ASSASYING THE NEED OF COMMERCIAL PLASMA VIRAL LOAD TESTING IN RESOURCE LIMITED SETTINGS
Arnaw Kishore¹, Sumana M. N²

HOW TO CITE THIS ARTICLE:

ABSTRACT: Around nine million Human Immunodeficiency Virus (HIV) infected individuals are on antiretroviral therapy (ART). People living with HIV/AIDS in resource-limited settings where HIV burden is usually high, there is an urgent need of affordable, accessible and inexpensive tests to monitor response to treatment. Quite a few commercially available assay has been introduced to measure Plasma Viral Load (PVL) as testing can increase adherence to ART and facilitate timely switching of failing regimens and thus minimizing the development of resistance. We analyzed Nucleic Acid Test (NAT) based assay and Non Nucleic Acid Test based assay for PVL testing. Though both the assay has its own advantage and disadvantages, but the use of Non Nucleic Acid Test has an upper hand in resource limited settings. It is the duty of administration, clinicians, microbiologist and health care personnel to introduce appropriate laboratory monitoring assays in resource-limited settings.

KEYWORDS: Plasma Viral Load, Nucleic Acid test, Non Nucleic Acid Test, HIV, Resource Limited Settings.

INTRODUCTION: It is estimated worldwide that over nine million Human Immunodeficiency Virus (HIV) infected individuals are on antiretroviral therapy (ART) and a substantial proportion have been on treatment for years.¹ Improved access to ART through price reductions, availability of drugs, and significant increases in funding from all corners of world have resulted in a dramatic expansion of the number of HIV infected individuals receiving treatment in low and middle-income countries.² People living with HIV/AIDS in resource-limited settings where HIV burden is usually high, there is an urgent need of affordable, accessible and inexpensive tests to monitor response to treatment.³ A lot of simplified public health approach that has been used to provide large-scale drug delivery; has been found in limited studies to be cost effective.⁴ Though HIV treatment is manageable without routine laboratory assessment,⁵ a CD4+ T cell count monitoring helps and allows the evaluation of disease progression⁶, and Plasma Viral load (PVL) testing can increase adherence to ART and facilitate timely switching of failing regimens and thus minimizing the development of resistance.⁷,⁸ More recently the focus has shifted toward evaluating the possibility and access to laboratory assays, such as measurement of CD4+cell count and PVL, for these regions to support HIV clinical management programs. One of these laboratory tools, the PVL assay, has become the standard of care for monitoring patients receiving ART in the developed world.⁹,¹⁰ The argument rose by Badri et al that monitoring of CD4+ cell count is an inadequate alternative to monitoring of viral load and cannot be used to substitute for viral load monitoring is receiving steadily growing support.¹¹ World Health Organization (WHO) guidelines published in 2004 for ART in resource-poor environments suggested that CD 4+ cell count measurement was desirable for initiation of treatment but that the use of viral load for monitoring was optional. These guidelines have been revised to suggest that increased access
to virological testing is highly desirable, particularly for clinical decision making related to switching drug regimens\(^\text{11}\). Monitoring HIV PVL is often not performed in resource-limited settings because the assays are costly, and require sophisticated, expensive laboratory equipment and trained technicians.\(^\text{12,13}\) Globally ART cohort continues to expand and mature, hence the need for ongoing monitoring is becoming increasingly important to ensure treatment efficacy and minimize the risk of drug resistance. A number of nucleic acid test (NAT) based assays has been developed that use reverse transcriptase polymerase chain reaction (RT-PCR), branched DNA (b-DNA), and nucleic acid sequence based amplification (NASBA) technologies.\(^\text{14}\) Nucleic acid–based amplification assays are the mainstay of viral load monitoring in high-income countries. Assay design is complicated by the high level of genetic heterogeneity characteristic of HIV-1 and the emergence of recombinant strains.\(^\text{15}\)

**Nucleic Acid Amplification Assays:**

**Nucleic acid amplification tests are divided into two parts:**

i. Target amplification.

ii. Signal amplification.

