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ORIGINAL RESEARCH ARTICLE

The Impact of COVID-19 Vaccination on the Italian Healthcare System: A Scenario Analysis

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Abstract

Background and Objective During 2020, the only instruments for fighting against the pandemic peaks were lockdowns, physical distancing, closure of schools and non-essential businesses, and travel restrictions. The new vaccination strategy adopted in Italy in 2021 represented a new perspective for policymakers.

Objective The aim of this study was to estimate the effects of the national immunisation strategy for coronavirus disease 2019 (COVID-19) in Italy on the national healthcare system.

Methods An epidemiological scenario analysis was developed in order to simulate the impact of the COVID-19 pandemic on the Italian national healthcare system in 2021. Hospitalisations, intensive care unit (ICU) admissions and death rates were modelled based on 2020 data. Costs were estimated using hospital admissions from the Policlinico of Tor Vergata Hospital in Rome. Two scenarios were tested, one with vaccination and the second without.

Results The roll-out of vaccinations to protect against COVID-19 was estimated to prevent 52,115 deaths in 2021, 45.2% less than what was expected in the absence of immunisation. Based on the assumptions underlying the two epidemiological scenarios, our model predicted an overall reduction of 2.4 million hospital admissions and 259,000 ICU admissions (74.9% and 71.3% less, respectively, than the world without vaccinations between June and December 2021). Overall, in Italy, the model estimated over €3.0 billion costs of hospitalisations due to COVID-19 in 2020. In 2021, vaccines prevented around 36% of the overall costs.

Conclusions This is the first study highlighting the effect of vaccines on the Italian healthcare system in terms of avoided cases, hospitalisations and costs. Our results have the potential to inform policymakers and the general population on the benefits of vaccinations.

Key Points

Deployment of vaccine immunisation reduced deaths by 42.5% compared with a world without vaccination.

The pressure on the Italian National Health Service decreased by 36% in terms of hospitalisations and intensive care unit admissions.

Vaccines are a key tool to reduce hospitalisations and related costs.

1 Introduction

The race to develop coronavirus disease 2019 (COVID-19) vaccines has occurred at an unprecedented pace. Nine months after the World Health Organization (WHO) announced the COVID-19 global pandemic outbreak in

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March 2020, the UK became the first nation to administer the vaccine developed by Pfizer-BioNTech to people most at risk from the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Two other vaccine candidates, one created by the US-based company Moderna and another by the English Oxford–AstraZeneca partnership, were rolled out by the first quarter of 2021. As of 18 October 2021, four vaccines (Pfizer/BioNTech, Moderna, Oxford–AstraZeneca AZD1222 and J&J Ad26.COV2.S) have been approved by the European Medicines Agency and the Italian Medicines Agency.

Italy's immunisation plan rolled out in December 2020 and followed a prioritisation strategy to cover healthcare workers, nursing home residents and people over 80 years of age first. As of 31 January 2022, 47,332,846 people have been vaccinated with two doses (87.64% of the population aged 12+ years). Moreover, 33,148,664 third doses were administered to the general population [1]. Despite that, more than 2 million people aged 40–49 years have not yet booked a first-dose appointment (76.9%), with some marked differences at the regional level. Therefore, in September 2021, the Italian government made it mandatory for public and private sector workers to have had at least one dose of the vaccine before entering their workplaces or otherwise face the risk of suspension and fines.

The incidence of COVID-19 infections among older patients is one of the factors that put the Italian National Health Service (NHS) under constant pressure during the first waves of the pandemic. Introducing the COVID-19 vaccination was fundamental to avoid hospital capacity saturation and progressively allow the release of regional restrictions such as lockdowns and limitations on economic activity. However, building public trust through clear communication of the benefits of vaccination is a key aspect to achieving higher levels of vaccination take-up by the general population, for all age classes and in all regions [2].

The objective of this study was to quantify the effects of the Italian national immunisation strategy in terms of infections, hospital admissions, deaths and associated costs. An epidemiological scenario analysis was developed in order to simulate the impact of the COVID-19 pandemic on the Italian national healthcare system in 2021 in the presence/absence of vaccination.

The remainder of the study is organised as follows. Section 2 outlines the evolution of the COVID-19 pandemic in Italy in terms of infections. Key moments were identified and employed to inform the scenario analysis. We then illustrate the main assumptions and the methodological steps we used to develop the scenarios and the estimation model. Section 3 describes the main results in terms of avoided cases, hospitalisations, deaths and costs. We conclude by discussing the main implications of the study in Section 4.

