diameter, more than 100 nm (Fig. 1a). In some specimens were detected more than a moderate number of VLPs, and rodlike VLPs 50–60 nm in diameter with a length of 110–160 nm were also detected that had surface projections similar to those of the 50- to 80-nm spherical particles (Fig. 2). The

diameter of the rodlike VLPs was 50–70 nm and their length was 110–160 nm. In addition, a 35- to 45-nm corelike structure containing the electron-dense material within a spherical VLP (Fig. 3a,b) and two inner cores of a rodlike VLP (Fig. 3c) were visualized by positive staining with uranyl acetate. These VLPs were found to be constantly banded in a sucrose density gradient at around 1.15–1.16 g/ml (range, 1.12–1.18 g/ml). GBV-C/HGV RNAs were not detected in any of the plasma samples (see Table 1).

Discussion

We found VLPs in ALT-elevated plasma samples from blood donors without infections of HBV and HCV that were consistently banded at around 1.15–1.16 g/ml by

Fig. 2. Negatively stained electron micrograph of rodlike VLPs presented in plasma containing a moderate number of the spherical VLPs. Rodlike VLPs from sample no. 7 (**a**) and sample no. 5 (**b**) are shown. Bar 100 nm



sucrose density gradient centrifugation. The majority were 50- to 80-nm spherical particles with 9- to 12-nm-long surface projections (see Fig. 1), and were, if anything, morphologically resembling togaviruses or coronaviruses. Positive staining revealed that the electron-dense material combined with uranium existed in a 35- to 45-nm internal core structure of the spherical virus-like particle, and indicated that the spherical particles had the nucleic acid therein (see Fig. 3). In addition, rodlike VLPs (Fig. 2) were observed concomitantly in the specimens containing many spherical VLPs, and the surface spikelike projections of rodlike forms looked similar to those of the spherical particles. Interestingly, two internal cores (Fig. 3c) were detected in a rodlike form, suggesting that this form could be a diploid particle

of the virus. Thus, we might consider that both the spherical and the rodlike virus-like particles belong to the same virus species.

In the past three decades, togavirus-like particles have been detected in acute-phase serum from a hemodialysed patient with non-A, non-B hepatitis and in the acute-phase urine of two icteric non-A, non-B hepatitis cases,¹¹ or in the liver of a patient with sporadic non-A, non-B fulminant hepatitis,¹² but the number of those objects was too small, and thus the etiological implications were not developed. Circulating VLPs, as presented here, were highly prevalent (92.3%) in ALT-elevated plasma samples, and were relatively easy to visualize by conventional electron microscopy, whereas in only one of ten normal controls were a few

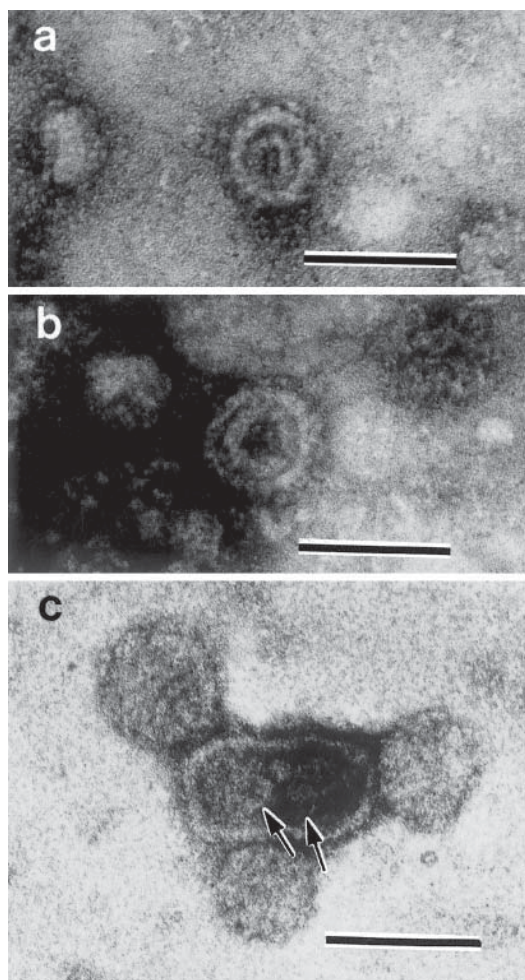


Fig. 3. Electron micrographs of positively stained VLPs showing internal corelike structures. Spherical VLPs from sample no. 6 (**a**) and sample no. 3 (**b**) and rodlike VLPs from sample no. 7 (**c**) are shown. **a** A 65-nm spherical VLP with a 35-nm inner core and surface spikelike projections; **b** 80-nm spherical VLP with a 45-nm core; **c** rodlike VLP 130 nm in the major axis and 70 nm in the minor axis containing two corelike structures (*arrows*) within an outer coat 10 nm thick. Bar 100 nm

spherical VLPs barely detectable despite careful observation. Thus, although the presence of the virus-like particles in the blood was significantly ($P < 0.001$) associated with the elevation of plasma ALT levels, indicating that these virus-like particles do cause liver cell necrosis, the nucleic acids of parenterally transmissible known hepatitis viruses were not detected in any tested plasma samples.

A novel DNA virus, which was designated TT virus (TTV), has been successfully cloned from serum of a patient with posttransfusion hepatitis of unknown etiology.¹³ TTV particles are 30- to 32-nm spherical particles with a density of 1.31–1.35 g/ml in cesium chloride.¹⁴ The morphology and buoyant density of TTV were quite different from the VLPs described in this article. Recently, a novel single-stranded DNA virus, which was named NV-F, has also been successfully cloned from the serum of a patient with non-A–E hepatitis without isolation of the virus particles.¹⁵ NV-

F DNA was detected in 17 (24.6%) of 69 patients with non-A–E and in 5 (2.8%) of 180 healthy individuals. Therefore, further morphological study and genomic study of NV-F should be carried out to evaluate whether the circulating VLPs were closely related to NV-F.

In conclusion, the presented VLPs, which morphologically resembled togaviruses or coronaviruses, may be a causative candidate virus of bloodborne non-A–G hepatitis, and details of the etiological implications should be further elucidated.

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