Detection is done using either end point polymerase chain reaction (PCR) or real-time PCR. The advantages of nucleic acid testing approaches are that many of these assays have been well validated and are available in quality-assured kits, and there is clinician familiarity with interpretation of results. Most of these assays vary considerably by sample preparation, amplification and detection methodology, region of the genome targeted, and dynamic range.\(^\text{16}\)

Nucleic Acid Tests by some diagnostic companies;

1. Roche (Roche Amplicor and COBAS Taqman);
   a. Roche Amplicor Monitor (version 1.5), which uses 3 different formats (manual, manual extraction, and comprehensive bioanalytical system).
   b. COBAS amplification and detection; COBAS Ampliprep/COBAS Amplicor (Roche Molecular Systems).\(^\text{18-20}\)

2. Bio Merieux (NASBA) NucliSENS EasyQ (versions 1.2 and 2) - The NucliSENS assay is a nucleic acid sequence–based amplification methodology using a molecular beacon detection format that can be semi-automated with use of the manual NucliSENS miniMag extraction methodology or automated using the EasyMag analyser.\(^\text{19-21}\)

3. Abbott (Real time) (b-DNA) - Abbott HIV-1 RealTime assay (Abbott Diagnostics) have developed HIV-1 viral load assays. The Roche (version 1.5) assay is a reverse-transcription PCR–based, target amplification assay targeting the gag p24 region of the genome.

4. Siemens (bDNA) Versant HIV-1 RNA assay (Version 3.0; bDNA; Siemens) is a nucleic acid hybridization method that depends on signal amplification performed in a 96-well format on the 440 bDNA analyser.

5. Biocentric generic viral load assay - A real-time PCR assay called the Biocentric generic viral load assay is available from Biocentric that can be placed on a variety of real-time analysers and is referred to as an open system.\(^\text{16}\)

In comparison to previous end-point detection methodologies, few companies have developed the real time technologies which are based on fluorescence to achieve simultaneous amplification...
and detection instead of end-point detection. These assays extend the subtype coverage to detect increasing numbers of non-B strains, which are prevalent in most affected countries. However, most of NAT PVL assays are expensive for the use in resource-crunched settings and require very sophisticated infrastructure facilities. Monitoring PVL in resource-limited settings faces tremendous challenges particularly:

i. Lack of bare minimum facility like electricity, water and air condition to perform the test
ii. Lab personnel lacking knowledge and skill of molecular biology to run the test
iii. Improper financial support with lack of transparency in the funds
iv. Not being robust methods.

