Cost-effectiveness of the COVID-19 test, trace and isolate program in Colombia

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Summary

Background During the COVID-19 pandemic, Test-Trace-Isolate (TTI) programs have been recommended as a risk mitigation strategy. However, many governments have hesitated to implement them due to their costs. This study aims to estimate the cost-effectiveness of implementing a national TTI program to reduce the number of severe and fatal cases of COVID-19 in Colombia.

Methods We developed a Markov simulation model of COVID-19 infection combined with a Susceptible-Infected-Recovered structure. We estimated the incremental cost-effectiveness of a comprehensive TTI strategy compared to no intervention over a one-year horizon, from both the health system and the societal perspective. Hospitalization and mortality rates were retrieved from Colombian surveillance data. We included program costs of TTI intervention, health services utilization, PCR diagnosis test, productivity loss, and government social program costs. We used the number of deaths and quality-adjusted life years (QALYs) as health outcomes. Sensitivity analyses were performed.

Findings Compared with no intervention, the TTI strategy reduces COVID-19 mortality by 67%. In addition, the program saves an average of $1,045 and $850 per case when observed from the social and the health system perspective, respectively. These savings are equivalent to two times the current health expenditures in Colombia per year.

Interpretation The TTI program is a highly cost-effective public health intervention to reduce the burden of COVID-19 in Colombia. TTI programs depend on their successful and speedy implementation.

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Keywords: Test-Trace-Isolate (TTI); Cost-effectiveness analysis; COVID-19; risk assessment and mitigation

Introduction

New evidence suggests that public health interventions are necessary to bring an end to the pandemic even with a successful vaccine rollout.[1-3] Several factors motivate the need to consider multiple approaches to pandemic mitigation. One of them is that the human and economic consequences of government-mandated lockdowns are substantial and cannot be maintained over long periods of time. The emergence of new variants is especially worrisome, given evidence suggesting higher transmissibility, higher severity of disease and potentially some degree of immunity escape. These factors suggest that countries should not be abandoning other public health measures - like TTI - after they achieved ''adequate'' vaccine coverage.

As scientific research continues to identify risk factors or alternative strategies to prevent transmission, Test-Trace-Isolate (TTI) programs have become an important strategy to reduce COVID-19 infection rates.[4,5] In East

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Research in context

Evidence before this study

Non-pharmacological interventions have been crucial to mitigate the devastating impacts of COVID-19. A search of the literature on August 6, 2021, using the terms "cost-effectiveness" AND ("COVID*" OR "SARS*") returned 288 results on PubMed and 897 results in medRxiv. Most results were focused on vaccination programs or other pharmacological interventions. Yet, less is known about the role of TTI to mitigate risk during the pandemic. We found less than 15 articles assessing test, trace, or isolate. None of them were based on a current implementing program or in Latin America.

Added value of this study

We used a Markov model based on a SIR structure to simulate COVID-19 transmission to evaluate the health economic impact of the test-trace-isolate program in Colombia. We find that the TTI program is a cost-effective strategy to improve population health outcomes and cost-saving in controlling the COVID-19 pandemic. TTI reduces the demand for highly specialized medical services (ICU hospitalization days) and the mortality rate.

Implications of all the available evidence

This study contributes to understanding the importance of TTI programs to mitigate the impacts of the COVID-19 pandemic. This is significantly important for both Low- and Middle- Income countries where the budget is highly limited and High-Income countries where the COVID-19 vaccination rate is under the herd immunity level. Moreover, TTI programs gain further relevance as the ground of public health interventions due to their high cost-effectiveness, the uncertain effects of the new COVID-19 variants, and the potential future pandemics.

Asian and Pacific countries, TTI programs were central to control transmission chains, and as a result, those countries imposed relatively few lockdowns. South Korea and Singapore exemplify the success of TTI in containing the virus spread, reducing the proportion of severe cases, and reducing mortality. However, these countries' health systems were prepared for an outbreak of emerging infectious diseases. For example, South Korea used a coordinated contact tracing system with data from mobile phones, cars, and credit card records.[6]

TTI assists with the control of transmission. Ideally, all COVID-19 cases should be followed up for 10 to 14 days, starting at diagnosis or through the end of the symptoms. However, during transmission peaks, existing resources are outstripped. Even high-income countries have been overwhelmed by skyrocketing cases. For example, The UK stopped its contact tracing program during the first wave, and the program capacity was focused on patients admitted to the hospital.[7] Likewise, Canada TTI was overburdened by the sheer number of cases, and they implemented a COVID-19 tracing app that was not as successful as expected.[8] Furthermore, some activities might be done through TTI systems. For example, TTI can serve as a platform for the assessment of needs for households in isolation, and the provision of financial support. Also, TTI can help governments to appropriately assess the mortality risk for those already infected and advise them about routes of care.[5,9]

The objective of TTI is to complement other public health interventions in a multifaceted mitigation strategy that includes vaccination, promoting the use of masks and social distancing, etc. However, governments need to be certain that investments in TTI are worth it their costs (monetary and non-monetary). This is especially true in Low- and Middle- income countries (LMICs) with highly restrictive budgets where investing in TTI comes with a number of limitations and opportunity costs. For this reason, an economic evaluation of the TTI program would contribute to take better informed decisions about implementing a TTI program.

