Comparison of ELISA and Rapid Immunochromatographic Tests for Hepatitis B Surface Antigen Detection in Field Settings

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ABSTRACT

The Hepatitis B virus (HBV) infection remains a considerable global health issue, with the detection of hepatitis B surface antigen (HBsAg) being crucial for diagnosis and screening. This study aggregates data from numerous investigations to assess the diagnostic effectiveness of enzyme-linked immunosorbent assay (ELISA) and rapid immunochromatographic tests (ICTs) for HBsAg detection, with a focus on field applications. Key findings indicate that ELISA consistently demonstrates remarkable sensitivity and specificity, reinforcing its position as the gold standard, although it requires laboratory equipment. In contrast, ICTs offer advantages in simplicity, speed, and cost-effectiveness, making them suitable for mass screening in resource-limited or high-endemic regions (e.g., Africa and Asia). ICTs have varying sensitivity (17.24%–100%), posing a considerable risk of false negatives in cases of low viral loads or low HBsAg titers, and offer moderate to high specificity, with occasional erroneous positives. Practical solutions endorse the utilization of ICTs for preliminary screening, followed by ELISA confirmation of positive or ambiguous results to enhance diagnostic accuracy. Emerging multiplex ICT systems, capable of concurrently detecting several HBV markers, exhibit promise but require further validation. These findings highlight the imperative of equilibrating performance, resource availability, and context when selecting HBsAg detection methods in field settings.

Keywords: Hepatitis B; HbsAg; ELISA; rapid test; immunochromatography; diagnostic accuracy

Introduction

The Hepatitis B virus (HBV) infection is a leading cause of chronic liver disease, cirrhosis, and hepatocellular carcinoma worldwide, particularly in resource-limited regions with elevated prevalence 1. The detection of hepatitis B surface antigen (HBsAg) serves as the primary serological marker for detecting both acute and chronic HBV infections, as it definitively signifies viral presence and is essential for blood donor screening, patient diagnosis, and preventive measures 1-3. The persistent presence of HBsAg in chronic infections underscores its clinical importance, and accurate diagnosis is crucial for reducing transmission and morbidity 4, 5.

In field settings, particularly in remote or resource-limited places, traditional laboratory methods such as enzyme-linked immunosorbent assay (ELISA) are sometimes unfeasible due to the necessity for specialized equipment, trained staff, and extended processing durations 4-7. ELISA continues to be the benchmark for HBsAg detection, with elevated analytical sensitivity and specificity 8-10. Nevertheless, rapid immunochromatographic tests (ICTs), commonly referred to as rapid diagnostic tests (RDTs), have surfaced as viable alternatives. These assays are straightforward, rapid, portable, and economical, rendering them suitable for point-of-care (POC) applications in field settings such as community screenings, mobile clinics, or areas with constrained healthcare infrastructure 6, 7, 11-13. ICTs utilize immunochromatographic principles to produce visual readouts within minutes via test strips, facilitating straightforward interpretation by non-expert users 7, 11, 14, 15.

Notwithstanding their benefits, ICTs encounter difficulties regarding sensitivity and trustworthiness. Research has indicated that the sensitivity of existing RDTs may be insufficient relative to ELISA, particularly for identifying low HBsAg levels in scenarios such as early acute infections, occult hepatitis B, or window-period infections 1, 3, 6, 10. This heterogeneity presents a danger of false negatives, hence affecting the efficacy of screening programs in high-burden regions 16-18. Moreover, although ICTs are more cost-effective and simpler to use, their efficacy may fall short of the standards necessary for conclusive diagnosis without supplementary testing 4, 6, 9, 19.

This study aims to thoroughly compare ELISA and ICTs for HBsAg detection in field settings, emphasizing performance indicators, operational practicality, and public health strategy implications. This study seeks to deliver a thorough evaluation by synthesizing empirical information from various clinical scenarios.

Methods

Study design

This study employed a literature-based statistical methodology to evaluate enzyme-linked immunosorbent assay (ELISA) and immunochromatographic tests (ICTs) for the detection of hepatitis B surface antigen (HBsAg) in field environments. Data were gathered from a curated collection of 50 research papers, concentrating on studies that directly assessed the efficacy of ELISA, ICTs, or both. These studies encompass a variety of geographical locales, including Africa, Asia, and South America, and feature distinct sample populations such as blood donors, clinical patients, and community cohorts. The selection emphasized relevance to practical applications, particularly in low-resource settings and areas with high endemicity.

Data extraction and criteria

Information was systematically extracted from each paper using a predefined protocol. Key variables included study population (e.g., sample size and demographic), test types (ELISA vs. ICT), setting description (e.g., field or clinic), performance metrics (sensitivity, specificity, and detection limits), and comparative outcomes. Sensitivity was defined as the proportion of true positives correctly identified, while specificity was the proportion of true negatives correctly identified. References to "rapid diagnostic tests" (RDTs), "immunochromatographic tests" (ICTs), or similar terms were categorized under ICTs 6, 11, 12, 17. Studies not reporting direct comparisons or HBsAg detection were excluded.

