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Abstract: Parvovirus 4 (PARV4) is a DNA virus frequently associated with human immunodeficiency virus (HIV) and hepatitis C virus (HCV) infections, but its clinical significance is unknown. We studied the prevalence of PARV4 antibodies in 2 cohorts of HIV- and HCV-infected individuals (n = 469) and the correlations with disease status. We found that PARV4 infection frequently occurred in individuals exposed to bloodborne viruses (95% in HCV-HIV coinfected intravenous drug users [IDUs]). There were no correlations between PARV4 serostatus and HCV outcomes. There was, however, a significant association with early HIV-related symptoms, although because this was tightly linked to both HCV status and clinical group (IDU), the specific role of PARV4 is not yet clear.

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Parvovirus 4 Infection and Clinical Outcome in High-Risk Populations

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Parvovirus 4 (PARV4) is a DNA virus frequently associated with human immunodeficiency virus (HIV) and hepatitis C virus (HCV) infections, but its clinical significance is unknown. We studied the prevalence of PARV4 antibodies in 2 cohorts of HIV- and HCV-infected individuals (n = 469) and the correlations with disease status. We found that PARV4 infection frequently occurred in individuals exposed to bloodborne viruses (95% in HCV-HIV coinfected intravenous drug users [IDUs]) [4, 6] but is uncommon in healthy individuals in Western countries, suggesting parenteral transmission [4, 6].

Parvovirus 4 is associated with human immunodeficiency virus (HIV) and hepatitis C virus (HCV) infections [3]; hence we were interested in the effect PARV4 might have on disease progression. PARV4 has been found in many tissues, including the bone marrow of HIV-positive individuals [3] and the liver of HCV-positive individuals [1, 7], but is also found in plasma, cerebrospinal fluid, skin, and myocardium [1, 2, 4, 6, 8]. Despite the detection of viral DNA in so many organs, PARV4 has rarely been linked to specific symptoms, except for a recent study linking PARV4 to encephalitis [8] and in the individual in whom PARV4 was discovered, who presented symptoms including pharyngitis, vomiting, and arthralgias [2]. Determining a pathological association is problematic because PARV4 is so frequently found in individuals burdened with HCV- or HIV-related disease. However, as a common coinfection with these pathogens, it may have an important impact on clinical disease. This is of increased importance in light of the recent examination of immune responses to this virus [9]. This revealed sustained high-frequency T-cell responses associated with an effector memory phenotype consistent with persistent exposure to immunogenic viral antigen. Because the antigen can be expressed in both lymphoid and hepatic tissues [3, 7], an impact on both HCV and HIV pathogenesis is plausible.

We therefore studied the impact of PARV4 serostatus on HCV- and HIV-related disease progression. To do this, we tested for PARV4-specific antibodies in 2 prospective cohorts of HCV- and HIV-infected individuals (mono- and coinfected). Hepatitis C viral clearance, genotype, patient gender, age, alanine aminotransferase (ALT) levels, tissue histology (fibrosis), CD4 slopes, and Centers for Disease Control and Prevention (CDC) events were analyzed in relation to PARV4 serostatus.

**METHODS**

**Study Subjects and Sample Collection**

Local ethical approval (MREC/98/3/55 and http://www.shcs.ch/30-study-design) and informed patient consent were obtained for 2 cohorts, totaling 469 individuals (Table 1). The first, which consisted of 193 individuals from the Swiss HIV cohort [10], was made up of 99 HIV-positive, HCV-negative men who have sex with men (MSM) and 94 HIV-HCV coinfected IDUs. The first sample taken at least 1 year after the first positive HIV serology was used in experiments. The
second group, which consisted of 276 individuals from the Trent HCV cohort, was divided into 44 individuals who cleared HCV vs 232 who became chronically infected and, among chronically infected individuals, 143 who had persistently mild liver fibrosis (Ishak fibrosis score always 0 or 1, 1–5 biopsies were taken per individual, across 1–25 years) vs 98 who progressed to severe fibrosis (Ishak fibrosis score 5 or 6). The most recent plasma sample available was tested in this latter cohort. Plasma samples were taken by each center and frozen until required.

Serological Screening
Plasma samples from these individuals were tested in duplicate for anti-PARV4 immunoglobulin G (IgG), as described elsewhere [6].

CD4 Slopes and CDC Events
CD4 counts were available for 114 of 193 individuals of the Swiss HIV cohort prior to antiretroviral therapy. CD4 slopes were calculated using GraphPad Prism when at least 3 time points were available, spanning 6 months minimum. CD4 counts were plotted relative to time (day 0 was the first available sample date) to determine CD4 slopes, which were then compared to PARV4 serostatus using Mann–Whitney tests. Kaplan–Meier survival curves were drawn to compare time to reach CDC-B and CDC-C events and death, defined by the CDC as hallmarks of HIV-related disease [11].

Statistical Analyses
Statistical analyses were carried out using the Mann–Whitney test, Fisher’s exact test, and log rank (Mantel–Cox test) using GraphPad Prism software. For more detailed statistic analyses on the Trent HCV cohort, the open-source R software (http://www.r-project.org) was used to perform a logistic regression to analyze the simultaneous relationship of age, gender, main risk factor (IDU or MSM), and ALT with PARV4 serostatus. The HCV genotype was excluded because this information was not available for all individuals. The log odds of being PARV4 seropositive were modeled as a linear function of all variables potentially affecting this. The formula was:

$$\text{Log odds (PARV4 serostatus)} \sim \text{age} + \text{gender} + \text{main risk factor} + \text{ALT}$$

where “∼” implies relationship. The coefficients of the model have approximately normal distributions; therefore P values were obtained to compare individual coefficients. This analysis was carried out on 263 individuals of the Trent HCV cohort with complete data sets.