The Colombia TTI Program

The Colombia TTI program is a national comprehensive program locally known as the Program for Testing, Tracing and Selective Sustainable Isolation (Programa de Pruebas, Rastreo y Aislamiento Selectivo Sostenible (PRASS)).[10] PRASS aims to reduce the rate of transmissibility and COVID-19 mortality. It includes the deployment of testing, contact tracing, isolation, and monitoring for cases and contacts using both a smartphone App and telephone contacts.[11] Once an index case is identified, patients must isolate with their cohabitant contacts. The index case must be monitored for assessment of warning signs or symptoms. Additionally, their close contacts of the last 14 days are traced, contacted, tested, and isolated.

We focused this research on the monitoring component of the program. This follow-up program contacts all new cases when they turn positive, but it prioritizes close follow-up to all COVID-19 positive cases with comorbidities, people older than 60 years, and men between 40-59 years old.[5] To decentralize the program, TTI was delegated to national insurance companies as part of their risk management and population health responsibilities.

Methodology

Overview

We developed a simulation model to estimate one-year outcomes and costs of the TTI program from both the health care and societal perspectives. The model has eight health states based on a Susceptible-Infected-Recovered (SIR) structure,[12,13] which has been used to

monitor and predict the spread of COVID-19. We compared two alternative scenarios in a hypothetical cohort of 50·3 million Colombian individuals: (1) status quo (no intervention) and (2) implementation of the TTI program. Transition probabilities, utility values to estimate quality-adjusted life-years, and costs were extracted from the literature or from Colombia-specific epidemiology data (see Table 1). Costs of lost productivity due to premature death were discounted by 3%.[14] All costs were adjusted for inflation to account for 2020 Colombian pesos. We used the average exchange rate of 2020 to transform Colombian pesos into U.S. dollars.

We computed the incremental cost-effectiveness ratio (ICER) and then used the Colombian gross domestic product (GDP) per capita in 2019 for comparison. The WHO suggests that interventions between one to three times the GDP per capita are considered cost-effective.[15] Analysis was conducted in R Studio software version 4·0·0 (R Foundation for Statistical Computing, Vienna, Austria) using *heemod* package (Filipovic-Pierucci, et al., 2017) for economic evaluation and ggplot2 to produce the figures (Wickham, 2009).

Model Structure. We developed a SIR model to simulate the Colombian population's transition through eight mutually exclusive Markov health states (Figure 1) with daily cycles for one full year. All individuals began in a susceptible state. Over time, people would become infected. Individuals in the ''Infection'' health state remain there for only one-day cycle, during which they transition to asymptomatic or symptomatic infection. We assumed four infected states based on current information and COVID-19 epidemiological data in Colombia: Asymptomatic, Mild, Moderate, and Severe.[16] The Moderate infected cases require hospitalization on regular floor and Severe infected cases require ICU hospitalization. Those who survive transit to recovered state and acquired immunity for the remainder of the period. We do not model reinfection. We included two outcome states: ''Recovered'' and ''Death''. Individuals remain in these states until the end of the time horizon. We did not include long-time complications of COVID-19 or mortality from non-COVID-19 causes. Finally, we assume only symptomatic infections lead to death, and we do not include an exposed state due to data availability.

We assume fourteen days are needed to recover from a mild or asymptomatic infection. Likewise, it takes at least five days to pass from mild to moderate infection. We assume three days in moderate infection to progress towards a severe illness. Corticosteroids could prolong the hospitalization stay for moderate infection.[17] Hence, the maximum stay at moderate infection in the monitoring program was 17 days vs. 10 days in no intervention strategy.[18] Similarly, the maximum stay at severe infection was established in 21 days for no intervention and 15 days for the monitoring program due to the

impact of the corticosteroids.[18,19] In total, an individual can be sick for up to 45 days, and then they recover or die.

