A structured multilevel telehealth service may reduce hospital admissions due to COVID-19 in an under-resourced region in Brazil: a retrospective cohort study.

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Abstract

Background: The pandemic represented a great stimulus for the adoption of telehealth, but data addressing its effectiveness over clinical outcomes are scarce.

Objective: This study aimed to evaluate the impact of a telehealth service on hospital admission and mortality of patients with flu syndrome in the context of COVID-19 pandemic.

Methods: A natural experiment was conducted in two Brazilian cities where a public COVID-19 telehealth service (TeleCOVID-19) was deployed. TeleCOVID-MG was a structured multilevel telehealth service, including (1) first response and risk stratification through both a chatbot software or a phone call center; (2) teleconsultations with nurses and medical doctors and (3) a telemonitoring system. It was included patients diagnosed with flu syndrome between June 1st 2020 and May 31th 2021. Sociodemographic, comorbidities and clinical outcomes data were extracted from the Brazilian official databases for Flu Syndrome, Severe Acute Respiratory Syndrome, and Mortality. Models for the clinical outcomes were estimated by logistic regression.

Results: The final study population comprised 82,182 adult patients with a valid registry at the Flu Syndrome notification system. When compared to patients who did not use the service (n=67,689, 82.4%), patients supported by TeleCOVID-MG (n=14,493, 17.6%) had a lower chance of hospitalization during the respiratory illness course, even after adjusting for sociodemographic and underlying medical conditions, (OR=0.82; 95% CI 0.71-0.94; P=.005). No difference in mortality was observed (OR=0.99; 95% CI 0.86-1.12; P=.829).

Conclusions: A telehealth service applied on a large scale in resource limited region to tackle COVID-19 was related to reduced hospitalizations without increasing the mortality. High-quality health care using inexpensive and readily available telehealth and digital health tools can be useful even in places with limited resources and low digital literacy.

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Running title: Telehealth may reduce hospital admissions of COVID-19 patients.

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Keywords: COVID-19; telehealth; health care; clinical outcomes; hospital admission; mortality

Abstract

Background: The COVID-19 pandemic represented a great stimulus for the adoption of telehealth and many initiatives in this field have emerged worldwide. However, despite this massive growth, data addressing its effectiveness over clinical outcomes are still scarce.

Objective: This study aimed to evaluate the impact of the adoption of a structured multilevel telehealth service on hospital admission during the acute illness course and mortality of adult patients with flu syndrome in the context of COVID-19 pandemic.

Methods: A retrospective cohort study was conducted in two Brazilian cities where a public COVID-19 telehealth service (TeleCOVID-MG) was deployed. TeleCOVID-MG was a structured multilevel telehealth service, including (1) first response and risk stratification through both a chatbot software or a phone call center; (2) teleconsultations with nurses and medical doctors and (3) a telemonitoring system. The present analysis included adult patients registered in the Flu Syndrome notification databases diagnosed with flu syndrome between June 1st 2020 and May 31th 2021. The exposed group was composed of patients with flu syndrome who used, at least one time, the TeleCOVID-MG during the illness course and the control group was formed of patients who did not use this telehealth service during the respiratory illness course. Sociodemographic, comorbidities and clinical outcomes data were extracted from the Brazilian official databases for Flu Syndrome, Severe Acute Respiratory Syndrome, and Mortality. Models for the clinical outcomes were estimated by logistic regression.

Results: The final study population comprised 82,182 adult patients with a valid registry at the Flu Syndrome notification system. When compared to patients who did not use the service (n=67,689, 82.4%), patients supported by TeleCOVID-MG (n=14,493, 17.6%) had a lower chance of hospitalization during the acute respiratory illness course, even after adjusting for sociodemographic and underlying medical conditions, (OR=0.82; 95% CI 0.71-0.94; *P*=.005). No difference in mortality was observed (OR=0.99; 95% CI 0.86-1.12; *P*=.829).

Conclusion: A telehealth service applied on a large scale in a limited resource region to tackle COVID-19 was related to reduced hospitalizations without increasing the mortality. Quality health care using inexpensive and readily available telehealth and digital health tools may be delivered in places with limited resources and should be considered as a potential and valuable health care strategy. The success of the telehealth initiative relies on a partnership between the involved

stakeholders to define the roles and responsibilities, to set an alignment between the different modalities and levels of health care and to address the usual drawbacks related to the implementation process, such as infrastructure and accessibility issues.

Introduction

The COVID-19 pandemic has accelerated the adoption of telehealth in outpatient settings [1]. The demands generated by the pandemic, such as the need for social distancing and home isolation in an effort to reduce virus spread and infection rates, the necessity to decrease the pressure on overwhelmed health systems, and to increase the health care providers' safety determined the scaled-up use of telehealth tools worldwide [2].

