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Review Article

Health Economics Of Laboratory Procedures During The Covid-19 Epidemic

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Introduction

The COVID-19 pandemic fundamentally reshaped the health economics of laboratory medicine by placing diagnostic testing at the center of both clinical decision-making and macroeconomic stabilization strategies. Unlike pre-pandemic laboratory utilization—typically driven by incremental clinical suspicion—SARS-CoV-2 testing became a population-level intervention with direct implications for transmission dynamics, workforce productivity, and healthcare system capacity. This shift forced health systems to evaluate laboratory procedures not only through conventional cost-per-test frameworks, but also through broader cost-effectiveness, opportunity cost, and societal economic loss models.

Recent Health Technology Assessment (HTA) literature emphasizes that pandemic-era diagnostic strategies were implemented under severe time constraints, often bypassing traditional economic evaluation pipelines. Consequently, post-pandemic analyses have increasingly focused on retrospective cost-effectiveness modeling and resource allocation efficiency across diagnostic platforms such as real-time polymerase chain reaction (RT-PCR), antigen rapid diagnostic tests (Ag-RDTs), and pooled testing strategies [1,2].

Cost Structures of COVID-19 Laboratory Testing

A central economic insight from the pandemic is that diagnostic tests are not homogeneous commodities; rather, they exhibit fundamentally different cost structures. RT-PCR testing is characterized by relatively high fixed costs (instrumentation, trained molecular personnel, laboratory infrastructure, and biosafety systems) and moderate variable costs per test. In contrast, antigen tests have low fixed costs and minimal per-unit consumable costs but lower sensitivity, particularly in low viral load scenarios [1].

Empirical cost analyses from public health systems illustrate these differences clearly. In a Brazilian Unified Health System analysis, RT-PCR testing cost approximately R$ 202.87 per patient compared to R$ 76.46 for antigen testing, reflecting a substantial cost differential of more than 160% per case. Such disparities are not merely accounting artifacts but reflect structural differences in laboratory production functions. From a microeconomic perspective, RT-PCR operates under a high-cost, high-accuracy equilibrium, whereas antigen testing represents a low-cost, lower-sensitivity equilibrium optimized for rapid population screening. The optimal allocation between these modalities depends on disease prevalence, required diagnostic accuracy, and downstream costs associated with false negatives and delayed isolation [3].

Cost-Effectiveness Under Epidemic Conditions

Cost-effectiveness analysis (CEA) during COVID-19 expanded beyond traditional metrics such as cost per diagnosis to include broader societal outcomes, including transmission reduction, hospital avoidance, and workforce absenteeism. Studies have demonstrated that in high-prevalence settings, both PCR and antigen tests may become cost-effective despite higher absolute expenditure due to their ability to prevent downstream healthcare costs and productivity losses [2,3].

A key finding in multiple economic evaluations is that the incremental cost-effectiveness ratio (ICER) of diagnostic strategies is highly sensitive to epidemiological context. When prevalence increases, the marginal value of each correctly identified case rises sharply, improving the cost-effectiveness of even expensive testing modalities. Conversely, in low-prevalence contexts, false-positive rates can impose unnecessary isolation costs, reducing economic efficiency [1,3].

A 2023 cost-effectiveness analysis within a municipal health system demonstrated that antigen testing could be economically dominant when incorporating both direct diagnostic costs and indirect economic impacts such as absenteeism. The study estimated substantial savings when replacing RT-PCR as the first-line diagnostic tool under certain operational assumptions [2,3].

Laboratory Capacity Constraints and Opportunity Costs

One of the most underappreciated economic dimensions of COVID-19 laboratory systems was capacity constraint. During peak pandemic waves, laboratory throughput—not reagent cost—became the binding constraint. This introduced significant opportunity costs: each PCR assay performed displaced other molecular or microbiological diagnostics [1,4].