<table>
<thead>
<tr>
<th>Assay type</th>
<th>Bio-merieux</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>References</td>
<td>33-35</td>
<td>36-37, 51</td>
</tr>
<tr>
<td>Assay type</td>
<td>NucliSENS HIV-1QT</td>
<td>NucliSENS EasyQ HIV-1 (version 2.0)</td>
</tr>
<tr>
<td>Assay type</td>
<td>NASBA; isothermal amplification; electro chemiluminescence detection; manual extraction, NucliSENS extractor, or Nuclisens miniMAG</td>
<td>NASBA; real-time detection; molecular beacons; Nuclisens miniMAG (Automatic); Nuclisens EasyMag (Manual)</td>
</tr>
<tr>
<td>Linear range, RNA copies/ml</td>
<td>51–5 million</td>
<td>10-10,000,000</td>
</tr>
<tr>
<td>Specimen type</td>
<td>Plasma, serum, DBS, any body fluid, EDTA, citrate, heparin</td>
<td>Plasma, serum, DBS, any body fluid</td>
</tr>
<tr>
<td>Specimen volume µl</td>
<td>200–1000</td>
<td>200–1000</td>
</tr>
<tr>
<td>Area of genome targeted</td>
<td>Gag; target amplification</td>
<td>Gag; signal amplification</td>
</tr>
<tr>
<td>Controls</td>
<td>3 Internal calibrators (synthetic RNAs): Qa (high), Qb (medium) and, Qc (low); positive, negative controls not supplied with kits and left to lab decision</td>
<td>1 Internal calibrator; no external controls provided and inclusion reduces throughput</td>
</tr>
<tr>
<td>Subtype reactivity</td>
<td>Group M; not suitable for G, O</td>
<td>Group M; (A-D, F-H, J) not suitable for O, G</td>
</tr>
<tr>
<td>Technical Skills</td>
<td>High</td>
<td>High-Med</td>
</tr>
<tr>
<td>------------------</td>
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</tr>
<tr>
<td>Lab Set Up</td>
<td>Centrifuge/vortex; water bath/heating block; biohazard hoods; reader</td>
<td>Centrifuge/vortex; analyzer; biohazard hoods</td>
</tr>
<tr>
<td>Thorough Output (no of samples/run)</td>
<td>20–30</td>
<td>miniMAG (12 per run); EasyMAG; EasyQ analyzer (48 per run)</td>
</tr>
<tr>
<td>Time to result in hrs</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>Cost/kit</td>
<td>40–100</td>
<td>40–60</td>
</tr>
<tr>
<td>FDA Approval</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CE Marketing</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Advantage/s</td>
<td>Isothermal; many sample types</td>
<td>Closed system; rapid; automated; medium technical skill</td>
</tr>
<tr>
<td>Disadvantage/s</td>
<td>Contamination risk; postamplification steps required; dedicated space and equipment; high technical skill; cost; technical support required</td>
<td>Dedicated space and equipment; cost; technical support required; not FDA approved; significant risk of contamination in high-volume laboratories</td>
</tr>
</tbody>
</table>

Table 1 Continued...