Taking these new challenges into account, the Telehealth Network of Minas Gerais (TNMG), one of the largest public telehealth services in Latin America, developed a synchronous teleconsultation and telemonitoring service to assist patients with suspected or confirmed COVID-19 [3,4]. This service is named TeleCOVID-MG and it was first deployed in two Brazilian medium-sized cities and then it was expanded to assist all the community of Universidade Federal de Minas Gerais (UFMG), a large public Brazilian university [3].

Although many telehealth services were developed and implemented during the pandemic context, data addressing the clinical effectiveness of the use of a telehealth service for the health assistance of patients with respiratory symptoms are scarce [5-6]. Most of the available studies have focused on different outcomes such as user satisfaction, system usability, and emotional comfort [3,5]. There is a lack of studies analyzing the impact of telehealth services on more objective outcomes, such as hospitalization and mortality rates, compared to the standard health care support, which is usually delivered in an in-person way. Moreover, the studies that do exist in this regard often show small samples and conflicting results [6].

Casariego-Vales and their team have conducted a study to assess the effectiveness of a proactive telemonitoring approach for patients with COVID-19. The study was conducted in the northwest region of Spain during the third wave of the pandemic. The results have shown that the patients who underwent a systematic telemonitoring program, which included different intensities of approaches tailored to the patient risk for adverse outcomes, presented lower rates of emergency department visits and hospitalization as compared to the patients who did not undergo

this systematic telemonitoring program. Additionally, these systematically telemonitored patients presented shorter hospital stays and a lower mortality rate during their first hospitalization [7].

In Michigan, United States, a study has examined the impact of a telehealth intervention which was a nurse-led, telephone-based active management protocol for individuals with COVID-19 who were in home isolation. Although the intervention group has shown a lower rate of hospitalization within 30 days compared to the control group, this result was not statistically significant [8].

In order to bring additional information on this regard, the main goal of this study was to evaluate the impact of the adoption of a structured multilevel telehealth service, including teleconsultation and telemonitoring services and digital health tools, on relevant clinical outcomes, like hospital admission and mortality, compared to the outcomes presented by the patients with flu syndrome who did not use the telehealth service during the respiratory illness course in a limited resource region, where the TeleCOVID-MG was deployed.

Methods

The TeleCOVID-MG service

The TeleCOVID-MG was developed by the TNMG, which represents a telehealth network created in 2005 through a partnership between seven public Universities of Minas Gerais State, in the Southeast region of Brazil. TNMG is a large telehealth service in Brazil and develops different activities in clinical support, research, and tele-education [9].

Soon after the first diagnosis of COVID-19 was confirmed in Brazil, the multidisciplinary team of the TNMG, including physicians with expertise in telemedicine, infectious diseases specialists, nurses, managers, and information technology specialists started to develop the TeleCOVID-MG system, according to the issued World Health Organization (WHO) and Brazilian Ministry of Health Guidelines for COVID-19. Based on these guidelines and other available scientific evidence about COVID-19, instructional material was developed for training the TeleCOVID-MG team. As new scientific evidence emerged, the system and the instructional material were updated. TeleCOVID-MG was a structured multilevel telehealth service, including teleconsultation and telemonitoring

services and digital health tools (chatbot) [10]. TeleCOVID-MG software runs on a web environment, which allows the full recording of all the activities [3,4]. TeleCOVID-MG structured database with collected data was used for this study.

The service was first implemented in two Brazilian cities, Divinópolis and Teófilo Otoni, in May 2020. After the implementation in these cities, the service was expanded in November 2020 to assist the faculty, public servants, and students of the UFMG. The service provided health support for Divinópolis and Teófilo Otoni populations until December 2021 and for the UFMG community until March 2023. TeleCOVID-MG was offered to the whole population of these cities and users were not charged for using it.

TeleCOVID-MG was built to work through the intersection of four different levels, as described elsewhere [3]. Level 1 represents the user's gateway to the service, which is done via a chatbot developed by the TNMG team or through a special telephone call center [10]; level 2 represents the nursing staff; level 3 represents the medical staff; and level 4 represents the telemonitoring service, conducted by medical students under supervision. Every health professional and medical student in the program was extensively trained to use the TeleCOVID-MG system and to provide health assistance to the patients, as previously described [3,4]. The informed consent was obtained from all the patients who used the TeleCOVID-MG service.

At level 1, the screening and risk stratification of the patient with respiratory complaints was conducted by the chatbot software or by professionals of the call center who were trained for the task, and it was performed through a list of questions elaborated drawing on the best available evidence [10]. According to the severity of the symptoms and the comorbidities, the patient was sent to teleconsultation with the nursing staff, at level 2, or with the medical staff, at level 3. At the end of this teleconsultation, the health professional could advise the patient to keep home isolation or to seek onsite evaluation at a primary care center or an emergency unit. In addition to carrying out teleconsultations, the TeleCOVID-MG system allowed the health professionals to issue prescriptions, reports, and orders for diagnostic COVID-19 tests. All these documents could be easily downloaded by the users. The software also enabled the generation of the compulsory report of COVID-19 suspect or confirmed cases, in compliance with requirements by the Brazilian Health Ministry [3,4].