2 Methods

2.1 Epidemiological Trends

We identified four key moments in the 2020-21 records of infections (see Online Appendix Fig. 1), as follows:

- The first key moment, the 'first wave', was defined by the pattern of infections recorded between February and April 2020. During this time, a peak of around 29,000 hospitalisations was recorded, with an average of 950 daily deaths (Table 1). The response by the Italian government was to introduce a series of progressive restrictions in order to delay the diffusion of coronavirus, including limitations on individual mobility and the closure of social, cultural, economic and industrial activities [3, 4]. These restrictions resulted in a decrease in COVID-19 cases and deaths until the end of March 2020 (see Online Appendix Fig. 1).
- The second key moment, the 'controlled phase', was the period between May and August 2020. In this time frame, a minimum of 713 hospitalisations and 3 daily deaths due to COVID-19 were recorded during the second half of July. During this period, the health authorities removed some restrictions to allow for unrestricted mobility between regions and for some economic and social activities. The number of daily infections remained constant over time until September 2020.
- A third key moment, the 'second wave', pertained to the period between September and December 2020. During this time, Italy was hit by a second wave of infections, which was recorded as more intense and deadly than the first. Over 34,500 hospitalisations and 990 daily deaths were registerd in Italy at the end of November (see Online Appendix Fig. 1). In contrast to that of the second wave of infections, the Italian government adopted a new containment strategy [5] valid between 6 November and 3 December 2020, which divided Italy into three tiers (yellow, orange and red) of increased restrictions. This approach was updated on a weekly basis and regions were allocated to one of the three tiers based on their most recent epidemiologic data (e.g., the number of infected people and free hospital beds in the previous week).
- In 2021, a fourth key moment was identified. A 'third wave' of infections was registered at the beginning of the vaccination period between February and May 2021. After this period, the number of hospitalisations, ICU

Table 1 Number of estimated cases by scenario and coverage simulation—Italy (1 January 2021–31 December 2021)

Scenario	Vaccination approach	Cases			Percentage of of avoided cases/cost		
		Hospitalisations	ICU admissions	Cumulative deaths	Hospitalisations	ICU admissions	Cumulative deaths
2021 simulation no vaccination	Cases (January–December)	6,306,631	751,687	115,358			
	June–December	3,178,037	363,664	63,389			
	Overall costs	€3,050,190,684	€1,609,097,125				
2021 RWD	Cases (January–December)	3,927,487	492,463	63,243	37.7%	34.5%	45.2%
	June–December	798,893	104,440	11,274	74.9%	71.3%	82.2%
	Overall costs	€1,899,521,989	€1,054,189,839		37.7%	34.5%	

ICU intensive care unit, *RWD* real-world data

admissions and deaths decreased between June and August 2021.

A fourth wave was expected during September 2021, however the slight increase in infections at the end of July 2021 decreased during the first week of September without any specific restrictions from the Italian Government. The fourth wave occurred during November and increased the number of infections until the end of December. Despite the rapid increase in infections (over 130,000 cases per day during January 2022), the pressure on hospitals remained under control in the vast majority of Italian regions.

2.2 Assumptions and Scenarios

The assumptions made in our model reflect the epidemiological trend in the number of cases registered in Italy since the start of the pandemic and the number of vaccine doses administered since January 2021. A first assumption is to consider June 2020 as a key moment in the evolution of COVID-19 infections as the milestone of having 50% of the adult population vaccinated was reached. Since then, the expected reduction in the number of daily cases has been accompanied by seasonal aspects, such as the advent of summer and the reduction of indoor social activities, as reflected in the number of cases registered during 2020, in the absence of vaccination. Therefore, a second key moment in the evolution of the COVID-19 pandemic was considered to be September 2021, when a clear change in the number of daily cases, compared with the corresponding rates of 2020, was registered.

Based on these assumptions, in order to predict the expected curve for August–December 2021 without vaccination, our model replicates the epidemiological trends recorded in 2020 by operating a shift in time based on the real data registered in 2021. The peak of the three curves (hospitalisation, ICU admissions and deaths) registered in October was matched with 2020 infection records and the corresponding points in time were identified. Specifically, we identified timeframes when, in 2020, the pandemic curve showed similar values as those reported at the peak time of October 2021. Consequently, two simulations were developed:

– Real-world data simulation (2021 RWD simulation) was built on the basis of the number of recorded cases from 8 October 2021 to 31 December 2021

  - A scenario without vaccination was built on the expectation of growing numbers of infections starting from 19 August 2021, similar to what was recorded in late 2020 (12 September 2020, 23 November 2020 and 3 December 2020 for hospitalisations, ICU admissions and deaths, respectively).

