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The economic burden of viral severe acute respiratory infections in the Kingdom of Saudi Arabia: A nationwide cost-of-illness study

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ABSTRACT

Objectives: The authors conducted a study to estimate the rising disease and economic burden of viral severe acute respiratory infections and their management, including COVID-19, respiratory syncytial virus, and influenza types A and B, in early and delayed diagnosis scenarios in the Kingdom of Saudi Arabia from a national perspective.
Methods: This cross-sectional study was conducted in May 2022 using a de novo Excel-based universal cost-of-illness calculator model. The study used primary data, such as expert interviews, as well as secondary data from a thorough literature search.
Results: The total economic burden of viral severe acute respiratory infections in patients with an early diagnosis was lower than those with a delayed diagnosis among patients with complications, both from the payer's (United States dollar [USD] 3846 million vs USD 4726 million) and societal (USD 4048 million vs USD 5020 million, respectively) perspectives. The major cost driver of the total economic burden for both early and delayed diagnosis was disease management costs: 49% (USD 1880 million) and 58% (USD 2730 million), respectively.
Conclusions: In the Kingdom of Saudi Arabia, the total economic burden for COVID-19, influenza (epidemic phase), and respiratory syncytial virus was higher with a delayed diagnosis vs an early diagnosis, emphasizing the importance of using a broader diagnostic method.

Introduction

Severe acute respiratory infection (SARI) accounts for a substantial morbidity and mortality, affecting patients of different age groups and individuals with compromised immune, cardiac, and pulmonary systems [1]. The World Health Organization (WHO) defines SARI as an acute respiratory infection with a history of fever or measured fever of ≥38°C, cough, and onset within the last 10 days requiring hospitalization [2]. The estimated mortality from SARI is approximately 4.2 million people worldwide each year [3]. SARIs are caused by different pathogens including viruses such as the novel coronavirus SARS-CoV-2, influenza (A and B) viruses, and respiratory syncytial virus (RSV) [1].

Viral SARIs impose a direct and indirect economic burden on public health. The most recent example is the COVID-19. As of February 2023, more than 756 million infections and 6.8 million COVID-related deaths were reported to the WHO [4]. In the Kingdom of Saudi Arabia (KSA), a total of 828,595 confirmed cases and 9593 deaths were reported during this period. The incidence and prevalence of symptomatic COVID-19 in the KSA were 879.7 per 100,000 people and 6.1%, respectively, while the overall case fatality was reported at 2% [4].

Viral SARIs due to SARS-CoV-2 heavily burdened the global health care systems in terms of resource utilization and expense management. Reports suggest that the estimated cumulative costs of the COVID-19 pandemic are more than $16 trillion, or approximately 90% of the annual gross domestic product of the US [5,6]. A recent retrospective study from the KSA reported the average cost per patient for the treatment of COVID-19 as 44,316 Saudi Arabian Riyal (SAR) (United States dollar [USD] 10,182.5) [7], which is much higher than the cost reported in the US (USD 3045) [5]. COVID-19 was a serious concern for patients since it posed a serious economic burden on health care systems, including the KSA [7].

Influenza and RSV are the other leading viral causes of SARIs [8]. Annually, around 1 billion influenza cases, with 3-5 million severe cases, are reported worldwide [9]. The Global Burden of Disease Study reported that it is a significant reason for hospitalization [10]. According to the Global Influenza Mortality Project (GLaMOR), influenza causes an

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average of 389,000 respiratory fatalities worldwide (uncertainty range 294,000-518,000) each year, accounting for around 2% of all annual respiratory deaths [11].

RSV infection is a common cause of hospitalization in older adults aged ≥65 years [12], and children aged <5 years around the world. The prevalence of RSV infection is high in the Middle East and North Africa region [13], with 1086 RSV infections, accounting for 23.5% of acute respiratory tract infections and 97.4% of total viral infections in the KSA alone [14].

Identifying the viral pathogen of SARI quickly will enable the adoption of appropriate therapeutic options and help control further transmission through public health interventions and infection control measures in healthcare facilities [15].

The present study was conducted to estimate the economic burden, including the total burden that includes the direct and indirect costs of viral SARIs management, including COVID-19, RSV, and influenza types A and B, in early and delayed diagnosis scenarios in the KSA, from a national (the payer and societal) perspective, considering the impact of vaccination and, further, to delineate the main cost drivers.