<table>
<thead>
<tr>
<th>Assay</th>
<th>Roche Molecular Systems</th>
<th>Abbott</th>
<th>Biocentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>References</td>
<td>38, 52</td>
<td>38, 41-44, 53</td>
<td>38, 45-47, 54</td>
</tr>
<tr>
<td>Variable</td>
<td>Amplicor HIV-1 Monitor (version 1.5)</td>
<td>COBAS Taqman</td>
<td>RealTime HIV-1</td>
</tr>
<tr>
<td>Assay type</td>
<td>RT-PCR; end point PCR; Microwell Plate Manual and COBAS Amplicor or COBAS</td>
<td>RT-PCR; real-time PCR; dual-labeled hydrolysis type probes; Armored RNA internal</td>
<td>RT-PCR; real-time PCR; partially ds real-time probe with fluorescent label; armoured</td>
</tr>
<tr>
<td><strong>Ampliprep/Amplicor quantitation standard (HIV QS); Two versions (version 1 and 2)</strong></td>
<td><strong>RNA internal standard; automated via m2000rt; automated extraction (Abbott m2000sp, previously m1000 LCx assay largely discontinued)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Linear range, RNA copies/ml</strong></td>
<td><strong>400–750,000 (standard); 50–100,000 (ultrasensitive)</strong></td>
<td><strong>40–10 million for version 1; 20–10 million for version 2</strong></td>
<td><strong>300–50 million</strong></td>
</tr>
<tr>
<td><strong>Specimen type</strong></td>
<td><strong>Plasma, Dried Blood Spot (DBS)</strong></td>
<td><strong>Plasma, DBS</strong></td>
<td><strong>Plasma, DBS</strong></td>
</tr>
<tr>
<td><strong>Specimen vol.</strong></td>
<td><strong>200 or 500</strong></td>
<td><strong>1000</strong></td>
<td><strong>200-1000</strong></td>
</tr>
<tr>
<td><strong>Area of genome targeted</strong></td>
<td><strong>Gag; target amplification; In version 2LTR and gag regions targeted</strong></td>
<td><strong>Pol integrase region; target amplification</strong></td>
<td><strong>One internal calibrator; no external controls provided</strong></td>
</tr>
<tr>
<td><strong>Controls</strong></td>
<td><strong>High positive; low positive; negative; internal control</strong></td>
<td><strong>High positive; low positive; negative; internal control standard</strong></td>
<td><strong>Low positive; negative; internal control</strong></td>
</tr>
<tr>
<td><strong>Subtype detecivity</strong></td>
<td><strong>Group M; not suitable for O</strong></td>
<td><strong>Group M (A-D, F-H; CRF01_AE) group O included for version 2.0</strong></td>
<td><strong>All; better for CRF02-AG recombinants</strong></td>
</tr>
<tr>
<td><strong>Technical Skills</strong></td>
<td><strong>High-Med, if automated</strong></td>
<td><strong>High-Med, if automated</strong></td>
<td><strong>High-Med, if automated</strong></td>
</tr>
<tr>
<td><strong>Lab Set Up</strong></td>
<td><strong>For manual, thermocycler, ELISA reader, washer, and microcentrifuge; for automated, COBAS Ampiprep and COBAS Amplicor analyzers</strong></td>
<td><strong>COBAS Taqman with or without COBAS Ampiprep 48 or 96 system; biohazard hoods; centrifuges; 168/8 h day per continuous loading</strong></td>
<td><strong>Automated extraction and prep (m2000sp); amplification and detection (m2000rt); bar code reader for primary tubes; centrifuge; biohazard hood</strong></td>
</tr>
<tr>
<td><strong>Thorough Output (no of samples/run)</strong></td>
<td><strong>12–48 (9–21 per run)</strong></td>
<td><strong>48 or 96</strong></td>
<td><strong>48 (includes 3 controls)</strong></td>
</tr>
<tr>
<td><strong>Time to</strong></td>
<td><strong>7</strong></td>
<td><strong>5</strong></td>
<td><strong>5</strong></td>
</tr>
</tbody>
</table>
Non Nucleic Acid Testing: The high cost of NAT test along with high cost of reagents and consumables restricts its implementation in recourse limited settings. In order to assay PVL monitoring in resource limited settings, alternative accessible inexpensive methods have been developed by different manufacturers and some of these have been validated in the recent years 16 such as the Cavidi ExaVir™ RT assay,22-24 and PerkinElmer Ultrasensitive p24 assay,23,25,26 are based on ELISA method, measuring the activity of reverse transcriptase (RT) enzyme and the concentration of p24 antigen. The use of these indirect measures of PVL require less equipment and skill, have thus been evaluated for resource-poor settings and include the ultrasensitive, heat-denatured p24 antigen quantification assay which is no longer being developed for viral load monitoring, and the ExaVir Load (Cavidi AB) reverse-transcriptase assay13,27,28. Recently, other approaches have included the evaluation of flow cytometry–based markers of activation, such as the quantification of bright CD38 expression on CD8 cells29,30.
### Table 2: Comparative Analysis of Various Non-Nucleic Acid Test Based Assay

