A Portable Multifunctional Platform for Rapid Molecular Screening of Bloodborne Pathogens from Whole Blood

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BACKGROUND

- Hemorrhage remains a leading cause of preventable death in combat casualty care. In far-forward and austere environments where stored blood products may be unavailable, walking blood bank protocols enable safe, timely blood transfusion when it matters most.
- Bloodborne pathogen screening is essential to reduce transfusion-transmitted infection risk. However, field-deployable screening tests are typically antibody-based and lack the analytical sensitivity of laboratory nucleic acid testing.
- We developed a compact analyzer with a workflow designed for CLIA-waived operation (requiring one liquid transfer step) that rapidly automates molecular bloodborne pathogen screening. Feasibility was demonstrated for HIV-1 and hepatitis C virus (HCV) RNA.

METHODS

- Reverse transcription PCR assays for HIV and HCV were implemented on a credit card-sized digital microfluidic cartridge using electrowetting-based droplet manipulations to automate sample preparation, magnetic bead–based nucleic acid capture, thermal cycling, and fluorescence detection.
- Preliminary limit of detection (LoD) was evaluated using contrived whole blood samples spiked with quantified viral material. Assay linearity was assessed across viral concentrations.
- Method comparison studies for HCV and HIV were performed using archived clinical specimens previously characterized by a comparator test.
- The automated workflow enabled sample-to-answer molecular detection from whole blood in ~30 minutes.

Figure 1. Baebies' point-of-care instrument and cartridge for bloodborne pathogen screening.

RESULTS

- **HCV:** We demonstrated a preliminary LoD of ~1,000 IU/mL for the HCV assay. Method comparison using banked clinical specimens (n=106) showed 94% positive percent agreement and 93% negative percent agreement compared with reference methods across specimens ranging from 1e3 to 1e8 IU/mL (including 13 samples below the limit of detection).
- **HIV:** The HIV assay demonstrated a preliminary LoD of 200 copies/mL and was linear from 200 to 1e7 copies/mL. Preliminary method comparison using archived samples (n=10) found good agreement with comparator data (regression line slope = 1.00 and total analytical error less than 0.75).

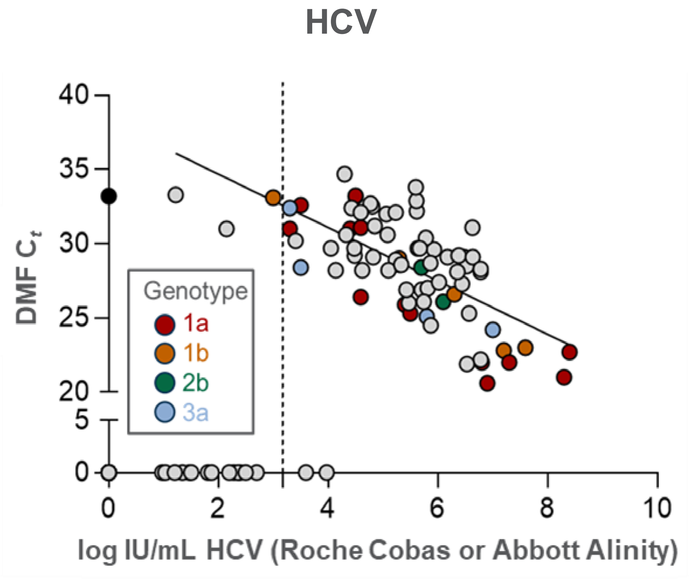

Figure 2. Patient samples covered multiple HCV genotypes including 1a (red), 1b (orange), 2b (green), 3a (blue), and unspecified (gray). Digital microfluidic (DMF) C_t values correlated with Roche Cobas or Abbott Alinity $\log_{10}$ IU/mL HCV concentration. One false positive was obtained (black dot). Dotted line indicates preliminary limit of detection at 1,000 IU/mL. A total of 106 samples were run (including 13 samples with HCV levels ≤ 1,000 IU/mL).

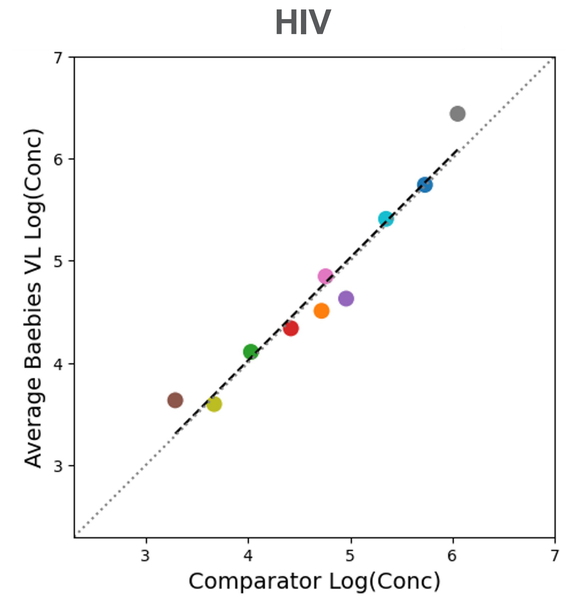

Figure 3. Ten clinical samples were run in duplicate on the Baebies viral load (VL) HIV assay and FDA-cleared comparator assays (Roche Cobas HIV-1 and Hologic Aptima HIV-1 Quant Dx assays). Bias, standard deviation, and total analytical error were calculated for each sample. Individual biases were less than 0.40 log(conc) and total analytical errors were less than 0.75.

CONCLUSIONS

- This compact diagnostic platform demonstrated approximately 30-minute molecular testing of HIV and HCV bloodborne pathogens from whole blood, supporting the feasibility of nucleic acid testing for austere donor screening during walking blood bank transfusions in combat casualty care and mass civilian casualty events.
- Work is ongoing to increase sensitivity of both tests prior to further clinical studies.

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