Methods

Study design and setting

A de novo Excel-based universal cost-of-illness (COI) calculator model was developed in May 2022 to quantify the total economic burden of viral SARIs (COVID-19, RSV, and influenza type A and B) in the KSA from a national (payer and societal) perspective, in line with the International Society for Pharmacoeconomics and Outcomes (ISPOR) best practices in modeling [16].

Data collection

Data generated through interviews

Literature reviews, surveys, and expert interviews were used for data collection. The model structure and data generated were validated by key opinion leaders (KOLs) and reported in the manuscript. Further details are provided in Figure S1.

Ministry of Health data and literature review

Relevant epidemiological data on viral SARI were retrieved from various programs and platforms at the agency of preventive health, Ministry of Health (MOH), KSA. In addition, published literature from the KSA on SARIs (COVID-19, influenza A and B, and RSV) covering the study period was reviewed.

The modeling

Model inputs with early and delayed diagnoses:

The COI model was based on inputs and adapted in accordance with the Saudi MOH standard management guidelines. All inputs and assumptions were further validated at a roundtable meeting of five multidisciplinary experts from the MOH preventative health agency (details in Table S1).

Population inputs:. Population inputs for viral SARIs were obtained from the literature and based on KOL inputs. They were categorized based on the patient pathway: screening phase, quarantine phase, and confirmed case inputs.

During the screening phase, the inputs considered for the model were as follows: country population, test positivity rate, incidence rate, and the proportion of patients in the patient-specific age group for the condition [17–22]. Confirmed case inputs for symptomatic and asymptomatic patients for each of the viral SARIs were also considered. The relevant inputs for the quarantine phase and confirmed cases of viral SARIs conditions are shown in Figure S2.

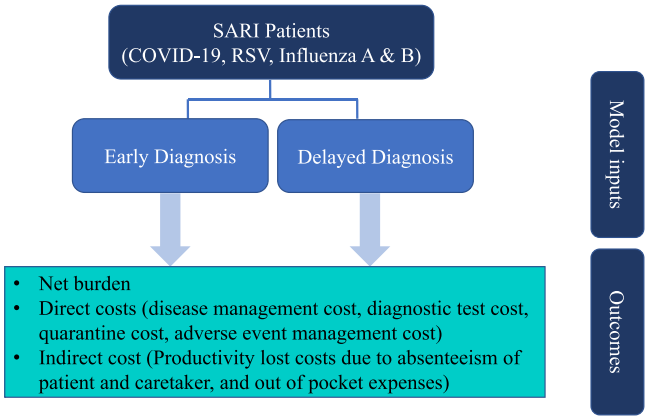

Figure 1. Model concept.
Abbreviation: RSV, respiratory syncytial virus.

Diagnosis inputs:. Diagnosis inputs for viral SARIs were categorized into diagnostic tests and quarantine inputs. Diagnostic test inputs comprised the early diagnosis scenario (Xpert® Xpress CoV-2 /Flu/ RSV plus test); and the delayed diagnosis scenario (standard-of-care reverse transcription polymerase chain reaction [RT-PCR] tests for COVID-19, influenza, and RSV). Quarantine inputs were classified into quarantine institutional and quarantine home inputs.

Viral SARI clinical management cost inputs:. Direct cost inputs included viral SARIs management costs which comprised the cost of consultation, drug acquisition, administration, diagnosis or monitoring, complications management costs, quarantine inputs, and data on resource utilization costs estimated in 2022 (Table S1). Data on resource utilization costs were obtained from the literature, KOL interviews, and round-table discussion (RTD). Drug acquisition costs were calculated by authors using cost, insurance, and freight prices. Drugs included in the management of viral SARIs were obtained from the MOH guidelines.

Non-drug costs and indirect costs:

Non-drug costs included, but were not limited to, indirect costs involving productivity losses due to the absenteeism of patients and caretakers. However, resource utilization costs included costs associated with diagnosis, physician visits, nurse visits, hospitalization, complications management, and adverse event management.

Expert interviews were mostly used to obtain costs for resource utilization and other indirect costs in the KSA, owing to the lack of published national data.

Modeling approach

An Excel-based micro-costing analysis (COI) was developed to estimate the total economic burden of viral SARIs (COVID-19, influenza A and B, and RSV) and their management associated with the current standard of care in the KSA over a 1-year period, both from the payer's (MOH) and societal perspectives.