To standardize analysis, data points with incomplete metrics (e.g., lacking specific

values) were omitted. For discordant results between tests, confirmation often involved gold standards like nucleic acid testing or repeat ELISA 8, 20, 21. The extracted data were synthesized into a comparative table. Statistical analysis focused on descriptive statistics, such as mean sensitivity and specificity ranges, calculated from aggregated values. This process adhered to strict reliance on the provided corpus to avoid unsubstantiated interpretations.

Limitations

As a secondary analysis, this study inherits limitations inherent to its source data. Key constraints include variability in study designs, methodologies, and reporting standards across the included literature, which may restrict the generalizability of aggregated findings. Additionally, the analysis is confined to metrics explicitly documented in the corpus, with no extrapolation beyond reported data. Ethical considerations were not formally addressed, as this work utilized anonymized, publicly accessible data from previously published sources.

Result

A total of 9 studies from the corpus provided quantifiable data for direct comparison of ELISA and immunochromatographic tests in HBsAg detection. Table 1 consolidates the results, summarizing sensitivity, specificity, sample size, study setting. ELISA consistently outperformed ICTs in sensitivity across diverse field settings, while ICTs shown benefits in cost, speed, and user-friendliness.

Sensitivity and specificity

ELISA demonstrated superior sensitivity (ranging from 43.75% to 100%) and specificity (85.6% to 100%) across all trials, with certain tests, such as the LIAISON XL Murex ELISA, attaining 100% sensitivity 1, 8, 9. This resilience facilitates dependable identification of early infections and minimal HBsAg levels 3. Conversely, ICTs shown inconsistent

Table 1: Comparison of ELISA and Immunochromatographic Tests for HBsAg Detection in Field Settings

Test Type	Sample Size	Setting	Sensitivity (%)	Specificity (%)
ELISA (GB HBsAg) [8]	1500	Field setting	43.75	98.82
ELISA [9]	Varied across included studies	Low-resource settings	85.6–100	95–100
ELISA [22]	200	Care center	100	100
ELISA [23]	250	Medical institute	95.12	99.82
ELISA [24]	400	Laboratory	100	100
ICT (SD Bioline Rapid) [8]	1500	Field setting	17.24	99.59
ICT [16]	151	Screening in endemic areas	91.43	98.28
ICT (Four HBsAg RDTs) [17]	1104	Ivory Coast (high endemicity)	97.1-100	99.8-100
ICT (Three POC-RDTs) [19]	511	Eastern Ethiopia (high HBV prevalence)	80.2 (overall)	99.8 (overall)
ICT (SD BIOLINE HBsAg RDT) [21]	250	Antenatal care clinic	99.2	100
ICT [22]	200	Care center	83.4	100
ICT [23]	250	Medical institute	92	97
ICT (Four HBsAg RDTs) [24]	400	Laboratory	25-75	95.9-98

and frequently diminished sensitivity; for instance, the SD Bioline Rapid ICT displayed a sensitivity of 17.24%, whereas pooled point-of-care RDTs (POC-RDTs) 19 attained 80.2%, signifying an elevated risk of false negatives. ICTs consistently exhibited excellent specificity (94.7–100%) 19, 25, rendering them dependable for excluding negative cases, although less appropriate for conclusive diagnosis 6, 10.

Operational performance in field settings

ICTs demonstrated superior speed, yielding results within 10 minutes through visual readouts 7, 14, in contrast to ELISA, which necessitates several hours for processing 4, 10. The cost-effectiveness of ICTs was a significant benefit; for example, in community serosurveys, they diminished dependence on laboratory infrastructure and specialized people 11-13, 26. Nevertheless, research has recorded instances where ICTs failed to detect positives subsequently found by ELISA, including a 1% false negative rate among blood donors 18, 20, underscoring the necessity for confirmatory testing in critical situations (e.g., blood transfusion units or maternity care).

Insights on sample and population

In high-endemicity field settings, bigger sample sizes (e.g., 4,500 8) enhanced statistical reliability. Nigeria 18 and Ethiopia 19 exhibited that ICTs could efficiently identify positives in mass screenings, with positive rates between 5% and 15%. Nigeria 18 and Ethiopia 19 demonstrated that ICTs could effectively detect positives in mass screenings. However, false negatives were more prevalent in complex cases, such as occult infections or early disease stages 1, 10. In terms of sensitivity, ELISA exhibited superior performance when employing sophisticated assays with lower detection limits achieving over 20 times the sensitivity of traditional methods, such as 0.09 mIU/mL in one study 27. In summary, while ICTs are beneficial for field deployment, ELISA maintains superior accuracy for HBsAg detection, particularly in scenarios necessitating high sensitivity. These findings guide plans for integrating the two approaches in practical settings.

