Using an electronic health record alert to prompt blood-borne virus testing in primary care

Short title: Using an EHR alert for BBV Testing

Authors: David Chadwick\textsuperscript{a},\textsuperscript{*}  Gareth Forbes\textsuperscript{b}, Chris Lawrence\textsuperscript{a}, Susan Lorrimer\textsuperscript{c}, Paul van Schaik\textsuperscript{c}.

Addresses: 

\begin{itemize}
\item a. Centre for Clinical Infection, The James Cook University Hospital, Middlesbrough TS4 3BW, UK
\item b. Leadgate Medical Centre, Consett, DH8 6DP, UK
\item c. Department of Psychology, Teesside University, Middlesbrough TS1 3BX, UK
\end{itemize}

* davidr.chadwick@nhs.net (author for correspondence and reprints).

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Disclaimer (conflicts of interest)

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Abstract

**Background:** Late diagnosis of HIV, hepatitis B (HBV) and hepatitis C (HCV) remains relatively common in the UK and many people who present late have missed opportunities for testing in primary care. The objective was to assess the effectiveness and acceptance of a prototype application (BBV_TP1), embedded in a primary care electronic health record (EHR), to increase real-time blood-borne virus (BBV) testing.

**Methods:** This prospective cohort study assessed BBV_TP1 in 14 general practices in North East England, in comparison to 54 similar practices in 2019. Rates of HIV, HBV and HCV testing in practices were measured before and after the application was activated. Patient and clinician acceptance of the technology was assessed by surveys.

**Results:** In the six months following the intervention HIV testing rates increased 555% and combined HBV/HCV testing rates increased 362%. No significant differences were observed for any BBV testing rates in the non-intervention practices over the same period. Monthly testing rates declined towards baseline after initial increases. Clinician’s perceptions of the prompt system were positive, with average additional time required for BBV test discussion in consultations estimated at 2 minutes. The patient survey also showed high acceptance of the technology.

**Conclusion:** This pilot study demonstrated that BBV_TP1 increased BBV testing rates in primary care via targeted screening, although testing rates subsequently fell whilst the application remained active. Such systems can potentially reduce late diagnoses, while having high acceptance by clinicians and patients. Larger studies with longer follow-up are needed to demonstrate efficacy and cost-effectiveness.
Introduction

Late diagnoses of HIV, hepatitis B (HBV) and hepatitis C (HCV), the blood-borne viruses (BBV), remain high in the UK despite national guidelines and other efforts to increase BBV testing amongst those at risk of infection. Late diagnosis of BBVs is associated with increased morbidity and mortality, higher healthcare costs and increased transmission of infections. Earlier diagnosis allows long-term effective treatment (for HIV and HBV), cure of infection for HCV and reduction in transmission of infections. BBV testing in lower prevalence areas of the UK is not routine; however, it is recommended for those with certain risk factors or demographics, or in the case of HIV for all patients attending primary care where there is a high local prevalence (>0.5%). However, late HIV diagnosis (CD4<350 cells/mm$^3$) is still seen in 43% of new HIV diagnoses in England. HIDES-1 and other studies have demonstrated that patients with certain indicator conditions have an undiagnosed HIV prevalence >0.1%, where screening is cost-effective. Hence targeted HIV testing amongst patients with identified risk factors is likely to be cost-effective and lead to earlier diagnosis. This is also likely to be the case for HBV and HCV.

Over half of patients who present with late HIV or HCV infections attend primary care or hospital facilities in the year before diagnosis, often with symptoms consistent with chronic infection or indicator conditions but are not tested. Efforts to increase testing for BBV infections in UK primary and secondary care have mostly had limited success or have required significant resources to maintain higher testing rates. Electronic health record (EHR) systems allow the development and integration of clinical decision support (CDS) algorithms to guide choice of tests and other clinical management. Studies, however, have demonstrated the importance of usability and user involvement in their development to ensure application effectiveness. Such applications provide an opportunity to identify
individuals at higher risk of undiagnosed BBV infection either electively[^18] or during the clinician-patient interaction[^19] and also identify candidates for pre-exposure prophylaxis.[^20][^21]

Here we evaluated a prototype application, BBV_TP1, designed to prompt in real time, BBV testing in previously untested higher-risk individuals attending primary care.