The model inputs included epidemiology data (Table S1) and unit costs for the management of SARIs with early and delayed diagnoses. The relative risk of early diagnosis was considered to be 0.58, based on the study by Cobre et al. [23], calculated using the odds ratio data [17]. The model concept is shown in Figure 1. All prices were stated in USD upon applying exchange rates for the KSA.

The impact of vaccination for COVID-19 (vaccination rate: 80%) and influenza vaccination during the epidemic and non-epidemic seasons vs Hajj season (vaccination rates: 23% vs 70%, respectively were also considered while assessing the total economic burden [17,18,22].

Model outcomes (projected outcomes)

The model outcomes included are as follows:

Total economic burden, which includes the sum of all the direct and indirect costs.

- Direct costs: Include disease management costs, diagnostic test costs, quarantine costs (COVID-19), and adverse events management costs.
- Indirect costs: Include productivity loss costs due to the absenteeism of patients and caregivers.

Analytical approach

This COI model calculated the total economic burden of the three major viral SARIs: COVID-19, RSV, and influenza at epidemic, non-epidemic, and during the Hajj period.

For all viral SARIs, subgroup analyses (Figure S2) were done to look at the costs of the outpatient department (OPD), the inpatient department (IPD), the intensive care unit (ICU), outpatient care, care after hospitalization, and managing complications.

Costs in each subgroup were categorized into costs of consultation, drug acquisition, drug administration, monitoring, and/or prognostic tests, hospitalization/bed, and other costs.

Indirect costs were calculated based on the absenteeism in the COVID-19 population due to home or institutional quarantine or hospital admission as per the Saudi MOH guidelines. According to the KOLs inputs, the average number of days lost for each patient due to home/institution isolation (quarantine) was estimated as 5 days (stable patients). For inpatient admission, the average days lost for patients and caregivers were 5 and 2 days respectively, while ICU admission resulted in 5 and 3 days for patients and caregivers respectively. Post-hospitalization care had resulted in 3 days lost for each patient with COVID-19. The average wage was calculated based on the wage of female/male workers reported in the General Authority of Statistics [18]. For patients with influenza and RSV, indirect costs included wage loss due to absenteeism.

In the case of early diagnosis, it has been assumed by clinicians and KOLs that there will be an early and accurate diagnosis, and thus the utilization of healthcare resources will be reduced.

In addition, one-way sensitivity analysis (OWSA), wherein each parameter was varied individually to isolate the consequences of the parameter on the results and outcomes of the study, was performed (Table S2).

Ethical consideration and compliance with ethics guidelines

This study was approved by the Central Institutional Review Board (IRB) Log No: 22-60 M. The study was conducted in compliance with existing literature findings and KOL/expert opinion and did not comprise any studies with human participants or animals.

Results

The model inputs (population, viral SARI direct management cost, and indirect cost)

Total country population, estimated incidence rates, and test positivity rates from secondary literature were used to estimate the number of patients for viral SARIs for early and delayed diagnosis (Table S3). The incidence rate of COVID-19 was 6% [18,19,22], with a general test positivity of 19% [22].

Influenza incidence and test positivity rates were estimated for the epidemic, non-epidemic, and Hajj seasons separately [17]. For the epidemic season, the incidence rates observed were 10 times greater than those for the non-epidemic season (10% vs 1.1%, respectively), with test positivity rates of 45.5% and 8.1%, respectively. During the Hajj season, an incidence rate of 5% and a test positivity rate of 22.7% were estimated in the Hajj area.

The estimated incidence rate was 7.6% [20], and the test positivity was 10% in the RSV-specific age group [21].

The total economic burden of viral SARIs conditions in the KSA

The study explored the economic burden of viral SARIs, which included costs pertaining to disease management, diagnostic tests, quarantine, complication management, and indirect costs for early and delayed diagnoses from both the payer's and societal perspectives. For COVID-19 and influenza, the effect of vaccination uptake on the total burden was also calculated.

The economic burden of viral SARIs on patients in the early diagnosis scenario compared with the delayed diagnosis scenario was USD 3,846 million vs USD 4,726 million, respectively from the payer perspective and USD 4,048 million vs USD 5,020 million, respectively from the societal perspective.

The major cost driver of the total burden was disease management costs for both early (~49%, USD 1880 million) and delayed diagnoses (~58% USD 2730 million) (Table 1). Other major cost drivers for both early and delayed diagnoses were diagnostic tests (~25%, USD 976 million vs ~8%, USD 398 million, respectively) and complication management (~22%, USD 839 million vs ~31%, USD 1448 million, respectively). A further breakdown of disease management costs reveals that monitoring costs play a significant role in both early (60%) and delayed (49%) diagnoses (Table S4).