All patients who were assessed by the nursing or medical teams at levels 2 and 3 were included in the telemonitoring program, which provided support to them for at least ten days after

the onset of respiratory symptoms. This telemonitoring service was delivered through a phone call and the patients with no alarm signs or decompensated comorbidities were monitored every 48 hours, while the patients with alarm signs and/or decompensated comorbidities were monitored every 24 hours. Undergraduate medical students from the local universities working under the supervision of a physician or a nurse composed the telemonitoring team [3,4].

There was also a nurse or a physician to supervise and give support to the level 2 and 3 professionals, respectively. All the supervisors were trained for the task and were available for clinical discussions and doubts clarification during the entire teleconsultation and telemonitoring duties. It is important to reinforce that, according to the clinical course of illness presented by the patient, a professional of any level, at any time, might request an evaluation by the staff of another level.

Finally, it is worth emphasizing that, during all the period the TeleCOVID-MG was kept in operation, a periodic and open dialogue was maintained with the local health managers to define the roles and responsibilities of the stakeholders and to set an alignment between the different modalities and levels of health care.

Study design and procedure

A retrospective cohort study was conducted with adult patients (≥18 years old) from Divinópolis and Teófilo Otoni Flu Syndrome compulsory notification databases who were registered between June 1st 2020 to May 31th 2021. The Divinópolis and Teófilo Otoni Flu databases include patients who live and/or have received health support during the illness course in one of these two cities.

The exposed group (TeleCOVID-MG group) was composed of the registered patients with flu syndrome who used, at least one time, the TeleCOVID-MG during the illness course and the unexposed group (control group) was formed of patients who did not use this telehealth service during the respiratory illness course. The main outcomes investigated were hospital admission during the acute respiratory illness course and mortality.

Divinópolis and Teófilo Otoni are both medium-sized cities. Divinópolis has higher demographic density and human development index (HDI), and better socioeconomic, educational and health indicators compared to Teófilo Otoni (Table 1) [11,12].

Table 1. Sociodemographic, economic, educational and health indicators of Divinópolis and Teófilo Otoni compared to Brazil's indicators [11,12]

	Divinópolis	Teófilo Otoni	Brazil
Sociodemographic indicators			
Population (n) - 2022	231,091	137,418	203,062,512
Demographic density (inhabitants/ km^2) - 2022	326.35	42.38	23.86
Human Development Index - 2010	0.764	0.701	0.760
Economic indicators			
Gross Domestic Product (R$) - 2020	29,331.04	19,873.45	35,935.74
Employed population rate (%) - 2020	27.4	22.1	28.4
Average monthly salary of formal workers in minimum wages (R$) - 2021	2.1	1.8	2.3
Educational indicators			
Schooling rate from 6 to 14 years old (%) - 2010	98.6	96.6	97.9
Basic Education Development Index - early years of elementary school - 2021	6.5	5.5	5.5
Health indicators			
Infant mortality rate (per 1,000 live births) - 2020	9.13	13.66	11.20
Number of physicians per 1,000 inhabitants - 2022	3.16	1.97	2.38
Households with sanitary sewage (%) - 2010	90.1	77.1	63.2

Data acquisition

The data used in the analysis were extracted from four different databases: (1) TeleCOVID-MG database; (2) Flu Syndrome compulsory notification database; (3) Severe Acute Respiratory Syndrome (SARS) compulsory notification database; (4) Mortality Information System (MIS) database. Although the three last are public databases, access to the identified data of the Flu syndrome and SARS databases was obtained upon a request to the municipal governments. In contrast, access to the identified data of the MIS database was solicited from the federal government.

The Flu Syndrome database is composed of the compulsory notification of patients with flu syndrome; the SARS database is composed of the compulsory notification of the patients who were admitted to the hospital with SARS; the MIS database is composed of the compulsory registration of the deaths of the Brazilian citizens. Flu syndrome is defined by the Brazilian Health Ministry as the occurrence of an acute respiratory illness characterized by the presence of at least two of the following symptoms: fever, chills, sore throat, headache, cough, runny nose, smell, or taste

disturbances. SARS is defined by the Brazilian Health Ministry as the occurrence of flu syndrome and at least one of the following symptoms: oxygen saturation below 95% (room air), dyspnea, persistent pressure or pain in the chest, cyanosis of the lips or face [13].

It is important to remark that the notification of flu syndrome and SARS can be made by any health professional at any level of health care. The patient's data necessary for filling up all the notification documents are standardized, but not all the fields are mandatory.

Data regarding hospital admission due to acute respiratory illness was obtained from the SARS database. In order to get more accurate mortality data, this register was extracted from all the three public databases. Identifying the patient's death in at least one of those databases was enough to characterize the final clinical outcome as "death". It is important to remark that, for the mortality analysis, all the deaths that occurred throughout the study period have been considered, regardless of their primary causes.