RESULTS
PARV4 Strongly Correlates With Intravenous Drug Use and Is Linked to CDC-B Event Occurrence
To address whether PARV4 has an impact on HIV disease progression, PARV4 serostatus was determined in 193 individuals from the Swiss HIV cohort (Table 1). First, we noted a striking association between PARV4 status and clinical group. In the HIV-positive, HCV-positive (IDU) group, a 95% prevalence of PARV4 was observed, compared with only 11% in the HIV-positive MSM group ($P < .0001$). We next analyzed CD4 slopes in relation to PARV4 status using serial CD4 counts available for 114 patients: 49 PARV4 IgG− individuals with CD4 slopes ranging from −41.3 to 5 cells/µL/month (median, −6.2), and 65 PARV4 IgG+ individuals with CD4 slopes ranging from −32.6 to 7.6 CD4 cells/µL/month (median, −6.3; data not shown). Using this approach we could not detect a difference in CD4 T cell decline between serologic groups ($P = .89$).

As another robust indicator of HIV disease progression, we assessed the occurrence of CDC-B and CDC-C events and death in PARV4-seropositive and -seronegative groups (Figure 1). The CDC-B symptoms were observed earlier in PARV4-seropositive individuals ($P = 0.02$). The association was not significant for CDC-C or death or between clinical groups (MSM vs IDU; data not shown). Thus, we did observe a correlation between PARV4 serostatus and early HIV disease progression, but the very close association between PARV4 serostatus, risk factor for HIV
PARV4 infection is also common in HCV mono-infected individuals.

The prevalence of PARV4 was also studied in 276 HCV-positive, HIV-negative individuals from the Trent HCV cohort. Thirty-one percent of individuals were PARV4 seropositive, and 36% in the IDU subset were PARV4 seropositive.

To determine if PARV4 serostatus affects clinical outcome in HCV-positive individuals, age, gender, HCV genotype, ALT levels, and main risk factor (IDU or non-IDU) were compared. No significant difference was seen between PARV4-seropositive and -seronegative individuals in gender, HCV genotype, age, or ALT levels (P = .89, .64, .26, and .34 respectively). We did, however, find a strong association between PARV4 serostatus and intravenous drug use as a risk factor (P = .01).

Next, the parameters of age, gender, ALT, and risk factor were analyzed together with PARV4 serology using a logistic regression framework. The results of this analysis show that only the IDU risk group significantly correlated with detection of PARV4 IgG (P = .01).

PARV4 does not affect the progression of HCV-related disease.

To assess the impact of PARV4 infection on HCV disease progression, 276 individuals from the Trent HCV cohort were grouped by clinical outcome. Study subjects were divided by PCR status: either persistently positive (n = 232) or always negative (n = 44), an indication of spontaneous HCV clearance. Thirty-six percent of individuals who had cleared HCV were PARV4 seropositive vs 29% of individuals who remained viremic (P = .37; data not shown).

Longitudinal biopsy data was available for 241 of these individuals. They were divided into those who maintained a mild fibrosis score (Ishak score 0 or 1 over time; n = 143) and those who progressed to severe liver fibrosis (Ishak score 5 or 6; n = 98). Twenty-nine percent of the individuals with mild fibrosis were PARV4 seropositive vs 31% of those with progressive disease (P = .78; data not shown). Finally, the treatment outcome of 131 individuals from the Trent HCV cohort was compared with their PARV4 serostatus. No significant difference was seen between patients who did not respond to treatment or relapsed and those who had a sustained virological response (P = .45; data not shown).

DISCUSSION

This study confirms that PARV4 infection is common in HCV-positive individuals, and even more so in HCV-positive IDUs coinfected with HIV. Although PARV4 did not influence HCV persistence, disease progression, or treatment response, PARV4-seropositive HIV-infected subjects progressed faster to HIV CDC-B symptoms than PARV4-seronegative individuals. However, because this was tightly linked to both HCV status and clinical group (IDU), the specific role of PARV4 is not yet clear.

Thirty-one percent of the HCV-positive, HIV-negative individuals of the Trent HCV cohort were PARV4 seropositive. This is in accordance with our previous study that found 26% seropositivity in 84 HCV-infected individuals [9] and other studies that tested for PARV4 IgG [6] or viral DNA directly [12]. Parvovirus 4 infections are acute and resolve rapidly, followed by complete or almost complete clearance of viremia and only very low viral loads on reactivation [12]. Parvovirus 4 may therefore be relatively inefficiently transmitted compared with HCV and HIV-1.

In the Swiss HIV cohort, a striking 95% of the HIV-positive, HCV-positive IDUs were PARV4 seropositive. This is the...
PARV4 infection, especially acute infection, is warranted given the extremely high prevalence of infection in HIV-positive, HCV-positive IDUs and the profound and long-lived T-cell responses elicited. Future studies to define its cellular and tissue targets may well shed further light on its pathogenesis, both as a single agent and in the context of coinfection.

Notes

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