Monitoring program. Monitoring reduces the probability of developing severe COVID-19. We simulated three possible schemes to perform the follow-up after a first initial risk evaluation: (i) low-risk people had no active follow-up with a call-in number in case of need, (ii) moderate-risk individuals had four phone-based follow-ups made by a nursing assistant during 5, 7, 10, 14 days after the infection day, and (iii) High-risk individuals received a pulse-oximeter and daily phone-based follow-up by a medical doctor. The risk profile was assigned using age, sex, clinical relevance, comorbidities presence (hypertension, diabetes, asthma, etc.), and indicators of socioeconomic vulnerability.[5] We included the costs of digital and in-person monitoring in both urban and rural locations. We assumed clinical benefits are derived from early corticosteroid treatment. This is a conservative assumption since early detection of symptoms and comprehensive treatment could have additional clinical benefits, including reducing the incidence of silent hypoxemia or worsening preexisting conditions.[20]

Model parameters. Cost. Costs were estimated by using current monitoring program data or from the literature. All costs were reported in 2020 US dollars (US $1 = 3693·36 Colombia pesos [COP]). We included the costs for direct health service consumption, PCR diagnosis test, direct and indirect monitoring program, and productivity loss, and government social assistance. We did not include costs related to mental health services or potential future treatment costs.

Costs were different for each infection state. The diagnosis tests (PCR test)[21] cost was included for all newly infected cases in the monitoring strategy and limited to symptomatic cases in the no intervention strategy. Also, we added the cost of social subsidies (given as an incentive for maintaining the quarantine),[22] and the daily productivity losses of both cases and their household contacts. Productivity loss was directly calculated from the Colombian GDP per capita in 2019 divided into 244 workdays by the number of economically active individuals in 2019[23] by the average number of people in a household in Colombia for 2020.[24] Likewise, the societal perspective included the productivity years of life lost for premature death (until retirement) with a 3% discount per year to adjust future costs to present value.[14]

The monitoring strategy included an additional cost for one primary care visit with a physician and the follow-up for 14 days. Monitoring cost was calculated using a weighted average of the risk profile cases in Colombia through October 2020. Moreover, it was assumed that

Parameter	Expected value	Range for Sensitivity Analysis		Source
		Lower	Upper	
Infection Population Statistics				
Colombian Population	50,300,000			[16,31]
Inverse Average Infectious Period (γ)	0·111			[32,33]
Basic Reproduction Number R_0	1·75	0·530	2·200	[25,26]
Transition Probabilities				
Susceptible to Infected	0·115	0·057	0·217	[30,32]
Infected to Asymptomatic	0·397	0·041	0·625	[34]
Asymptomatic to Recovery	1			Assumed
Infected to Mild symptomatic[1]	0·603	0·375	0·959	[25,26]
Mild symptomatc to Recovery[1]	0·673	0·984	0·990	
Mild symptomatc to Death	0·013	0·010	0·016	[16,31]
Mild to Moderate symptomatic	0·314	0·016	0·703	[25,26]
Moderate to Severe symptomatic	0·115	0·086	0·531	[25,26]
Moderate symptomatic to Recovery[1]	0·735	0·812	0·887	
Moderate symptomatic to Death	0·150	0·113	0·188	[16,31]
Severe symptomatic to Recovery[1]	0·478	0·348	0·609	
Severe symptomatic to Death	0·522	0·391	0·652	[16,31]
Effect Modifiers of Interventions				
Risk progression reduction with monitoring	0·480	0·340	0·660	[17]
Mortality probability reduction with monitoring in Mild and Moderate Disease	0·200	0·040	0·900	[19]
Mortality probability reduction with monitoring in Severe Disease	0·592	0·406	0·862	[18]
Daily Costs (USD$ 2020)				
Infected				
Diagnosis test (PCR)	40·460	16·184	58·531	[17]
Social subsidies	55·030	41·270	68·783	[18]
Sick day	152·630	114·472	190·787	[19]
Mild infection				
Medication	0·835	0·626	1·043	[31]
Moderate infection				
Primary care visit, tests, and x-ray	46·687	35·015	58·358	[21,35]
Emergency care visit, tests, and x-ray	405·515	304·136	506·894	[21,35]
Hospital bed	323·565	242·674	404·457	[36]
ICU bed	642·613	481·960	803·266	[36]
Death				
Productivity loss	25,055	18,791	31,318	[14]
Monitoring				
First care visit	14·757	11·068	18·446	[31]
Diary Follow-up	2·481	1·860	3·101	[31]
Utilities Weights				
Utility of Susceptible	0·953	0·018	1·000	[29]
Utility of Infected	0·833	0·017	1·000	[25,26]
Utility of Asymptomatic	0·833	0·017	1·000	[25,26]
Utility of Mild symptoms	0·5	0·01	0·990	[25,26]
Utility of Moderate symptoms	0·25	0·005	0·495	[25,26]
Utility of Severe symptoms	0·05	0·001	0·099	[25,26]
Utility of Recover	0·953	0·018	1·000	[29]