The total economic burden of COVID-19 in the KSA

The total burden of early and late diagnoses in patients with COVID-19 associated complications, was compared using model inputs. The relative risk of early diagnosis was set at 0.58, and vaccination had a low impact on COVID-19 during the epidemic phase.

The total burden, from the payer's perspective, for COVID-19 was a total of USD 1198 million for patients with an early diagnosis, and USD 1520 million for those with a delayed diagnosis. The total burden decreased with vaccination and was lower in patients with an early diagnosis compared with those with a delayed diagnosis (USD 927 million vs USD 982 million, respectively).

Similarly, for COVID-19's total burden, from a societal perspective, and regardless of the vaccination status, the total cost burden was lower in patients with early diagnosis vs those with delayed diagnosis (Table 2 and Table S5).

The total economic burden for Influenza

Results for influenza were compared during the epidemic, non-epidemic, and the Hajj seasons in relation to early vs delayed diagnosis and vaccination status, as summarized in Tables 3, and S6.

Based on MOH estimates, there were more people (pilgrims, visitors, and citizens) who got vaccinated for influenza during Hajj season (70%) than during the epidemic and non-epidemic seasons (23%). The total economic burden from the payer's perspective, was lower for patients with complications who were diagnosed early than for those who were diagnosed later, regardless of their vaccination status (with vaccination: USD 230 million and USD 285 million; without vaccination: USD 260 million and USD 351 million).

During the epidemic phase, from the payer's perspective, a lower economic burden was observed in patients with complications with early diagnosis compared with those with delayed diagnosis, both with vaccination (USD 986 million and USD 1297 million) and without vaccination (USD 1025 million and USD 1384 million).

During the non-epidemic phase, from the payer's perspective, no substantial difference was noted in the cost burden for early vs delayed diagnosis (USD 365 million and USD 368 million), when vaccination impact was considered. But when considering vaccination impact, the total economic burden was slightly higher for early diagnosis than for delayed diagnosis, from both the payer (USD 356 million and USD 348 million) and societal (USD 359 million and USD 356 million) perspectives.

Table 1
Total burden of viral SARIs, in patients with complications at early and delayed diagnoses: payer and societal perspectives (without vaccination impact).

Burden of viral SARIs	Societal		Payer	
Early diagnosis	Per patient (USD)	All patients (USD, %)	Per patient (USD)	All patients (USD, %)
Total burden	50,259.32	4,048,051,384.42 (100)	46,487.20	3,846,504,682.52 (100)
Disease management cost	44,617.29	1,880,431,733.82 (46.45)	44,617.29	1,880,431,733.82 (48.89)
Diagnostic test cost	195.90	976,662,537.52 (24.13)	195.90	976,662,537.52 (25.39)
Quarantine cost	271.76	149,528,573.21 (3.69)	271.76	149,528,573.21 (3.89)
Complication management cost	1,402.25	839,881,837.97 (20.75)	1,402.25	839,881,837.97 (21.83)
Indirect cost	3,772.12	201,546,701.90 (4.98)	3,772.12	201,546,701.90 (5.24)
Burden of viral SARIs	Societal		Payer	
Delayed diagnosis	Per patient (USD)	All patients (USD, %)	Per patient (USD)	All patients (USD, %)
Total burden	63,234.12	5,020,856,409.93 (100)	58,372.55	4,726,421,507.48 (100)
Disease management cost	55,603.15	2,730,183,029.42 (54.38)	55,603.15	2,730,183,029.42 (57.76)
Diagnostic test cost	79.96	398,637,770.41 (7.94)	79.96	398,637,770.41 (8.43)
Quarantine cost	271.76	149,528,573.21 (2.98)	271.76	149,528,573.21 (3.16)
Complication management cost	2,417.67	1,448,072,134.43 (28.84)	2,417.67	1,448,072,134.43 (30.64)
Indirect cost	4,861.57	294,434,902.45 (5.86)	4,861.57	294,434,902.45 (6.23)

Abbreviations: SARI, severe acute respiratory infection; USD, United States dollar, %, percentage.
Conversion rate used: 1 Saudi Arabian Riyal (SAR) = 0.2665324054 USD (February 8, 2023).

