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ORIGINAL ARTICLE

Implementation of Tele-ICU during the COVID-19 pandemic

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ABSTRACT

Objective: To describe the implementation of a Tele-ICU program during the COVID-19 pandemic, as well as to describe and analyze the results of the first four months of operation of the program. **Methods:** This was a descriptive observational study of the implementation of a Tele-ICU program, followed by a retrospective analysis of clinical data of patients with COVID-19 admitted to ICUs between April and July of 2020. **Results:** The Tele-ICU program was implemented over a four-week period and proved to be feasible during the pandemic. Participants were trained remotely, and the program had an evidence-based design, the objective being to standardize care for patients with COVID-19. More than 100,000 views were recorded on the free online platforms and the mobile application. During the study period, the cases of 326 patients with COVID-19 were evaluated through the program. The median age was 60 years (IQR, 49-68 years). There was a predominance of males (56%). There was also a high prevalence of hypertension (49.1%) and diabetes mellitus (38.4%). At ICU admission, 83.7% of patients were on invasive mechanical ventilation, with a median PaO_2/FiO_2 ratio < 150. It was possible to use lung-protective ventilation in 75% of the patients. Overall, in-hospital mortality was 68%, and ICU mortality was 65%. **Conclusions:** Our Tele-ICU program provided multidisciplinary training to health care professionals and clinical follow-up for hundreds of critically ill patients. This public health care network initiative was unprecedented and proved to be feasible during the COVID-19 pandemic, encouraging the creation of similar projects that combine evidence-based practices, training, and Tele-ICU.

Keywords: Telemedicine; Critical care; Coronavirus infections; Patient care management.

INTRODUCTION

Prior to the current pandemic, the aging of the population and the steady increase in respiratory diseases had already alerted us to the need to mobilize technological resources and meet a growing demand for medical professionals trained in intensive care.[1] COVID-19, caused by the new coronavirus (SARS-CoV-2), was first identified in late 2019,[2,3] and there have since been millions of cases worldwide[4] and thousands of deaths in Brazil, which ranks third among the countries most affected by the pandemic.[5] Respiratory failure results in 10-25% of hospitalized patients requiring invasive mechanical ventilation (IMV).[6] The overall rate of IMV use in ICUs in Brazil has increased, from 22% before the pandemic to 48% at present.[7] The challenge of providing patient care during the pandemic has led to a discussion about the allocation of material and human resources.[6]

Through the application of telecommunications technology to health, telemedicine provides remote care. The use of telemedicine is strategic because it enables the exchange of knowledge between teams, as well as the training and education of multidisciplinary teams. Telemedicine also allows the auditing and monitoring of the processes involved in patient care.[8] The application of telemedicine to the care of critically ill patients shortens ICU stays, thereby increasing the availability of beds, and reduces overall in-hospital mortality.[9-12] During the pandemic, telemedicine was put forward as an option for the entire chain of care, from triage[13] to the dissemination of information—to health care teams providing patient care and to the general population.[14] In the state of New York, the epicenter of the pandemic in the United States, an existing telemedicine service was expanded, allowing telemetry of adverse events and facilitating bed management, as well as informing decisions regarding the management of material and human resources.[15] Even specialties not directly related to COVID-19, such as orthopedics, have implemented telemedicine to allow patient treatment during the pandemic.[8] In Brazil, telemedicine was approved by the Brazilian National Ministry of Health in Article 3 of Law no. 13,979, which was enacted on February 6, 2020, on an extraordinary and temporary basis during the pandemic period.

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Severe cases of COVID-19 progress to ARDS, the treatment of which is based on the adoption of lung-protective ventilation (LPV) strategies.[16,17] Nevertheless, the use of LPV strategies by health care professionals is still limited,[18] possibly because of their lack of knowledge about these strategies, inappropriate training, or lack of confidence in their ability to manage mechanical ventilators.[19-21]

The Respiratory ICU of the *Instituto do Coração* (InCor, Heart Institute) of the *Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo* (HCFMUSP, University of São Paulo School of Medicine *Hospital das Clínicas*) serves as a referral center for the treatment of severe respiratory cases and mechanical ventilation to public health care facilities in the state of São Paulo. The ICU team, in partnership with the *Secretaria de Estado da Saúde de São Paulo* (SES-SP, São Paulo State Department of Health), developed a treatment and training protocol for public ICUs in the state of São Paulo for use during the pandemic. The protocol focuses on interventions that are feasible via telemedicine: care of patients with suspected or confirmed COVID-19 respiratory failure; and training of multidisciplinary ICU teams during the pandemic.

The primary objective of the present article was to describe the implementation of a Tele-ICU program during the COVID-19 pandemic. The secondary objective was to describe and analyze the results of the first four months of operation of this new Tele-ICU program.

METHODS

Study description

This study describes the implementation of a Tele-ICU program, followed by a retrospective analysis of the clinical data of patients with COVID-19 admitted to the participating ICUs between April and July of 2020. The study was approved by the HCFMUSP Research Ethics Committee (Protocol no. 4.222.334). The Tele-ICU program was developed with the support and participation of the SES-SP.