Table 1: Model parameters
ICU, intensive care unit
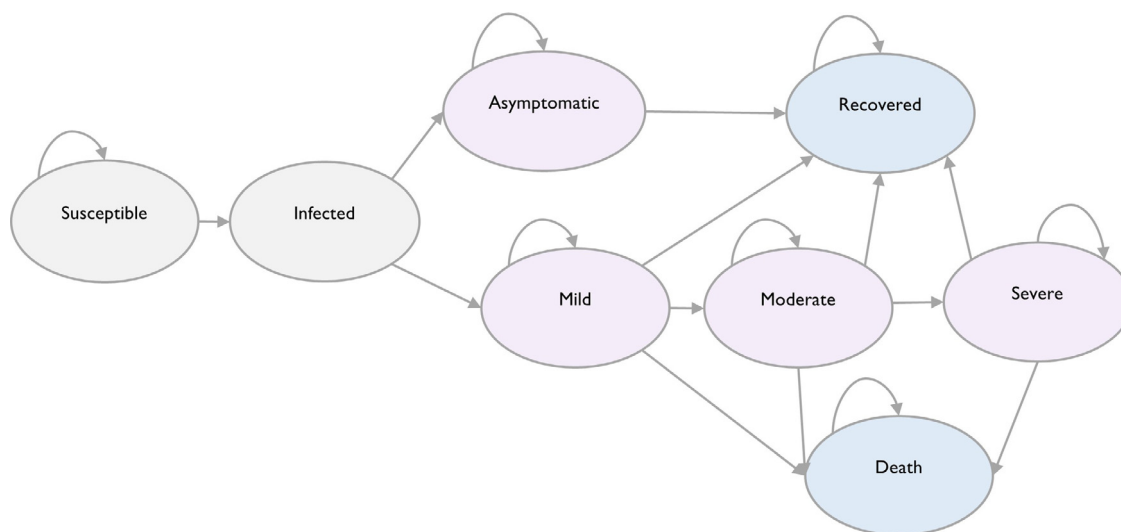[1] Remainder from 1.0

Figure 1. Markov model Diagram. Structure of the model of COVID-19 infection and progression. Patients progressed through a modified "SIR" process (Susceptible − Infected − Recovered). There are four infection states and two outcome states shown in purple and blue, respectively

20% of the cases were not available for phone monitoring, and in-person follow-up was required (See Table 3). Asymptomatic health state costs were only included for the monitoring program since these cases were not detected in the other scenario, assuming 100% compliance for monitoring. The cost of daily monitoring included direct and indirect costs. The direct cost was calculated using the average daily salary of a contact tracer divided by the average number of daily contact's capacity for the tracer. The indirect costs were given by the software and technology investments.

Health Utilities. Health utilities were based on the Euro-QoL-5D Index score reported in other studies.[25−28] We use the average Colombian general population utility of 0·953 for Susceptible and Recovered states.[29] The utility of symptomatic infected individuals was reduced according to disutility weights obtained from patients experiencing influenza infection.[25,27] The disutility weight was applied only for the duration of infection, except for the dead cases, who have a utility equals to zero from the day of death.

Transition Probabilities. We used outcome rates of severity and mortality from Colombia's Ministry of Health to calculate the transition probabilities of Infected Mild, Moderate, or Severe to Death.[16] These were rescaled to a daily probability. We used the Colombian effective reproductive number, average infectious period, and transmission rate to calculate the transition probability from Susceptible to Infected.[19,30] It was given by:

$$Recovery\ rate = \gamma = \frac{1}{Incubation\ rate}$$

$$Force\ of\ infection = \lambda = \gamma * R_0$$

Transition probability Susceptible to Infected

$$= 1 - e^{-\lambda}$$

The remaining transition probabilities were retrieved from the literature.[22,24]

Sensitivity Analysis. The expected parameter values were varied to test model uncertainty. For parameters reporting 95% confidence intervals or standard deviation, we used those ranges. For the remaining parameters, values were ranged by ±25% around the mean. We produced a tornado diagram using one-way sensitivity analyses. We conducted probabilistic sensitivity analysis (PSA) using 1000 Monte Carlo simulations with no intervention as the baseline approach. We used a gamma distribution for costs, normal distributions for utilities, binomial distribution for probabilities, and log-normal for reduction risk parameters. The PSA characterizes the impact of uncertainty on all parameters simultaneously. Finally, we included a sensitivity analysis with a productivity loss equals to 60% of the previous calculation as many workers were able to continue their work remotely during quarantine

Assumptions. We assumed that recovered patients are immune, and reinfection is not possible. Also, all individuals with moderate or severe diseases are referred to hospitals and intensive care units (ICUs), respectively. Moreover, we assumed an even distribution of COVID-19 outcomes, social subsidies availability, and healthcare resources across Colombia. The heterogeneity of lethality rates among different subpopulations