Table 2
Total burden of COVID-19, with and without complications, at early and delayed diagnoses: payer and societal perspectives (with vaccination impact).

Burden of COVID-19		Early diagnosis		Delayed diagnosis	
		Per patient (USD)	All patients (USD)	Per patient (USD)	All patients (USD)
Societal	**Total burden with complication**[a]	15,890.60	1,066,300,801.95	19,151.47	1,124,014,668.49
	Total burden without complication	15,402.49	875,323,247.06	18,309.90	794,743,022.14
Payer	**Total burden with complication**[a]	15,146.65	927,578,362.17	18,146.99	982,785,020.42
	Total burden without complication	14,658.53	736,600,807.28	17,305.42	653,513,374.07
Disease management cost		14,321.47	367,623,250.25	17,007.00	414,413,787.06
Diagnostic test cost		65.30	219,448,983.82	26.65	89,571,013.80
Quarantine cost		271.76	149,528,573.21	271.76	149,528,573.21
Complication management cost		488.11	190,977,554.88	841.57	329,271,646.35
Indirect cost (wage loss)		743.95	138,722,439.78	1004.48	141,229,648.07

Abbreviations: USD, United States dollar.
Conversion rate used: 1 Saudi Arabian Riyal (SAR)= 0.2665324054 USD (February 8, 2023).
[a] Complications included Myocarditis, Acute myocardial infarction, Acute heart failure, Pulmonary embolism, Deep vein thrombosis, Pneumonia, Acute respiratory distress syndrome and Sepsis.

The total economic burden for RSV

It was found that patients who were diagnosed with RSV early had lower costs than those who were diagnosed later (USD 1622 million vs USD 1821 million for payers and USD 1667 million vs USD 1920 million for society, respectively) (Table 4).

A tornado plot illustrating OWSA results

For patients with COVID-19, it was demonstrated that the test positivity rate of COVID-19, population of the country, and incidence rate of COVID-19 introduced the maximum amount of difference to the total burden of COVID-19 results (Figure S3).

For influenza, it was demonstrated that the test positivity rate for the non-epidemic phase, the incidence rate for the non-epidemic phase, the proportion of patients with symptomatic influenza, and the proportion of patients with symptomatic tested in the first test, all affected the total burden of influenza (Figure S4).

For RSV, it was demonstrated that the total burden of RSV was affected by the test positivity rate, population of the country, proportion of the patients with RSV, with a specific age group for RSV, incidence rate of RSV, proportion of patients with symptomatic RSV, and proportion of patients with symptomatic in the first test had a significant impact on the total economic burden of RSV (Figure S5).

Discussion

Viral SARIs are highly prevalent and exhibit high mortality rates contributing to a pronounced economic burden. As a result, understanding the impact of timely diagnosis and developing effective treatment strategies to reduce direct and indirect costs, in addition to the total economic burden of vaccination, are critical for efficient resource allocation in health care. As far as we know, this is the first study on the economic burden of viral SARIs in the KSA.

The current study estimated the cost per patient of the three major viral SARIs: COVID-19, RSV, and influenza at epidemic, non-epidemic, and during the Hajj period in KSA (details in Tables 2-4, S5, and S6).

The relatively lower influenza vaccination uptake compared to earlier years may have contributed to a higher burden of SARIs [24].

In the early and delayed diagnoses scenarios (~49% and ~58%, respectively), disease management was primarily responsible for the total economic burden. Data on the total burden of viral SARIs from the payer and societal perspectives in Middle Eastern countries, including the KSA, are scarce and conflicting. A study from the KSA found laboratory investigations and treatment costs to be the major cost drivers [7], while another study from Iran found hospital beds, medicines, and medical consumables to drive major costs [25].

A breakdown of costs indicated higher diagnostic costs for patients with early diagnosis compared with delayed diagnosis (~25% and ~8%,

Table 3
Total burden of Influenza, with and without complications, at early and delayed diagnoses during non-epidemic, epidemic, and hajj period: payer and societal perspectives (with vaccination impact).