Potential cofounders used as adjustment variables included city of flu syndrome notification, age, sex and underlying medical conditions, such as chronic respiratory diseases, chronic cardiovascular diseases, diabetes, chronic kidney disease, immunosuppression, high risk pregnancy and chromosomal diseases. These data were extracted from the Flu Syndrome database. Finally, the linkage between the four databases was made using the patient's name and the number of his individual taxpayer register.

This manuscript was written according to the STROBE guidelines for reporting observational studies [14].

Statistical analysis

Statistical analyses were performed in three steps: (i) descriptive, (ii) bivariate (evaluation of the association of the outcome with each variable of interest) and (iii) multivariate analyses.

Descriptive analyses were run to summarize all variables, stratified into exposed and unexposed groups. Categorical variables were summarized by absolute and relative frequencies (sex, city of flu syndrome notification, city of residence, underlying medical conditions, and clinical outcomes). The Shapiro-Wilk normality test was performed to determine whether the continuous variable was normally distributed (age). This variable was found to have a non-normal distribution, so it was summarized using median and interquartile range (IQR). The variables included in this study were not missing.

In the bivariate analysis, demographics, city of flu syndrome notification, underlying medical conditions, and clinical outcomes were assessed using Chi-square test to compare proportions. The Wilcoxon rank sum test was used to compare medians of continuous variables.

Models for the primary outcomes were estimated by logistic regression; the shaping process of the prediction models divided variables into four blocks by adopting a forward approach, mutually inserted in the regression models one to four. As the primary goal of the analysis was to identify the association of TeleCOVID-MG service with the clinical outcomes (mortality and hospital admission during acute respiratory illness course), this variable was tested in all four models. The first one included TeleCOVID-MG service only. The second added city of flu syndrome notification; the third added sex and age; and the fourth added the underlying medical conditions. For the regression models, odds ratio (OR) and their respective 95% confidence interval (CI) were estimated.

Concerning the choice of variables, we have considered the current recommendations of Steyerberg and Harrell [15,16]. For these authors, it is better to use subject matter knowledge than statistical methods for variable selection. In this strategy, significance testing of adjustment variables is not necessary, especially if subject-specific knowledge supports the estimated effects [14, 15]. Thus, we grouped variables parsimoniously in blocks, aggregating variables mode distal to more proximal ones: geography (cities), biological features (age and sex), and clinical predisposing features (underlying medical conditions).

All analyses were performed in the R software (version 4.0.2) with the tidyverse, lubridate, stringi, rlang, jsonlite, Rcurl, writexl, openxlsx, and readxl and lmtest packages. The *P-value* < .05 was considered statistically significant.