No	Assumptions
1	Recovered patients are immune, and reinfection is not possible
2	All individuals with moderate diseases are referred to hospitals
3	All individuals with severe diseases are referred to ICUs
4	A uniform distribution was assumed of COVID-19 outcomes, social subsidies availability, and healthcare resources across Colombia
5	The heterogeneity of lethality rates was omitted
6	The transition probabilities were constant over time
7	Recovered individuals report no long-term effects from COVID -19
8	Monitoring effectiveness was equal to early corticosteroids treatment
9	The follow-up visits were 15 minutes
10	The first primary care visit was of 30 minutes
11	All individuals were tested with a PCR test and the average waiting time for the result was three days
12	The cohabiting contacts comply with isolation recommendation per 14 days
13	The transmission rate used did not include differences for the circulating variants of SARS-CoV-2
14	The productivity loss was assumed to equal 100% during the symptomatic infected states

***Table 2*: Simulation model assumptions**
ICU, intensive care unit; PCR, Polymerase chain Reaction

according to age and health conditions was omitted. The transition probabilities were constant over time, which did not include changes in COVID-19 transmission associated with epidemic waves. It was assumed that recovered individuals return to their baseline utility (no long-term effects from COVID-19). Monitoring effectiveness was assumed to equal early corticosteroids treatment,[17−19] which is a conservative assumption given other benefits from early monitoring that are more difficult to quantify. The follow-up visits were assumed to last 15 minutes and a first primary care visit of 30 minutes. We assumed that all individuals were tested with a PCR test and the average waiting time for the result was three days. Assumptions are presented in Table 2.

Ethical approval. This study was approved by the Institutional Review Board of the Johns Hopkins Bloomberg School of Public Health and deemed not human subjects research (IRB number: 14144).

Role of the funding source. This study was sponsored by the Colombian Ministry of Health through award number PUJ-04519-20. The funding was used to develop the PRASS' prioritization tool and evaluate its cost-effectiveness.

Results

In our one-year simulation, the TTI program increased quality-adjusted survival by 0.44 compared to no TTI program. The program prevented 84,730 deaths, potentially saving US $2.123 billion dollars for potential productive years of life lost. During the first pandemic wave in Colombia, excess mortality was 15,728 deaths, which is an increase of 32% with respect to the

Risk Category	Definition	Intervention	Weighting percentage
High priority	Patients with at least one high risk comorbidities, older than 60 years or men between 40-59 years old	Daily phone-based follow-up by a medical doctor plus pulse-oximeter	0.42
Medium priority	Men under 40 years old, pregnant women, or patients living in household of lower socioeconomic status	Four phone-based follow-ups made by a nursing assistant during 5, 7, 10, 14 days after the infection day	0.11
Low priority	Young (< 60 years old), healthy and non-pregnant women	No active follow-up with a call-in number in case of need	0.47
Rural area	Cases were not available for phone monitoring, and in-person follow-up was required	In person first care visit and follow-up	0.2

***Table 3*: Monitoring program description**

	ECONOMIC IMPACT				
Perspective	Comparator	Δcost	Δeffectiveness		ICER
		($)	(QALYs)	(Life expectancy)	($/QALYs)
Social	Standard				
	Monitoring	-1045·52	0·44	0·30	Dominates
Health Care	Standard				
	Monitoring	-850·19	0·44	0·30	Dominates

Table 4: Cost-Effectiveness Analysis Comparing Monitoring to No Intervention to Address Colombian COVID-19 Pandemic.
ICER, Incremental cost-effectiveness ratio; QALY, quality-adjusted life-year

	EPIDEMIOLOGIC IMPACT (Annual)					
	Hospital Days		ICU Days		Deaths	
	(N)	(Cost $ billion)	(N)	(Cost $ billion)	(N)	(Cost $ billion)
Standard	30,050,494	9·723	31,649,666	20·338	126·431	3.168
Monitoring	35,092,622	11·355	18,846,101	12·111	41·701	1.045
(Δ %)	17%		-40%		-67%	
(Δ $billion)	1·632		-8·228		-2.123	
Total Difference Health Care Perspective			$billion -6.596			
Total Difference Social Perspective			$billion -8.719			

Table 5: Base case population-level outcomes
ICU, intensive care unit

historical average.[37] The TTI program saved US $1,045 and US $850 per case in the social and health system perspective, respectively. These savings are equivalent to up two times the annual Colombia per capita health-care spending in 2019. Moreover, the model with lower productivity loss showed savings of US$1,028 per case in the social perspective. The TTI monitoring program was cost-effective at any willingness-to-pay threshold (Table 4 & Table 5).

Most of these changes are attributed to the reduction in the number of ICU days and the number of deaths. The savings on ICU expenses are important and could be higher if the cost associated with the shortage of ICU were included. Even though monitoring slightly increases the number of hospitalization days due to the required treatment time prolongation, reducing ICU days' expenses compensates the hospitalization cost. It saves an additional US $8·2 billion dollars annually.