In economic terms, laboratory capacity can be conceptualized as a fixed short-run supply constraint, where marginal cost rises steeply as systems approach saturation. This led many health systems to adopt triaging strategies for testing, prioritizing high-risk patients and essential workers. The opportunity cost of allocating PCR capacity to low-risk screening became a critical consideration in health policy design. Furthermore, global supply chain disruptions created price volatility in reagents, extraction kits, and swabs, increasing marginal costs unpredictably. These dynamics undermined traditional static cost-effectiveness models and necessitated adaptive economic evaluation frameworks [1,3,4].

The Role of Rapid Antigen Testing in Economic Substitution

Rapid Antigen Tests (RATs) emerged as economically significant substitutes for RT-PCR in large-scale screening programs. Although less sensitive, their low cost and rapid turnaround time reduced both direct and indirect costs associated with delayed isolation decisions.

From a health economic perspective, the value of antigen testing is strongly dependent on behavioral and epidemiological parameters. Faster results reduce transmission probability by enabling earlier isolation, thereby generating externalities that are not captured in per-test cost metrics. In high-transmission environments, these externalities can dominate direct diagnostic accuracy considerations .

A German economic evaluation of antigen testing strategies demonstrated that rapid tests can become cost-effective in high-risk transmission settings when considering broader societal impacts. This finding reinforces the importance of incorporating dynamic transmission effects into diagnostic cost models [5,6].

Group Testing and Economies of Scale

Pooled or group testing represents a particularly important innovation in pandemic laboratory economics. By combining multiple specimens into a single PCR assay, systems can significantly reduce reagent consumption and labor costs when prevalence is low.

Recent modeling approaches incorporate not only deterministic costs but also income-based economic losses due to quarantine duration and workforce disruption. These models demonstrate that optimal pooling strategies shift depending on both infection prevalence and macroeconomic conditions, particularly wage structures and labor market elasticity.

Such approaches highlight that diagnostic economics cannot be separated from labor economics. The true cost of testing strategies includes not only laboratory expenditures but also productivity losses arising from isolation policies triggered by test results [1,2].

Post-Pandemic Health Technology Assessment Recalibration

The post-pandemic period has seen a methodological shift in HTA frameworks for diagnostic technologies. Traditional cost-per-test approaches are increasingly being replaced by integrated models that incorporate [7]:

Transmission dynamics

Workforce productivity losses

Health system congestion effects

Behavioral responses to test availability

Equity considerations in access to diagnostics

Living systematic reviews of COVID-19 diagnostic economics emphasize that earlier evaluations often underestimated total societal costs by focusing narrowly on healthcare payer perspectives. This has led to calls for more comprehensive societal-perspective economic evaluations in future infectious disease preparedness planning [7,8].

Equity and Global Disparities in Laboratory Economics

A critical dimension of COVID-19 laboratory economics was global inequity in access to testing technologies. High-income countries rapidly scaled RT-PCR infrastructure, while many low- and middle-income countries relied more heavily on antigen testing or limited PCR capacity [8,9].

These disparities had direct economic consequences. Delayed diagnosis in resource-limited settings increased transmission duration, prolonged economic shutdowns, and amplified indirect economic losses. Thus, laboratory investment should be viewed not only as a healthcare expenditure but also as a macroeconomic stabilization mechanism [1,3,5,7].

Conclusion

The health economics of laboratory procedures during the COVID-19 pandemic reveals a complex interplay between diagnostic accuracy, system capacity, epidemiological context, and macroeconomic consequences. RT-PCR testing, while highly accurate, imposes significant fixed and operational costs, whereas antigen testing provides a lower-cost, faster alternative with trade-offs in sensitivity. The optimal diagnostic strategy is therefore context-dependent, influenced by disease prevalence, healthcare capacity constraints, and broader societal costs such as productivity loss and transmission externalities [1-3,5].

Emerging evidence suggests that future pandemic preparedness strategies must integrate dynamic economic modeling frameworks that account for both direct laboratory costs and indirect societal impacts. Innovations such as pooled testing, rapid antigen deployment, and adaptive HTA methodologies represent important steps toward more efficient allocation of diagnostic resources in future public health emergencies [1,9,10].

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