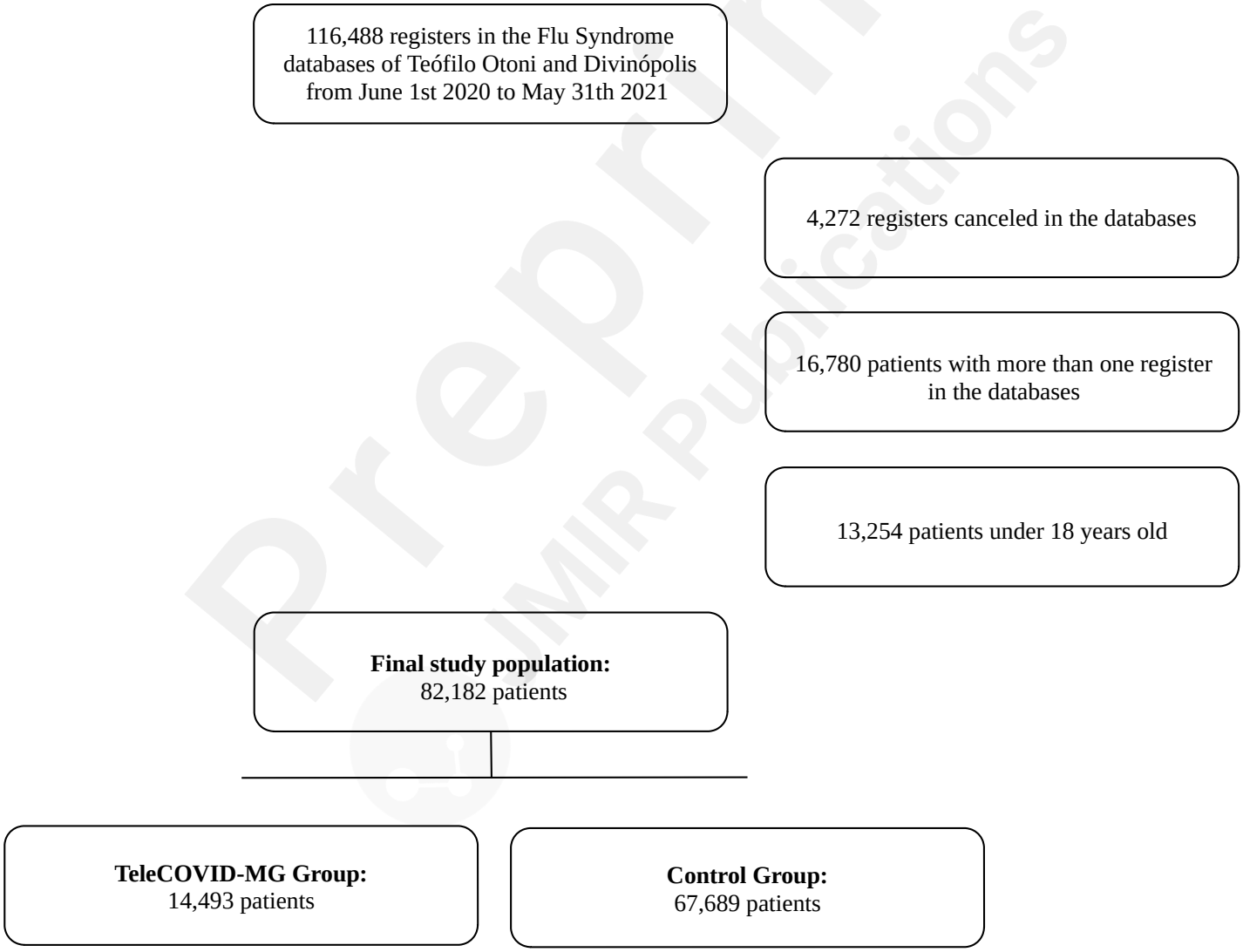
Ethical Statement

Ethical approval for this research was obtained from the Federal University of Minas Gerais' Research Ethics Committee (CAAE: 35953620.9.0000.5149). Informed consent was provided by all the patients who were supported by the TeleCOVID-MG service. The researchers signed up a confidentiality term to access the identified data of the public databases. After the linkage of the databases, data was de-identified for the analysis. No compensation was provided for the research participants.

Results

Throughout the analyzed period, 116,488 registers were found in the Flu Syndrome notification system of Teófilo Otoni and Divinópolis. Of those, 4,272 registers were canceled in the database, 16,780 patients had more than one register and 13,254 patients were under 18 years old. So, the final study population was composed of 82,182 patients (Figure 1). For the analysis, it was used the first register of the patient in the Flu Syndrome database and all the included variables were not missing.

Figure 1. Flowchart of patient's inclusion



Among the included patients, 14,493 (17.6%) used the TeleCOVID-MG service at least one time during the illness course (TeleCOVI-MG group) and the other 67,689 (82.4%) did not receive any kind of telehealth support by the TeleCOVID-MG (control group). The sociodemographic and clinical characteristics of the patients are described in Table 2.

Table 2. Sociodemographic and clinical characteristics of the patients

	Overall	TeleCOVID-MG Group	Control group	*P*-value[a]
	n=82,182	n=14,493 (17.6%)	n=67,689 (82.4%)	
Age, years - median (IQR)	38 (28 - 51)	37 (27 - 49)	39 (29 - 51)	<.001
Women - n (%)	44,847 (54.6%)	8,854 (61.1%)	35,993 (53.2%)	<.001
City of flu syndrome notification				<.001
Divinópolis - n (%)	46,313 (56.4%)	3,662 (25.3%)	42,651 (63.0%)	
Teófilo Otoni - n (%)	25,276 (30.8%)	6,269 (43.3%)	19,007 (28.1%)	
Other - n (%)	10,593 (12.9%)	4,562 (31.5%)	6,031 (8.9%)	
City of residence				<.001
Divinópolis - n (%)	47,507 (57.8%)	6,091 (42.0%)	41,416 (61.2%)	
Teofilo Otoni - n (%)	27,232 (33.1%)	8,205 (56.6%)	19,027 (28.1%)	
Other - n (%)	7,443 (9.1%)	197 (1.4%)	7,246 (10.7%)	
Underlying medical conditions				
Chronic respiratory diseases - n (%)	1,272 (1.5%)	253 (1.7%)	1,019 (1.5%)	.034
Chronic cardiovascular diseases - n (%)	2,794 (3.4%)	581 (4.0%)	2,213 (3.3%)	<.001
Diabetes - n (%)	2,107 (2.6%)	448 (3.1%)	1,659 (2.5%)	<.001
Chronic kidney disease - n (%)	203 (0.2%)	20 (0.1%)	183 (0.3%)	.004
Immunosuppression - n (%)	431 (0.5%)	82 (0.6%)	349 (0.5%)	.448
High risk pregnancy - n (%)	407 (0.5%)	103 (0.7%)	304 (0.4%)	<.001
Chromosomal diseases - n (%)	139 (0.2%)	28 (0.2%)	111 (0.2%)	.437
Clinical outcomes				
Hospital admission - n (%)	1,980 (2.4%)	269 (1.9%)	1,711 (2.5%)	<.001
Death - n (%)	1,978 (2.4%)	299 (2.1%)	1,679 (2.5%)	0.003