In one-way sensitivity analysis, the model's primary results and conclusions did not change (Figure 2). The incremental cost per quality-adjusted life-year (QALY) gained is most sensitive to changes in the transition probability from moderate to severe cases, UCI day cost, relative risk of progression, relative risk of mortality in all infected states, and death probability in severe cases. When we included the outcome utilities, the main influential factor over the ICER was the utility of the recovered individuals. In the PSA, the TTI program dominated in all the iterations compared to no intervention (mean ICER = -2365; 95% CI = -3222, -1508) (see Figure 3).

Discussion

The TTI program in Colombia is a highly cost-effective strategy to address COVID-19. It saves lives and reduces costs for the health system and society as a whole. This conclusion holds even when the model considers only the direct benefits to monitoring individuals and not secondary benefits due to a potential reduced transmission, which are likely to underestimate the benefits, so our results are likely conservative. The impact on survival of COVID-19 monitoring are highly dependent on how early the diseases is detected and therefore, monitoring needs to be complementary to other interventions to be fully effective. Monitoring for COVID-19 does not have to be limited to clinical assessment. It can also serve to assess social and economic needs of those affected by the disease. Although TTI strategies require a sizeable upfront investment in technologies and compete with different budget requirements as the vaccination, governments may need to finance and work
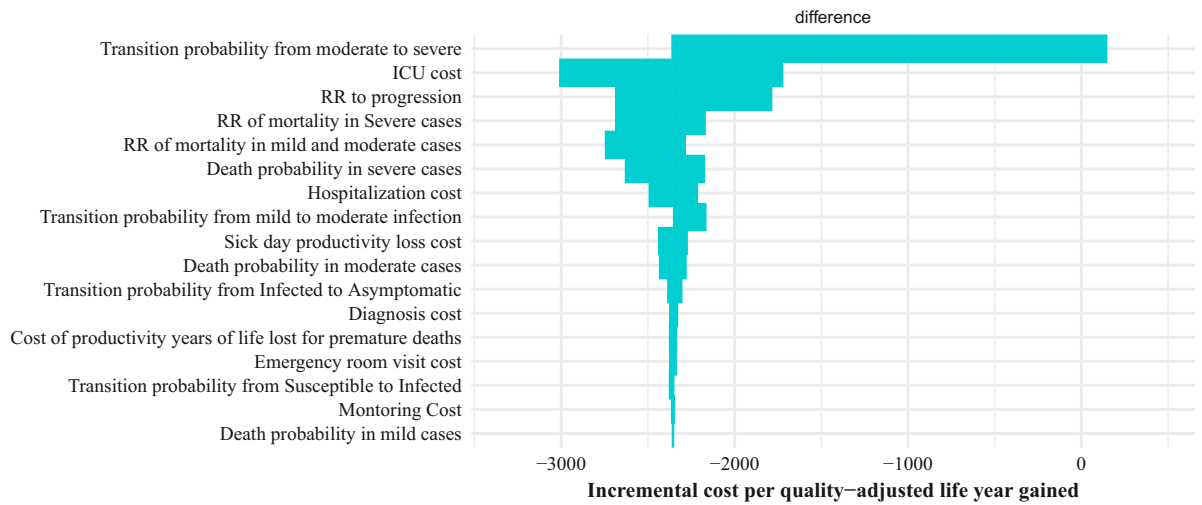
Figure 2. Tornado diagram. It shows the impact of the sensitivity analysis on the incremental cost per QALY gained by TTI prom compared to no intervention. RR, Relative risk; ICU, Intensive Care Unit.

towards implement both strategies at the same time to get higher returns to both investments. Installed capacity for TTI may also be beneficial to contribute to the rollout at scale for COVID-19 vaccination programs.

The COVID-19 pandemic has challenged health systems, requiring rapid adaptation to an increased demand for services. This led to the growth of institutional capacities and investing in technology to mitigate the restrictions to in-person encounters, including for example telemedicine services offered. Particularly, the case monitoring program was relatively successful on engaging the Colombian health insurance organizations in active risk management. The monitoring program is part of a broad strategy to control the COVID-19 pandemic. However, since each health insurer developed its own structured follow-up schedule, the system has been highly fragmented and created heterogeneity among the investments made on human capital and physical resources. Nevertheless, our study highlights the significant impact of this policy and its importance.