Burden of Influenza: non-epidemic					
Burden of Influenza		Early diagnosis		Delayed diagnosis	
		Per patient (USD)	All patients (USD)	Per patient (USD)	All patients (USD)
Societal	**Total burden with complication**[a]	12,263.64	359,681,998.82	18,084.69	356,349,911.07
	Total burden without complication	11,893.56	267,310,478.28	17,446.62	197,088,668.76
Payer	**Total burden with complication**[a]	11,199.20	356,846,132.06	16,502.36	348,244,350.33
	Total burden without complication	10,829.12	264,474,611.52	15,864.29	188,983,108.02
Disease management cost	10,763.82	53,476,510.98	15,837.64	102,861,434.33	
Diagnostic test cost	65.30	210,998,100.55	26.65	86,121,673.69	
Quarantine cost	0.00	0.00	0.00	0.00	
Complication management cost	370.08	92,371,520.54	638.07	159,261,242.31	
Indirect cost (wage Loss)	1064.43	2,835,866.76	1582.32	8,105,560.74	
Burden of Influenza: epidemic					
Burden of Influenza		Early diagnosis		Delayed diagnosis	
		Per patient (USD)	All patients (USD)	Per patient (USD)	All patients (USD)
Societal	**Total burden with complication**[a]	12,263.64	998,777,303.28	18,084.69	1,333,015,639.31
	Total burden without complication	11,893.56	590,856,434.64	17,446.62	629,703,796.81
Payer	**Total burden with complication**[a]	11,199.20	986,253,862.90	16,502.36	1,297,220,760.56
	Total burden without complication	10,829.12	578,332,994.26	15,864.29	593,908,918.07
Disease management cost		10,763.82	236,157,039.33	15,837.64	454,245,263.00
Diagnostic test cost		65.30	342,175,954.93	26.65	139,663,655.07
Quarantine cost		0.00	0.00	0.00	0.00
Complication management cost[a]		370.08	407,920,868.65	638.07	703,311,842.49
Indirect cost (wage Loss)		1,064.43	12,523,440.38	1,582.32	35,794,878.75
Burden of Influenza- hajj period					
Burden of Influenza		Early diagnosis		Delayed diagnosis	
		Per patient (USD)	All patients (USD)	Per patient (USD)	All patients (USD)
Societal	**Total burden with complication**[a]	11,202.18	232,547,217.26	16,254.60	292,156,819.36
	Total burden without complication	10,880.65	142,510,683.25	15,700.23	136,921,415.90
Payer	**Total burden with complication**[a]	10,231.56	230,063,422.34	14,834.02	285,319,446.34
	Total burden without complication	9,910.03	140,026,888.34	14,279.65	130,084,042.89
Disease management cost	9,844.73	53,098,955.31	14,253.00	94,603,253.90	
Diagnostic test cost	65.30	86,927,933.04	26.65	35,480,788.99	
Quarantine cost	0.00	0.00	0.00	0.00	
Complication management cost	321.53	90,036,534.00	554.37	155,235,403.45	
Indirect cost (wage loss)	970.62	2,483,794.91	1,420.58	6,837,373.01	

Abbreviations: USD, United States dollar.
Conversion rate used: 1 Saudi Arabian Riyal (SAR)= 0.2665324054 USD (February 8, 2023).
[a] Complications included Myocarditis, Acute myocardial infarction, Acute heart failure, Pulmonary embolism, Deep vein thrombosis, Pneumonia, Acute respiratory distress syndrome and Sepsis.

respectively) due to the price of the Xpert® Xpress CoV-2/Flu/RSV plus test; however, the early diagnosis of viral SARIs contributed to lower costs related to complication management compared with delayed diagnosis (~22% and ~31%, respectively), thereby resulting in a lower total economic burden for early diagnosis of viral SARI. Moreover, early testing along with prevention with vaccination is important to curb the spread of SARI viruses.

In our model, the disease management costs were Saudi Arabian Riyal (SAR) 7050 million (USD 1880 million) and SAR 10,238 million (USD 2730 million) for early and delayed diagnoses, respectively. In previous literature, the management cost varied across different periods, settings, and regions. Between 2020-2021, the total cost of medical services for hospitalized patients with COVID-19 in KSA was estimated at USD 51,565,628, which included patients admitted to the general ward (USD 38,895) and ICU (USD 24,207,297) [7]. Another study noticed high direct medical cost burden per patient with COVID-19 in the KSA (USD 11,387.86 ± USD 7949.66 for general ward patients and USD 21,178.21± USD 14,839.38 for patients in ICU) [26].

Complication management costs increased the overall cost by 22% (from USD 839 million to USD 1448 million) in our study. In a US study,

Table 4
Total burden of RSV, with and without complications, at early and delayed diagnoses: payer and societal perspectives.