[a]Pearson's Chi-squared test; Wilcoxon rank sum test

The TeleCOVID-MG group had a median age two years lower than the control group (39 vs. 37 years), higher frequency of women (61.1% vs 53.2%), and a slightly higher frequency of diabetes (3.1% vs 2.5%), chronic respiratory (1.7% vs. 1.5%) and cardiac diseases (4.0% vs. 3.3%), as well as high risk pregnancy (0.7% vs. 0.4%, $P < .05$ for all).

With regards to outcomes, the TeleCOVID-MG group had a lower frequency of hospital admission (1.9% vs. 2.5%, $P < .001$) and mortality (2.1% vs. 2.5%, $P = .003$) than the control group (Table 2).

Among the included patients who were accessed through the TeleCOVID-MG system during the illness course, 197 (2.0%) were advised to seek an onsite evaluation at a primary care center and 407 (4.1%) at an emergency department. The other 9,327 (93.9%) were advised to keep domiciliary

isolation and were monitored by the TeleCOVID-MG team.

In regression for hospital admission during the acute illness course, the telehealth intervention remained associated with a lower chance of hospitalization after adjusting for sociodemographic variables and underlying medical conditions (Table 3). In the fully-adjusted model (fourth model), there was a lower chance of hospitalization in patients who used the TeleCOVID-MG service (OR=0.82, 95% CI 0.71-0.94, *P* = .005) and a greater chance of this outcome among the patients in whom flu syndrome notification was reported in Teófilo Otoni (OR=1.5), men (OR=1.77), and patients with the following diseases: chronic cardiovascular disease (OR=1.35), diabetes (OR=1.83), chronic kidney disease (OR=2.18), immunosuppression (OR=1.87) and high pregnancy risk (OR=3.32) (Table 3).

Table 3. Predictors of hospital admission by logistic regression model

	OR (95% CI)	***P*-value**
Mode1		
TeleCOVID-MG group	0.73 (0.64-0.83)	<.001
Model 2		
TeleCOVID-MG group	0.64 (0.56-0.73)	<.001
City of flu syndrome notification (Teófilo Otoni)	1.58 (1.44-1.73)	<.001
Model 3		
TeleCOVID-MG group	0.85 (0.74-0.97)	.019
City of flu syndrome notification (Teófilo Otoni)	1.42 (1.29-1.56)	<.001
Male sex	1.75 (1.59-1.92)	<.001
Age	1.07 (1.07-1.08)	<.001
Model 4		
TeleCOVID-MG group	0.82 (0.71-0.94)	.005
City of flu syndrome notification (Teófilo Otoni)	1.50 (1.36-1.65)	<.001
Male sex	1.77 (1.61-1.95)	<.001
Age	1.07 (1.07-1.07)	<.001
Chronic respiratory diseases	1.14 (0.85-1.52)	.368
Chronic cardiovascular diseases	1.35 (1.15-1.58)	<.001
Diabetes	1.83 (1.54-2.17)	<.001
Chronic kidney disease	2.18 (1.34-3.43)	.001
Immunosuppression	1.87 (1.25-2.73)	.002
High risk pregnancy	3.32 (1.29-6.96)	.005
Chromosomal diseases	1.33 (0.63-2.54)	.417

OR: odds ratio; CI: confidence interval

In regression for mortality (Table 4), the telehealth support showed a reduction in the chance of death in the model with the telehealth intervention alone (OR=0.83, 95% CI 0.73-0.94, *P* = .003) and in the model 2, that included the city of flu syndrome notification (OR=0.79, 95% CI 0.69-0.89, *P* < .001). However, in the models 3 and 4, which included gender, age, and underlying medical conditions, the OR values were close to 1.0. After the inclusion of all variables, age (OR=1.06), Teófilo Otoni as the city of flu syndrome notification (OR=1.12), male gender (OR=1.52), and having chronic cardiovascular diseases (OR=1.34), diabetes (OR=1.51), immunosuppression (OR=2.37), chromosomal diseases (OR=2.37) remained associated with a greater chance of death due to flu syndrome (Table 4).