Discussion

This work systematically compares ELISA and immunochromatographic assays for HBsAg detection in field settings, highlighting their distinct strengths, limitations, and application for HBV management in resource-constrained circumstances. According to the synthesized data, ELISA consistently shown enhanced sensitivity and reliability, demonstrating great performance across many clinical situations (e.g., achieving up to 100% sensitivity for advanced tests 8, 9). This renders it essential for verifying infections, particularly in instances of low viral loads, such as occult hepatitis B or early acute phases, where precise identification is vital for commencing prompt treatment and averting transmission 1, 3, 10. In contrast, ICTs provided benefits in terms of simplicity and affordability, facilitating swift, extensive screens with limited infrastructure 7, 11-13. Nonetheless, its fluctuating sensitivity (e.g., as low as 17.24% 8) presents considerable concerns, potentially resulting in underdiagnosis and false negatives among populations such as blood donors or high-risk groups 17-20.

The variation in performance can be ascribed to intrinsic variances in assay methods. ELISA employs enzyme amplification to provide great sensitivity, enabling the detection of extremely low HBsAg quantities, with detection limits of 0.09 mIU/mL in optimal assays 27, 28. Conversely, ICTs frequently depend on visual interpretation and colloidal gold-based techniques, which may lack the

analytical precision necessary to identify early infection signals or quantify antigens, hence constraining their efficacy without supplementary confirmatory measures 2, 3, 6. This was demonstrated in field research conducted in Ethiopia, where ICTs yielded false negatives despite a high prevalence, underscoring how environmental conditions (e.g., inadequate storage) could amplify limits 19. Cost-benefit studies from the corpus endorse ICTs for routine screens in high-burden regions, since they diminish costs and enhance accessibility 4, 12, 26; however, ELISA should be favored when high precision is critical, such as in blood banks or prenatal care 20, 21.

These findings correspond with the current literature that critiques ICTs for insufficient sensitivity, potentially hindering global HBV elimination objectives in endemic areas 3, 4, 6. Recent improvements, including immunochromatographic strips with improved visibility and integrated tests, demonstrate potential in enhancing field-friendly sensitivity 7, 29, 30. One study indicated that ICTs exhibited great sensitivity (e.g., 98% 25) when tailored for specific groups, implying that focused development could mitigate the performance disparity. This highlights the possibility for incorporating ICTs into diagnostic algorithms—utilizing them for preliminary screening followed by ELISA confirmation—as a cost-effective approach to improve overall surveillance efficiency 9, 13, 19.

Operational issues in field settings must be resolved. The ease of ICTs facilitates their use in mobile clinics or community campaigns, hence enhancing testing coverage in underserved regions; nonetheless, user training and quality control are crucial to reduce errors. Future study ought to concentrate on the advancement of next-generation ICTs with higher analytical sensitivity, potentially utilizing nanotechnologies such as fluorescent nanoparticles or improved gold labeling 28, 30. Furthermore, broadening assessments to encompass a wider range of groups and longitudinal data may address the discrepancies identified in this investigation.

In conclusion, whereas ELISA is the standard for HBsAg detection, ICTs offer a practical alternative for field use when paired with confirmatory techniques. Optimizing HBV control regimens necessitates a balance among cost, speed, and accuracy.

Conclusion

This thorough investigation comparing ELISA and fast immunochromatographic assays for HBsAg detection in field settings demonstrates that both approaches possess unique advantages and limits for HBV diagnosis. ELISA continually exhibited great sensitivity and specificity, reaching up to 100% in refined assays 8, 9, so establishing itself as the ideal method for accurate diagnosis in situations necessitating precise detection, such as occult infections or early disease stages 1, 3, 10. However, its dependence on laboratory infrastructure constrains its usefulness in resource-limited settings 4-7. Conversely, ICTs provide operational simplicity, rapidity (yielding results in under 10 minutes), and cost-efficiency, enabling extensive screens in field environments such as high-endemicity areas 7, 11-13, 19. Nonetheless, their inconsistent and frequently diminished sensitivity (e.g., 17.24–80.2% 8, 19) requires supplementary use alongside ELISA or other confirmatory assays to reduce the likelihood of false negatives 9, 18, 20.

The synthesis of many studies suggests that ICTs are optimally utilized for initial screening in community-based programs, where rapid results and accessibility improve HBV

surveillance. To achieve a definitive diagnosis, ELISA should be utilized to guarantee precision 3, 4, 6. Advancing the development of more sensitive ICTs via technological advances may close this performance gap, enhancing their effectiveness in worldwide initiatives to eradicate HBV. This equitable strategy will enhance public health initiatives in practical environments, ultimately diminishing the global HBV burden.

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