Burden of RSV		Early diagnosis		Delayed diagnosis	
		Per patient (USD)	All patients (USD)	Per patient (USD)	All patients (USD)
Societal	**Total burden with complication**[a]	16,692.92	1,667,286,784.62	16,666.64	1,920,185,068.02
	Total burden without complication	16,675.84	1,648,837,696.01	16,637.20	1,888,376,294.57
Payer	**Total burden with complication**[a]	15,158.72	1,622,606,223.30	15,132.44	1,821,624,510.96
	Total burden without complication	15,141.63	1,604,157,134.70	15,102.99	1,789,815,737.51
Disease management cost	15,076.33	1,189,119,535.93	15,076.33	1,620,412,635.97	
Diagnostic test cost	65.30	415,037,598.77	26.65	169,403,101.54	
Quarantine cost	0.00	0.00	0.00	0.00	
Complication management cost	17.08	18,449,088.60	29.45	31,808,773.45	
Indirect cost (wage loss)	1,534.21	44,680,561.32	1,534.21	98,560,557.06	

Abbreviations: RSV, respiratory syncytial virus; USD, United States dollar.
Conversion rate used: 1 Saudi Arabian Riyal (SAR)= 0.2665324054 USD (February 8, 2023).
[a] Complications included Myocarditis, Acute myocardial infarction, Acute heart failure, Pulmonary embolism, Deep vein thrombosis, Pneumonia, Acute respiratory distress syndrome and Sepsis.

the median hospital charges increased from USD 43,986 to USD 198,394 among hospitalized patients with COVID-19 requiring ICU and invasive mechanical ventilation [27]. Rae et al. [28] estimated an average hospital cost of USD 9763 for hospitalized patients with COVID-19 without complications and USD 34,223-88,114 for patients with mechanical ventilation.

Our model also reported significantly lower indirect costs from both perspectives in the early diagnosis (USD 3772.12 per patient) and late diagnosis (USD 4861.57 per patient), compared with the costs reported in Iran, where the mean indirect costs were estimated to be USD 11,634 per person [25].

In this study, we found that the total burden of influenza during the epidemic phase from the payer perspective decreased with early diagnosis compared to delayed diagnosis (USD 986 million vs USD 1297 million). Putri et al. [29] estimated the annual total economic burden of influenza on the US health care system and society to be USD 11.2 billion (USD 6.3-25.3 billion), which included direct medical costs of USD 3.2 billion and indirect costs of USD 8.0 billion.

Our study estimated the economic burden for early diagnosis of viral SARIs (COVID-19, influenza, and RSV) vs conventional RT-PCR for COVID-19, influenza, and RSV. The total economic burden was lower with early diagnosis for COVID-19 and influenza especially during the epidemic phase and during Hajj, when vaccination impact was considered. Early identification of the viral etiology of viral SARIs may have contributed to total cost reduction by lowering the cost of treatment, as well as reducing hospital and ICU admissions.

Limitations

As with any modeling analysis, this study has a few limitations that should be considered while evaluating the results.

The retrospective nature of the study limited our ability to perform further validation of the data. For example, it was not possible to examine the effect of SARS-CoV-2 variants across successive pandemic waves. Additionally, the effect of frequent amendments to testing, management, and vaccination policies could not be measured. When reliable input data were not available, we relied on expert opinions to generate model inputs (assumptions) on diseases epidemiology, vaccination status, frequency of resource utilization, treatment options, and costs. Moreover, the authors did not consider the sensitivity of the diagnosis test as an input parameter, which is one of the model limitations. We attempted to reduce the inherent bias of this approach by expanding the spectrum of experts and rounding interviews.

Conclusion

In the KSA, patients with an early diagnosis showed a lower economic burden of viral SARIs compared with those with a delayed diagnosis using separate RT-PCR tests from the provider and the public perspectives, both among patients with and without complications. Mortality for COVID-19 and influenza patients with complications was lower with early diagnosis than with delayed diagnosis, both during the epidemic and Hajj seasons, when the impact of vaccination was considered. Rapid diagnostic tools will help accelerate the treatment process and reduce the economic burden (total, direct, and indirect costs) of viral SARIs.

Declaration of Competing Interest

The authors have no competing interests to declare.

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Ethical approval

Not required.

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Author contributions

All authors participated and contributed in the study design, methodology validation, data collection, data analysis, drafting and revision of the manuscript.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijregi.2023.11.016.

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