Table 4. Predictors of mortality by logistic regression model

	OR (95% CI)	***P*-value**
Model 1		
TeleCOVID-MG group	0.83 (0.73-0.94)	.003
Model 2		
TeleCOVID-MG group	0.79 (0.69-0.89)	<.001
City of flu syndrome notification (Teófilo Otoni)	1.2 (1.09-1.32)	<.001
Model 3		
TeleCOVID-MG group	1.01 (0.89-1.15)	.852
City of flu syndrome notification (Teófilo Otoni)	1.07 (0.97-1.18)	.162
Male sex	1.5 (1.37-1.65)	<.001
Age	1.07 (1.06-1.07)	<.001
Model 4		
TeleCOVID-MG group	0.99 (0.86-1.12)	.828
City of flu syndrome notification (Teófilo Otoni)	1.12 (1.02-1.24)	.020
Male sex	1.52 (1.38-1.66)	<.001
Age	1.06 (1.06-1.07)	<.001
Chronic respiratory diseases	1.28 (0.96-1.67)	.078
Chronic cardiovascular diseases	1.34 (1.14-1.57)	<.001
Diabetes	1.51 (1.26-1.8)	<.001
Chronic kidney disease	2.28 (1.41-3.54)	<.001
Immunosuppression	2.37 (1.63-3.34)	<.001
High risk pregnancy	2.02 (0.71-4.45)	.125
Chromosomal diseases	2.37 (1.28-4.1)	.004

OR: odds ratio; CI: confidence interval

Discussion

Principal results

In an effort of avoiding virus spread, preserving home isolation and protecting health care professionals of a potential SARS-CoV-2 contamination, multiple telehealth initiatives had emerged worldwide [1,17,18]. Along with the large adoption of telehealth tools in the pandemic context, concerns about usability, safety, costs, and efficacy related to this innovative practice have emerged. In this retrospective cohort study, it was investigated the impact of the adoption of a structured multilevel public COVID-19 telehealth service on hospital admission and mortality, compared to the outcomes presented by patients who did not use the studied telehealth service. It has been demonstrated a lower chance of hospitalization during the acute illness course in the TeleCOVID-MG group, even after adjusting for sociodemographic and underlying medical conditions, and no difference in mortality between the groups.

The COVID-19 pandemic brought an extra challenge for providing quality health assistance and this was particularly important for countries like Brazil, with large dimensions and significant health inequities [9,19]. In places like that, telehealth solutions become even more attractive and knowing that remote health services have the potential to provide high-quality health assistance is valuable information for health managers to better plan health interventions.

Moreover, in addition to the clinical outcomes reached using the structured multilevel public COVID-19 telehealth service, it is reasonable to consider that this telehealth initiative contributed to achieve other important outcomes that were not measured in this study. Providing remote health support to the patients who did not need to seek an onsite evaluation in most situations, the telehealth service probably contributed to decrease contamination rates and to increase health professionals' safety, that are important outcomes that should be considered in future research in this field.

There are different issues regarding the deployment of a telehealth service that must be carefully examined like costs, professional and patient acceptance and satisfaction, technology availability, and data safety. Regarding the costs, there is a large body of evidence that telehealth initiatives are cost-saving in different scenarios and, specifically about COVID-19, our group has already demonstrated that the TeleCOVID-MG service increased the access to healthcare and was an economically attractive strategy [20-24]. Regarding the acceptance and the availability of the technology, it is important to remark that teleconsultation was not regulated in Brazil before March 2020 and TeleCOVID-MG was a pioneer in providing this kind of service to the population [25]. Around 17.6% of the adult population with respiratory symptoms in the two studied cities have used the service during the analyzed period and, in contrast to our initial concerns about the patient acceptance, we consider this utilization rate a promising kickoff. Compared to other telehealth

services described in literature that demonstrate higher utilization rates [26], this COVID-19 teleconsultation service was offered in a medium-income country, for a population with a low digital literacy level and no culture of using telehealth services. So, the results of this study are important to demonstrate that, in specific scenarios, it is possible to offer high-quality health care using inexpensive and readily available technology in places with limited resources and low digital literacy. However, it is important to remark that the success of the telehealth initiatives in achieving good adoption and positive clinical results also relies on the agreements performed with the local health managers and on the integration of this modality of care with the in-person health care in their different levels. Keeping the partnership is essential to solve the usual drawbacks we find on the way of a telehealth program implementation, like infrastructure and accessibility issues, and to renegotiate the roles and responsibilities of the stakeholders whenever necessary.

Finally, with the increasing use of technology worldwide, the use of telehealth tools is becoming more feasible, legislations in this regard are being reviewed or created and growing evidence about professional and user acceptance and usability are being published [26-29]. It seems that the use of telehealth tools is in a one-way direction, without return. So, scientific efforts must be done to clarify even more their potentials and limitations.