2.3 Data Sources

Data were retrieved from the Italian National Institute of Statistics (ISTAT) and the Italian National Institute of Health (ISS) [https://www.epicentro.iss.it/coronavirus/sars-cov-2-sorveglianza-dati]. Epidemiological data on the SARS-CoV-2 epidemic in Italy in terms of hospital admissions, access to the ICU, and deaths covering the period from 21 February 2020 to 31 January 2022 were downloaded. Age-stratified death rates were used to calculate the distribution of COVID-19-related hospitalisations and ICU admissions. COVID-19 events were classified by age group, i.e. <60 years, 60–79 years, and ≥80 years (electronic supplementary Table 1).

2.4 Cost Estimation

Costs were calculated based on a sample of 996 patients admitted between 2 March 2020 and 27 December 2020 to the 'Policlinico Tor Vergata' hospital in Rome. Patients aged ≥18 years and admitted with a COVID-19-diagnosed infection were included. Costs due to hospitalisations were estimated using the diagnosis-related groups (DRGs) of patients at the time of their discharge based on their age and sex as well as the consumption of resources during their hospital stay (see Online Appendix Table 2). Average daily costs were obtained by dividing the cost per patient by the length of stay.

3 Results

There are substantial benefits from vaccine immunisation in preventing infections and avoiding hospital utilisation and deaths. As of 31 December 2021, the model estimated a reduction of 82.2% of deaths compared with a world without vaccination. Furthermore, the pressure on the healthcare system decreased by 74.9% in terms of reduced access to hospitals and 71.3% of ICU services compared with a scenario without immunisation, between June and December 2021. Overall, the Italian healthcare system was reliefed of 2,379,144 hospitalisations and 259,224 ICU admissions as of 31 December 2021 (Table 1).

By the end of 2021, 82.2% of deaths forecasted in the absence of immunisation were prevented between June and December 2021 (52,115 deaths avoided), meaning that the effect of immunisation could avoid 45.2% of deaths in 2021. Figure 1 reports the expected trends in hospitalisations, ICU admissions and deaths in the presence/absence of vaccination.

Thanks to the successful vaccination roll-out, our model estimates a reduction in costs incurred by the healthcare system by a total of €2.9 billion (37.7% less due to hospitalisations and 34.5% less in terms of ICU admissions) by the end of 2021.

4 Discussion

This study provides a first estimation of the effects of vaccine immunisation in terms of healthcare resource utilisation and costs. At the time this work was performed, booster vaccine doses were administered to healthcare professionals and the general population in Italy. Therefore, ensuring increased awareness of the true value of vaccination is of great importance to contrast vaccine hesitancy, which is a common phenomenon in Italy despite the high vaccination coverage already achieved.

The success of COVID-19 vaccination campaigns in European countries is the result of intertwined explanatory factors related to demand and supply. These factors include demographic aspects, economic situation, ability to secure sufficient vaccine supply, and population acceptance [6]. Our model aims to inform decision makers in a timely and appropriate manner in order to communicate the benefits of vaccination roll-out and reach the highest vaccination coverage. Our findings confirm the fundamental role vaccines play and convey a message on the economic and societal value of vaccinations.

To our knowledge, this is the first study that estimates the hospitalisation costs sustained by the Italian NHS for the management of COVID-19 patients. During 2020, the only instruments for fighting against the pandemic peaks were lockdowns, physical distancing, closure of schools and non-essential businesses, and travel restrictions [7]. However, this strategy has slow effects over time and produces adverse social and economic impacts [8, 9]. Vaccination demonstrates that this impact could be strongly reduced, and a new perspective should be instigated by policy makers.

This study also has some methodological limitations. First, the model did not include any epidemiological simulations in the analysis. Consequently, a scenario without vaccination represents a fictitious analysis of the overall number of cases detectable in Italy without the new COVID-19 prevention strategy. Second, several assumptions were made based on the data and knowledge accumulated in 2020–2021. The data informing our model are constantly being updated and therefore some of the assumptions used may require an update. However, the model will be constantly calibrated and updated with new data, and thus it represents a potential tool that policy makers may find helpful in the control of the pandemic and in the management of the vaccination campaign (the first version of this model was produced in January 2020 [10]).

5 Conclusion

COVID-19 has put the Italian economic and health systems under immense pressure. Restrictions have been implemented to control the spread of the virus and to make sure that the health system is able to bear the additional demands caused by the pandemic. While controlling the spread of infections and protecting the NHS from collapse, restrictions were introduced at an incredibly high cost to the economy.