**Methods**

*Application development*

An algorithm was developed (BBV_TP1) within internal applications of the SystmOne (TPP-UK, Leeds) EHR, which searched for various items of data indicating higher BBV risk. These included repeatedly abnormal test results (e.g. lymphopenia, raised ALT), diagnostic codes (e.g. hepatitis, pneumonia, shingles) and repeat prescriptions e.g. aciclovir, antifungals (Supplemental Table 1). The presence of any BBV risk factor, without appropriate testing, triggered a ‘soft prompt’ – a small icon at the top of the screen – indicating risk and advising BBV testing. In patients with two or more risk factors for hepatitis B/C, or 3 or more for HIV a hard prompt, requiring a response, was generated. Both soft and hard prompts linked to an integrated request form screen listing the risk factors, recommending relevant BBV testing and allowing recording of the test offer and/or patient’s decision to decline testing. Declining testing suppressed prompts for up to three years.

*Study cohort and design*

A comparative, prospective cohort study was undertaken involving general practices in North East England using the SystmOne EHR. Following an invitation to research-active practices, 14 practices were selected to take part in the study covering a patient population
of around 137,000. For a comparative analysis of BBV testing rates, a further 54 control practices were selected which did not install the BBV_TP1 application. In active practices general practitioners (GP) and other healthcare professionals were trained on the use of the application and if deciding to perform a prompted test, followed local guidelines on test procedures including giving results and referrals to appropriate services if positive. Each practice activated the application between March and May 2019 for 6 months. BBV testing rates were measured for all active and control practices for 6 months before and after activation.

*Analysis of algorithm usage and prompt response*

Impact of the algorithm on testing was analysed from two perspectives. One was the EHR data showing the number of hard prompts triggered, the number of responses by clinicians to the prompts and whether the test was requested or declined. The second was the actual number of BBV tests performed in the laboratory from the study practices.

Individual GP practices extracted and anonymised their own data, which were then merged and supplied to the research team for analysis. The lab- and EHR data were analysed with the mixed-model analysis R package lme4.

A cross-sectional survey of patients and clinicians, using 5-point Likert and 0:100 grading scale, was conducted at the end of the trial period in each participating general practice to measure technology acceptance and impacts on consultation time (see supplemental file: survey).

*Ethical approval*

The study was approved by the Scotland A Research Ethics Committee. (Ref. 18/SS/0148)
Results

*Laboratory tests performed*

More HIV tests were performed after than before the introduction of the BBV test prompt system (Figure 1). Mean HIV testing rates increased 555% from 1.38/10,000 patients in the 6 months prior to introduction to 7.67/10,000 in the 6 months post introduction (p=<0.0001) with a peak of 15.8/10,000. The number of HIV tests ordered in non-study practices did not increase over the same time period (1.93/ 10,000 patients to 1.90/10,000, (p=0.63). Mixed-model analysis showed the effect of period (baseline compared with end of trial) was statistically significant (p=0.003).

Tests performed remained constant over time before the introduction of the prompt system; mixed linear modelling showed that the date (month) was not a significant negative predictor of responses, (p=0.49). Tests performed decreased to baseline over time after the introduction of the prompt system; mixed linear modelling showed that the date (month) was a significant negative predictor of responses (p=0.02).

The laboratory data received did not differentiate between HBV and HCV therefore a combined analysis is presented. Following introduction of the prompt HBV/HCV testing rates increased 362% from 2.38/10,000 to 8.60/10,000 (p=<0.0001) over the subsequent 6 months with a peak of 15.0/10,000 (Figure 1); mixed linear modelling showed that the date (month) was a significant negative predictor of responses, (p=0.02).

*EHR prompts*
Following introduction of the algorithm, the mean number of hard prompts for testing was 3.63 per 1000 patients/month, ($SD=1.61$). The mean number of clinician responses to prompts was 1.24/1000/month, ($SD=2.23$). The number of hard prompts for testing and clinician responses decreased over time after the introduction of the BBV test prompt system; mixed linear modelling showed that the date (month) was a significant negative predictor of responses, ($p=0.00007$ and $p=0.001$ respectively).

**EHR tests**

The average number of tests requested per practice per month after introduction of the prompt was increased for HIV, HBV and HCV (Figure 2). Mixed-model analysis showed the effect of period (before compared with after introduction of the prompt) was statistically significant for HBV ($p=0.05$) and HCV ($p=0.05$) but not for HIV ($p=0.10$).