Comparison with prior work

A large amount of evidence in different fields of telehealth has been produced, but data regarding the clinical efficacy of this practice in COVID-19 field are still scarce [5,6]

A systematic review of 64 studies focusing on telehealth-based services for COVID-19 [5] revealed that only two studies have measured mortality as an outcome, but none of them has included control groups in their methods [30,31]. Another systematic review prepared by the Johns Hopkins University Center for Evidence-Based Practice evaluated the use of telehealth during the pandemic in different settings, but no comparative studies on the effectiveness of COVID-19 telehealth programs in reducing mortality were available [6]. Regarding the comparison of hospitalization rates between patients who were assisted by a specific COVID-19 telehealth program during the illness course and patients who did not receive the telehealth support, there were only two studies available, with conflicting results [7,8]. Considering the sample sizes of both studies and the follow-up length, the conclusion of the systematic review was that, among the patients who received care for COVID-19, those who received an initial telehealth visit might have higher hospitalization rates compared with those who received in-person care (strength of evidence: low). This statement is

open to be discussed as the primary study responsible for this conclusion in the systematic review presents additional information and results [7]. Although the primary study really indicates that a high-intensity and protocolized telemonitoring program is related to higher hospitalization rates, this result was predictable, as the intensity of the telemonitoring actions was tailored to the risk of the patients to present adverse outcomes. On the other hand, considering all the patients who were included in the study, the comparison between the groups showed that those who underwent to a systematic telemonitoring program, which was tailored to the age and to the clinical characteristics of the patients, presented lower rates of hospital admissions than the patients who did not undergo to the systematic telemonitoring program for COVID-19. For instance, our results are consistent with this study, since both have demonstrated that a systematic telehealth support provided through widely available technology can reach positive clinical outcomes and underscored the potential of its utilization as part of a comprehensive healthcare strategy.

It is worth emphasizing that both studies included in the systematic review were conducted in high-income countries and presented a shorter follow-up (68 days and 30 days) [7,8]. In contrast, the present study evaluated the clinical effectiveness of a structured multilevel public COVID-19 telehealth in a limited resource region and included 82,182 patients, who were followed-up for one year. In this pioneering analysis, which spans an extended duration and involves a significant number of patients, the findings highlighted that embracing a public COVID-19 telehealth service yielded a positive impact over hospital admissions without increasing mortality.

Limitations

The most important limitation of this study is related to the data quality of the public databases we have used in the analysis, mainly regarding the comorbidities, the socio-economic status and the ethnicity of the included patients.

Regarding the comorbidities, although this data is not missing, there is no orientation about the proper definition of each comorbidity. As the notification fields can be filled up by any health professional, the understanding about each comorbidity may vary. The last Brazilian survey shows a prevalence of self-reported hypertension of 23.9% in the adult population, while the estimated prevalence of self-reported diabetes is 7.7% [32]. Our data shows lower comorbidities prevalence. The registered prevalence of chronic cardiovascular diseases was 3.4% and of diabetes was 2.6% in the studied population. Despite this limitation, data misfiling probably occurred in both groups in the

same fashion.

Regarding the socio-economic status and the ethnicity of the patients, that could bring additional information for the results, as this data is missing, it was not included in the analysis. However, it is important to remark that, since the TeleCOVID-MG was a public and free of charge service, most patients supported by this telehealth program did not have a private health insurance.

Conclusions

Despite the massive growth of telehealth initiatives during the pandemic, data regarding the clinical effectiveness of this approach targeting flu syndrome is still lacking [5,6]. This is a retrospective cohort study conducted in a limited resourced region to evaluate the impact of the adoption of a public structured multilevel COVID-19 telehealth service over relevant clinical outcomes present by adult patients with flu syndrome, in comparison with the standard health assistance currently provided, which is primarily delivered in an in-person way. This study demonstrates that a structured multilevel COVID-19 telehealth adopted in a large scale can contribute to decrease the hospital admissions, without increasing the mortality, and may be considered as a potential and valuable health care strategy, even in places with limited resources. The success of the telehealth initiatives relies on a partnership between the involved stakeholders to coordinate actions within an established health care plan that addresses the specificities of the different target populations.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author (Oliveira CRA). The data are not publicly available due to restrictions related to the confidentiality and privacy of the research participants.

Use of Generative Artificial Intelligence (AI) Disclosure

The authors declare that generative AI was not used in any portion of the manuscript writing.

Conflicts of Interests Disclosure

The authors declare that there is no conflict of interest.

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Abbreviations

TNMG: Telehealth Network of Minas Gerais
UFMG: Universidade Federal de Minas Gerais
SARS: Severe Acute Respiratory Syndrome
OR: odds ratio
CI: confidence interval
AI: Artificial Intelligence

Authorship Contribution Statement

Oliveira CRA and Ribeiro ALP coordinated the research; Oliveira CRA, Pires MC, Meira KC, Jesus JC, Paixão MC, Mendes MS, Ribeiro LB, Alkmim MBM and Ribeiro ALP obtained and organized the data; Oliveira CRA, Pires MC, Meira KC, Jesus JC, Borges IN, Ribeiro LB, Marcolino MS and Ribeiro ALP analyzed the data; Oliveira CRA, Meira KC, Jesus JC, Borges IN and Marcolino MS drafted the manuscript; all authors reviewed and edited the manuscript; all authors approved the final version.

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Supplementary Files

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