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ultrasensitive, heat-denatured p24 antigen quantitation assay (Perkin Elmer Life Sciences)</th>
<th>ExaVir load (version 3; Cavidi)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>References</strong></td>
<td>56</td>
<td>28, 55, 56</td>
</tr>
<tr>
<td><strong>Assay type</strong></td>
<td>Enzyme immunoassay for quantitation of p24 antigen; separate external buffer required</td>
<td>Enzyme immunoassay for quantitation of reverse transcriptase activity; colorimetric reading</td>
</tr>
<tr>
<td><strong>Detection</strong></td>
<td>Colorimetric or fluorimetric; Quanti kin detection software</td>
<td>Colorimetric detection software provided by company with kit start up package</td>
</tr>
<tr>
<td><strong>Dynamic range, RNA copies/ml</strong></td>
<td>Clinical cutoff: 10,000–30,000 RNA copies/mL; reported as fg/mL: 1–3000fg/mL</td>
<td>RNA copies/mL equivalents; version 3: 200 to 1600,000 RNA copies/mL equivalents</td>
</tr>
<tr>
<td><strong>Specimen type</strong></td>
<td>Plasma (ACD, CDPA-1, EDTA, sodium citrate, or heparin), serum, or cell culture supernatant</td>
<td>Plasma</td>
</tr>
<tr>
<td><strong>Specimen volume</strong></td>
<td>200–450</td>
<td>1-1000</td>
</tr>
<tr>
<td><strong>Controls</strong></td>
<td>5 Concentrations (VQA serum quality controls and diluents correction controls not provided in kit)</td>
<td>Serially diluted standard and recommended plasma pool for control</td>
</tr>
<tr>
<td><strong>Subtype reactivity</strong></td>
<td>HIV-1 (all subtypes); HIV-2</td>
<td>HIV-1</td>
</tr>
<tr>
<td><strong>Time to result</strong></td>
<td>2.5 h</td>
<td>2.5 days (colorimetric); 1.5 days (fluorimetric)</td>
</tr>
<tr>
<td><strong>Technical Skills</strong></td>
<td>Low to medium</td>
<td>Low to medium</td>
</tr>
<tr>
<td><strong>Lab Set Up</strong></td>
<td>Simple ELISA plate washer and reader; incubator; refrigerator and/or freezer; dry heat block</td>
<td>Incubator; freezer to store samples; ELISA plate washer and reader</td>
</tr>
<tr>
<td><strong>Thorough Output</strong></td>
<td>High; 96 samples per run</td>
<td>32 samples per run</td>
</tr>
<tr>
<td><strong>Cost/kit</strong></td>
<td>$20–$30</td>
<td>$15–$25</td>
</tr>
<tr>
<td><strong>FDA Approval</strong></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>CE Marketing</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Advantage/s</strong></td>
<td>Easy training; simple ELISA plate washer and reader; no separate areas required; high throughput; can be used for infant diagnosis of HIV infection [27]</td>
<td>Easy training; simple ELISA plate washer and reader; no separate areas required; can be used for NNRTI resistance monitoring</td>
</tr>
<tr>
<td><strong>Disadvantage/s</strong></td>
<td>Not sensitive enough to facilitate treatment changes in any setting; inconsistent supply; external buffer required</td>
<td>Controls not supplied</td>
</tr>
</tbody>
</table>

References: 56

**Assay type**
- Enzyme immunoassay for quantitation of p24 antigen; separate external buffer required
- Enzyme immunoassay for quantitation of reverse transcriptase activity; colorimetric reading

**Detection**
- Colorimetric or fluorimetric; Quanti kin detection software
- Colorimetric detection software provided by company with kit start up package

**Dynamic range, RNA copies/ml**
- Clinical cutoff: 10,000–30,000 RNA copies/mL; reported as fg/mL: 1–3000fg/mL
- RNA copies/mL equivalents; version 3: 200 to 1600,000 RNA copies/mL equivalents

**Specimen type**
- Plasma (ACD, CDPA-1, EDTA, sodium citrate, or heparin), serum, or cell culture supernatant

**Specimen volume**
- 200–450
- 1-1000

**Controls**
- 5 Concentrations (VQA serum quality controls and diluents correction controls not provided in kit)
- Serially diluted standard and recommended plasma pool for control

**Subtype reactivity**
- HIV-1 (all subtypes); HIV-2
- HIV-1

**Time to result**
- 2.5 h
- 2.5 days (colorimetric); 1.5 days (fluorimetric)

**Technical Skills**
- Low to medium
- Low to medium

**Lab Set Up**
- Simple ELISA plate washer and reader; incubator; refrigerator and/or freezer; dry heat block
- Incubator; freezer to store samples; ELISA plate washer and reader