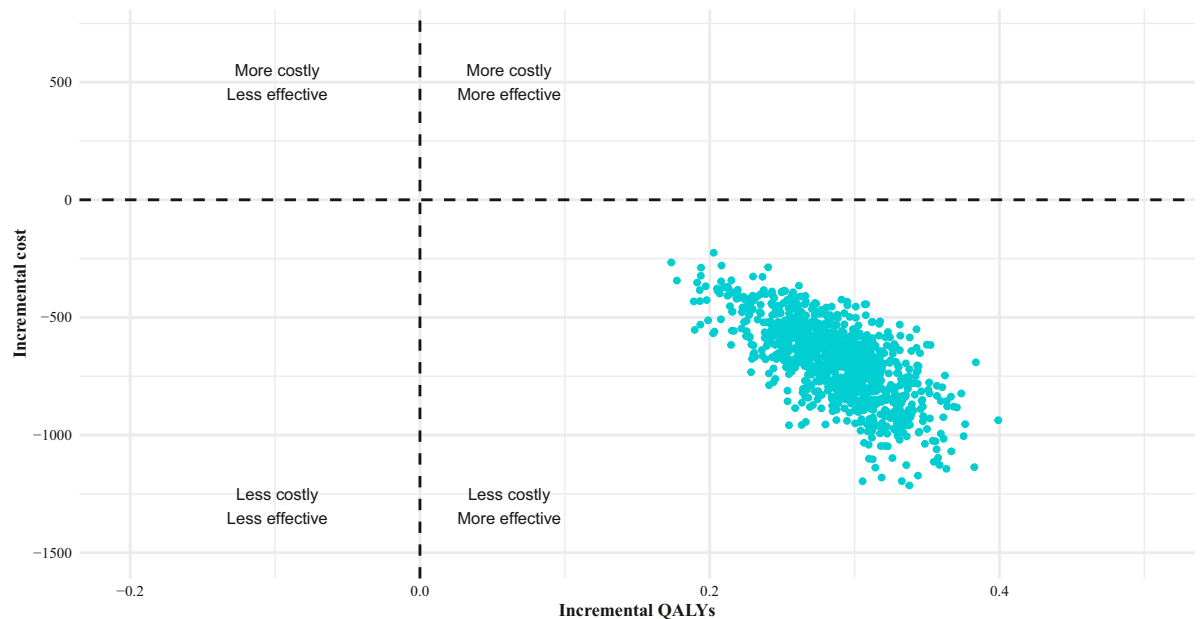TTI programs should be maintained and strengthen across the LMICs. The Colombian case monitoring

Figure 3. Incremental cost-effectiveness plane of 1000 Monte-Carlo Simulations.

program's positive impact, showed by this study, could act synergically with other non-pharmacological interventions. Even this study provides evidence to support public financial assistance to help low-income individuals to stay at home and reducing the virus spread. Moreover, it is required a labor policy that allows asymptomatic infected workers to stay in preventive isolation to contain the transmission of the virus without losing their jobs. High fines and penalties to employers who required employees with COVID-19 to return to work without fully recovering may increase the efficiency and effectiveness of these strategies.

The effectiveness of the TTI strategies in containing COVID-19 spread is determined by the control of ''hidden'' infection chains due to the undetected spreaders, TTI-avoiders, and pre- or asymptomatic cases. Moreover, the number of new cases used to exceed the TTI capacity. Therefore, it is fundamental to prioritize the cases with higher risk of developing severe disease or spreading the virus in the monitoring and contact tracing programs, respectively. Further, it is crucial to increase the cooperation among institutions and individuals, early and complete isolation, and comprehensive contact tracing.[6]

Additionally, implementing a TTI program in a middle-income country like Colombia has many structural difficulties compared to the successful experiences in high-income countries like South Korea. Socio-economic inequalities, labor informality, governance and institutional constraints, low-risk perception, and poverty make it difficult to comply with isolation and measures, even with access to health services.[38] In particular, labor informality makes it challenging to comply with the measures since the subsidies arrive long after isolation and are conditioned on the test being positive.[39] Moreover, not all employers are equally committed to providing alternatives for isolation when asymptomatic people cannot access sick leave. This may determine a lower adherence to isolation, thus affecting the effectiveness of the program.

Nonetheless, there are barriers to be overcome during the implementation and program scale-up. First, creating incentives and making the program's benefits more visible to promote the acceptability, adoption, and high penetration among the healthcare insurers. Second, establishing clear and measurable indicators that allow a performance control and accountability. Third, improving the communication strategy to highlight the monitoring program's importance to succeed in pandemic control, both in human lives and in economic terms. Fourth, the TTI needs coordination, cooperation, and trust at different levels of government. Finally, the cost-effectiveness may also be sensitive to increasing productivity in testing, which may be accomplished by improvements in testing technologies and enhancing organizational capacity, mainly in labs.

The cost-effectiveness of the case monitoring program can also set the stage for other prevention strategies using telemedicine and technology innovations. Moreover, telemedicine increases access to healthcare services, reduces work absenteeism, reduces geographic barriers, and allows a close follow-up of chronic conditions such as hypertension and diabetes.[40,41] Before the Pandemic, Colombia had a legal framework for telemedicine,[42] but it was scarcely implemented until the COVID-19 pandemic. In 2020, most ambulatory healthcare services were provided with telemedicine, the capacities were increased, and the health professionals adapted their practice to this care strategy. However, it is required to elaborate a legal framework in the countries where it is not available,[43] evaluate the quality of the telemedicine services and adjust to the community needs. Specifically, there is a need to improve internet and phone access, access to technological resources, internet connectivity, and digital education to allow broad dissemination of this strategy.[44] Hence, the learnings and capacities built conducting case monitoring can inform strategies to improve telemedicine as a whole.