Vaccines are key tools to control the pressure on the healthcare system and, at the same time, allow the return to commercial and social activities. This study aimed to analyse the primary effects of introducing COVID-19 vaccinations on the Italian national healthcare system. We developed an estimation model to forecast the potential benefits of

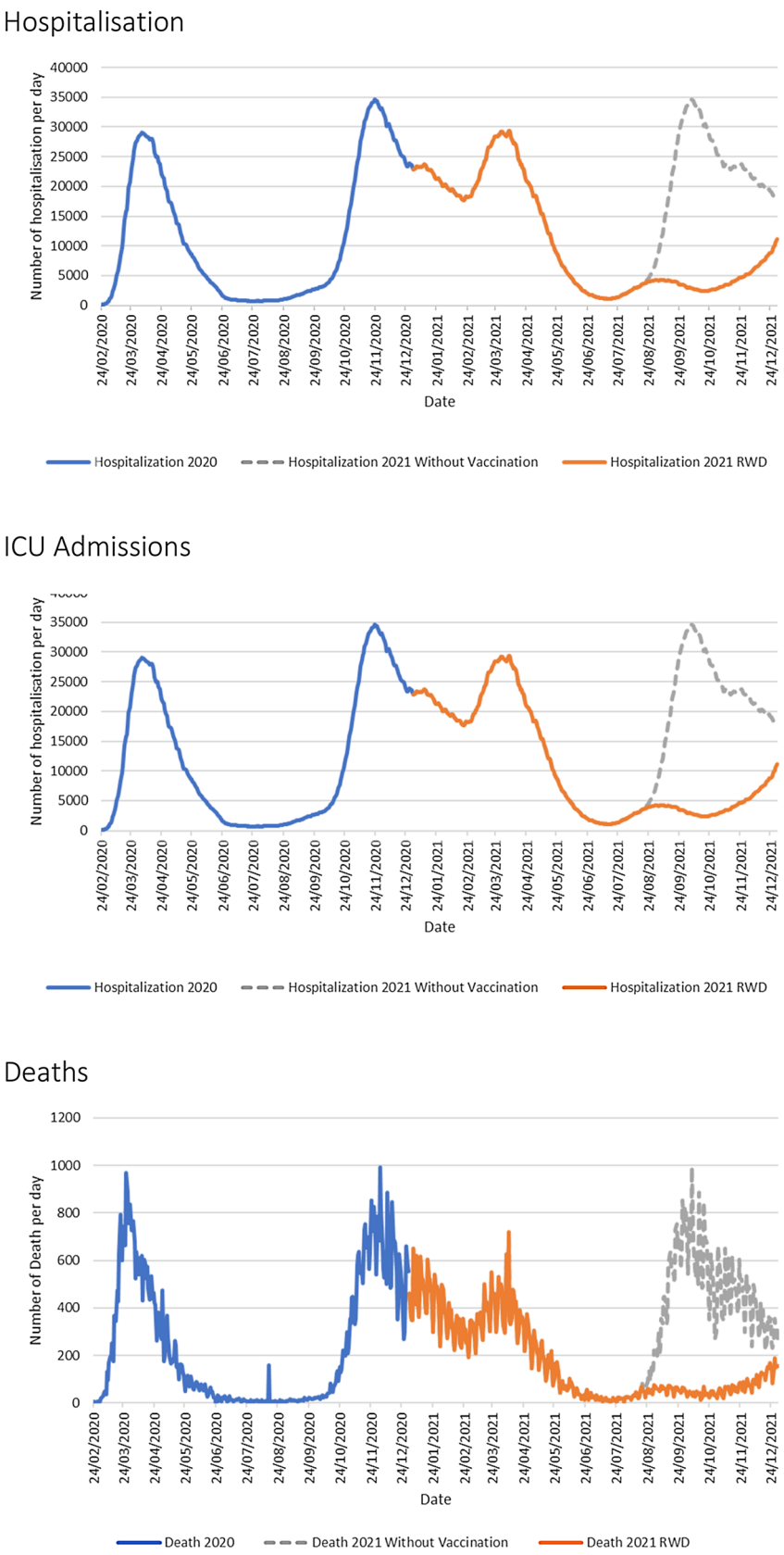

Fig. 1 COVID-related events by scenario and simulation—Italy (1 January 2020–31 December 2021). *COVID-19* coronavirus disease 2019, *ICU* intensive care unit, *RWD* real-world data

immunisation in terms of reduced mortality, hospitalisations and ICU admissions.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40261-022-01127-9.

Declarations

Conflict of interest Andrea Marcellusi, Gianluca Fabiano, Paolo Sciattella, Massimo Andreoni and Francesco Saverio Mennini declare no conflicts of interest.

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Code availability Not applicable.

Authors' contributions AM, GF and FSM designed the study, conducted the analysis and finalised the draft of the manuscript. AM, FSM and MA provided guidance on the methodology, reviewed the results and critically assessed the manuscript. AM and PS managed the data and performed the statistical analysis. All authors provided data and/or reviewed the results of the final draft of the manuscript, and approved the final version of the manuscript.

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