**Thorough Output**
- High; 96 samples per run
- 32 samples per run

**Cost/kit**
- $20–$30
- $15–$25

**FDA Approval**
- No
- No

**CE Marketing**
- No
- Yes

**Advantage/s**
- Easy training; simple ELISA plate washer and reader; no separate areas required; high throughput; can be used for infant diagnosis of HIV infection [27]
- Easy training; simple ELISA plate washer and reader; no separate areas required; can be used for NNRTI resistance monitoring

**Disadvantage/s**
- Not sensitive enough to facilitate treatment changes in any setting; inconsistent supply; external buffer required
- Controls not supplied
Advantages | Disadvantages
--- | ---
It is simple to perform | Lengthy and tedious process and takes time approx of 72hrs
It is inexpensive | 1 ml of plasma is required, which is difficult to get in pediatric patients
It does not require sophisticated infrastructure facilities and expensive equipment | a lack of standard positive and negative controls [34]
No requirement of highly skilled technical staff | Requires skilled staff

Table 3: Advantages and Disadvantages Cavidi Exavir™ PVL Assay over the Standard RT-PCR Assay are,

Though the alternative methods (Non NAT methods) have dramatically reduced the cost $15-20 in comparison with NAT based PVL assay which costs $ 70-100. The assay described here viz ExaVir™ assay and the ultrasensitive p24 assay are much simpler and cost effective than all the NAT methods.

**Proposed Viral Load Testing Algorithm for Resource-Poor Environments:** It is recommended in high income countries that viral load testing be conducted at baseline; 2–8 weeks after initiation of ART to assess early virological response and then after every 3-4 months. This may not be in case of resource limited countries. Non-NAT are appropriate in such cases to measure PVL. The quality of testing is an important consideration in the selection of technologies. Even if the best test is purchased, if the test is performed badly, the results will not be useful. The selection of a VL technology needs to take into account the following:

1. Can staff be trained on the technology with ease?
2. Is there access to technical support?
3. Is it possible to perform regular maintenance?

**CONCLUSION:** Not a single stone should be left unturned to develop and introduce appropriate monitoring assay in resource-limited settings, as the benefit of ART with minimum drug resistance seems to be largely dependent on adequate monitoring. Issues like cost factor, adequate laboratory monitoring, skills and knowledge of technical staff, self-life of kits and reagent and there delivery should be taken into consideration apart from External quality assurance schemes (EQAS) should be taken into consideration at the time of implementation. The assays should be validated to ensure that the results are reproducible reliable and accurate.

The NAT test and Non NAT test works on two different principles. The NAT or Plasma HIV RNA assay measures virion-associated RNA while the Non NAT or RT assay measures the activity of a virion-associated enzyme required for replication. Measuring RT enzyme activity as marker for PVL has several advantages in the international setting apart from being inexpensive with less technical skills.

The reverse transcriptase enzyme is well conserved across different genetic clade types; therefore the RT assay would be expected to function well in areas of the world where non-clade B
strains, including complex recombinant strains, are common. While the NAT assay cannot differentiate between functional and defective virions and therefore may not reflect true viral replication activity, whereas the RT assay quantifies actual reverse transcriptase activity. It is the duty of administration, clinicians, microbiologist and health care personnel to introduce appropriate laboratory monitoring assays in resource-limited settings. As we are highly burdened by HIV/AIDS all effort should be counted in providing better and cheaper method for diagnosis and prognosis of HIV/AIDS as PVL has emerged as an important factor.

REFERENCES:
15. Von Truchsess I, HB, Schatzl HM, Hackett J Jr. The first B/G intersubtype recombinant form of human immunodeficiency virus type 1 (HIV-1) identified in Germany was undetected or underquantitated by some commercial viral load assays. J Med Virol 2006; 78:311–317.


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