The assignment of the TTI program on the healthcare insurers led to a decentralization of the strategy. Positive externalities to the community from effective monitoring effort implies that the potential social benefits can outweigh the benefits to an individual health insurer. In addition, the public nature of the monitoring activities suggests that an insurer may have incentives to free-ride the monitoring effort of other insurers implementing the TTI strategy. In the current health system, insurers have a low incentive to conduct contact tracing since they do not directly reap the direct benefits of reducing transmission among not enrolled individuals. However, they have a solid incentive to conduct case monitoring as this potentially reduces future health care costs, which has been evidenced in this study. This difference in incentives likely explains that whereas the case monitoring program was successfully deployed in Colombia, the contact tracing program has struggled to start off. Such difference provides evidence that future efforts need to be made to align the contact tracing system with additional incentives to the insurers.

The PRASS program in Colombia has put the Colombian health system to the test. The health insurance model has shown adequate performance to carry out risk management activities at the individual level, but at the expense of showing high differences by socio-economic level.[33] There have been challenges to coordinate and align the risk mitigation activities among the health insurers, providers, and governmental surveillance organization. We hope that these results will encourage the policy-makers and health system actors to implement these highly cost-effective strategies, and that collective risk management should also be the

Articles

center of the actions of the health system, and that therefore all stakeholders should be involved.

This research has some limitations. The analysis used health disutilities from a different population (influenza) since, at this point, there are not health utility studies in COVID-19 to the best of our knowledge. We did not include the fixed costs required to develop and scale the program and the associated cost of the healthcare services shortages. However, the high figures suggest that the sunk costs could be covered in a relatively short period of time. The benefits of setting up this program may have spillovers for future pandemics. Likewise, using QALYs could be problematic to measure the individual's utility in this case since it only considers the infection's effect on health status. However, it does not include other factors that affect individuals, such as anxiety and other mental health problems related to not being able to work or feeling lonely. Finally, the variability of transmission probability was not considered, even when Colombia has had three waves and has implemented other strategies to reduce and control the pandemic.

In conclusion, these findings indicate that TTI program as implemented in Colombia represents a cost-effective use of resources, even when the costs and disutilities associated with long COVID-19 were not included. These benefits may be fundamental to argue in favor of implementing similar programs for other diseases and encourage collective risk management approaches within the health systems interventions. The results might imply that new policies integrating telemedicine, predictive analysis, and population health to upgrade control and prevention programs might reduce costs and minimize the health harm of future pandemics.

Translated Abstract

Antecedentes: El uso de mascarilla y distanciamiento social han sido un pilar en salud pública para reducir la transmisión y la mortalidad por COVID-19. Asimismo, muchos países han utilizado la estrategia de testeo-rastreo-aislamiento (TRA) para fortalecer la mitigación del riego. El objetivo de este estudio es estimar la costo-efectividad del programa de TRA para reducir el número de casos severos y fatales de COVID-19 en Colombia.

Metodología: Se utilizó un modelo de simulación de Markov combinado con un modelo SIR (Susceptible, Infectado, Recuperado) para simular la transmisión de la infección por COVID-19 en Colombia. Estimamos la costo-efectividad incremental del programa de monitoreo de la estrategia PRASS comparado con ninguna intervención durante un año. Incluimos la perspectiva del sistema de salud y la sociedad. Las tasas de hospitalización y letalidad se obtuvieron de los reportes epidemiológicos de Colombia. Incluimos los costos del programa, la utilización de servicios de salud, diagnostico con prueba PCR, pérdida de productividad y subsidios sociales gubernamentales. Los resultados en salud usados fueron el número de muertes y los años de vida ajustados por calidad. Se realizaron análisis de sensibilidad.

Hallazgos: Comparado con ninguna intervención, la estrategia de TRA reduce la mortalidad por COVID-19 en 67%. Asimismo, los ahorros del programa en promedio son $1,045 y $850 por caso en la perspectiva social y del sistema de salud, respectivamente. Esto es equiparable a dos veces el gasto de salud anual en Colombia per cápita.

Interpretación: La estrategia de TRA en Colombia es altamente costo-efectiva. Esta es dependiente de la capacidad del programa da hacer una identificación temprana y dar asistencia médica y social a los nuevos casos. Nuestros resultados ejemplifican el éxito de estrategias integrales usando análisis predictivos y telemedicina para mejorar los programas de prevención.

Palabras clave

PRASS, Análisis de Costo-efectividad, COVID-19, evaluación del riego, mitigación

Declaration of Competing Interest

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lana.2021.100109.

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