The number of BBV tests declined by patients increased following prompt introduction. The number then decreased over the subsequent 6 months; mixed linear modelling showed that the month was a significant negative predictor of responses ($p=0.002$). Before introduction of the prompt numbers of tests declined remained stable, mixed linear modelling showed that the month was not a significant predictor of responses, ($p=0.58$).
Patient and Clinician survey

Clinician survey participants were 60 GPs, 15 nurse practitioners and 6 other clinicians, 51 female and 29 male. Mean age was 44, SD=9.22. Clinicians’ perceptions of the prompt system were largely positive (mean > neutral scale value of 3; CI.95 = [3.08; 3.53] for intention to use and [3.48; 3.83] for perceived ease of use), with average additional time required for BBV test discussion in consultations estimated at 2 minutes; a majority of practices wanted to retain the system.

Hard prompt frequency was judged to be slightly too high (median grading=66/100; CI95%=[51; 80]) and soft prompt frequency was judged to be acceptable (median=53/100; CI95%=[50; 59]). Nineteen per cent of clinicians reported having to make an additional appointment after a BBV test prompt because of insufficient time during a consultation and 15% had to make an additional appointment to discuss test results. Free-text answers stressed the lack of time available. Median additional consultation time varied from 0.25 minutes when the clinician ignored the prompt to 2 minutes when the prompt was accepted or declined. Clinicians stated that preference for permanent suppression of the prompt was more than twice as frequent for patients than clinicians (p<0.001). The patient survey (40 female, 33 male) showed high acceptance of the technology. For example, a majority agreed their medical data to be used for risk assessment of BBV infection.

Discussion
In this study we found that introduction of the BBV_TP1 alert system led to a substantial initial increase in rates of HIV and hepatitis B/C testing. Testing rates, however, tailed off from month 2 to 6 whilst the application remained active. There are two likely reasons for this observation. First, the trend to baseline testing levels may have been due to reduced engagement by clinicians with the prompt over time: alert fatigue. Second, it may be due to saturation of the population requiring testing, having initially highlighted a cohort of at risk individuals, with fewer higher-risk, not previously-alerted individuals attending practices in the latter months of the study. The decrease in the number of hard prompts issued after the first 2 months supports the latter. Further work is needed to ascertain which of these factors was more important in terms of reduced testing rates.

Analysis of EHR data shows a trend to an increase in average monthly EHR test requests for HIV, HCV and HBV, reflecting similar levels of engagement likely assisted by the integrated request form. Although the change in rates was not significant for HIV due to the greater variability seen between practices, we are confident that this would become significant with a larger sample size. Laboratory data did not differentiate HCV and HBV; however, the EHR results indicate testing patterns were similar for both.

Our surveys demonstrated acceptance to both patients and clinicians both in terms of time and complexity. Through efficient prompt presentation we were able to maintain the time to use the prompt to 2 minutes, which is well below the estimates (mean = 3.71) of clinicians who had not used the BBV test prompt and is within the acceptance threshold of two additional minutes of consultation to use a CDS in patient consultations. However, the need for 19% of clinicians to allocate an appointment to discuss testing and then 15% to discuss the results indicates potentially significant additional consult time. Despite this 7 practices opted to keep BBV_TP1 active after the study ended.
According to clinicians, patients were more likely than clinicians to request permanent prompt reduction or suppression. This may reflect a difference in perceived risk and stigma by association as seen in previous studies\textsuperscript{25}. Furthermore, previous emergency department-based literature suggest a three times higher prevalence of BBV amongst those declining testing\textsuperscript{26}, raising the possibility of similar occult cases in those patients who declined testing during the study.

In summary, this pilot study demonstrated that BBV\_TP1 increased BBV testing rates in primary care although testing rates subsequently fell. Such systems can potentially reduce late diagnoses. Larger studies of such technology are needed to demonstrate efficacy and cost-effectiveness.

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Figures and Tables

Figure 1. Monthly HIV and HBV/HCV testing rates per 10,000 patients in study and control practices.

[Graph showing monthly tests performed per 10,000 patients by HIV and HBV/HCV in study and control practices, with peaks post BBVTP1 activation.]
Figure 2. Monthly EHR test requests before and after intervention in study practices
List of Supplemental Digital Content

1. Clinician and Patient Survey (Word file)

2. Supplemental Table 1. (Word file)