Description of the treatment protocol

Specialists (in pulmonology, infectious diseases, clinical emergencies, and anesthesiology) at the HCFMUSP gathered and, after a review of the literature and consensus meetings, developed a treatment protocol for patients with COVID-19 ARDS and respiratory failure. The protocol was validated by the São Paulo State Coronavirus Contingency Center and was adopted by the SES-SP as the standard of care for the entire public health care network in the state.

The treatment protocol (see supplementary material) emphasizes the best practices in intensive care with an emphasis on LPV, suggesting a V_T of 6 mL/kg of ideal body weight, monitoring of plateau pressure, monitoring of driving pressure, and use of rescue maneuvers for patients with refractory hypoxemia. The protocol also recommends appropriate hand hygiene and use of personal protective equipment; proper selection of laboratory and imaging tests; use of fluids, antibiotics, and corticosteroids; prophylaxis of thromboembolic events; and weaning from IMV.

Implementation of the Tele-ICU program

The SES-SP elected the InCor-HCFMUSP Respiratory ICU (Agreement no. 20/2018) as the coordinating center of this Tele-ICU program for public hospitals in the state of São Paulo (SES TeleUTI Agreement no. 1140/2020).

The selection of hospitals to be invited to adopt the Tele-ICU program was made by the SES-SP, under the guidance of the São Paulo State Coronavirus Contingency Center, and was based on the incidence of patients with COVID-19 in their catchment area, those at which the incidence was highest being selected. The Tele-ICU program was implemented in two phases. Phase I included 9 hospitals, and phase II included an additional 11 hospitals. The participating hospitals are described in greater detail in Table S1 (supplementary material).

The InCor Information Technology Department developed its own platform, designated "iConf", which uses the main web conferencing resources of a commercial system, although under an open-source license (see supplementary material). On the iConf platform, all Tele-ICU data are stored on a server at InCor and are not shared with or handled by third parties, in compliance with the General Personal Data Protection Law (Law no. 13,853, which was enacted in 2019).

At InCor, the Tele-ICU program has a physical space consisting of rooms with two telemedicine stations each; in addition, there is a multidisciplinary room for data analysis and program planning, as well as a room for technical administrative support. At Incor and in the ICUs that participated in the Tele-ICU program, the telemedicine stations were set up with dual high-resolution monitors, a camera, an echo-canceling microphone, and an audio playback device. During the web conferencing sessions between health care professionals, the interaction between the teams was displayed on one of the monitors, whereas test results, materials of educational interest, and even a whiteboard for free writing were displayed on the other monitor (Figure S2, supplementary material).

In the last week of March, the final model of care was tested, and the Tele-ICU program began to operate fully on April 1, 2020. Teleconsultations occurred daily at predetermined times. Each telemedicine session between ICUs was planned to last about one hour, approximately 10 min being allocated to discuss each patient. In those discussions, a specialist physician at InCor helped collect clinical data for the purpose of diagnosis, discussed the findings, and recommended treatment in accordance with the protocol. Data

were then collected on a form that was structured and designed specifically for this Tele-ICU program, in accordance with the guidelines established by the REDCap Consortium.[22] The form, which was shared by the two ICU teams, ensured confidentiality. The selection of patients for discussion was the prerogative of the ICU team at the hospital where the patient was being treated.

Training of health care professionals and dissemination of the treatment protocol

The ICU teams selected to receive the Tele-ICU program were provided training by an InCor multidisciplinary team specializing in intensive care. Given the impossibility of face-to-face practical training during the pandemic, strategies were sought for diversifying the dissemination of knowledge, including distance training courses through video classes, tutorials, use of official portals, and adaptation of the protocol to mobile applications.

For the purpose of its wider dissemination, the treatment protocol for patients with COVID-19 was made available via free online platforms on the websites of the HCFMUSP *Escola de Educação Permanente* (EEP, School of Continuing Education; https://incor.eephcfmusp.org.br/course/index.php?categoryid=2) and of the SES-SP (http://eadses.saude.sp.gov.br/). Case discussion sessions were permeated with theoretical concepts, clarification was encouraged, and additional activities could be scheduled by video conference. The total duration of use of the distance education material on the platform was 25 h.

As support material for the training sessions and to facilitate patient care, a mobile application was made available for free.[23] The application included ideal body weight calculators for LPV, tutorials on oxygen therapy supplementation and forms of noninvasive mechanical ventilation, tutorials on orotracheal intubation, and a dose calculator for medications for rapid-sequence orotracheal intubation, as well as for dilutions of sedatives, analgesics, neuromuscular blocking agents, and vasoactive drugs.

Continuous assessment of the Tele-ICU program

The monitoring of the implementation of the Tele-ICU program aimed to improve health care professional performance in providing care. Performance and training indicators were chosen: number of discussions per teleconsultation; number of patients followed; number of canceled teleconsultations; mean number of patient discussions per visit; and number of clinical data forms completed. The analysis was sent to the hospital managers and to the SES-SP. If the result was below the target value, an action plan was agreed upon with the hospital manager and was reassessed in the following weeks. The initial goal was for 70% of teleconsultations to occur on the scheduled day, with a suggested daily average of three cases per teleconsultation. Another goal was to have < 20% of records with missing data that would preclude evaluation. Hospitals were contacted on a weekly basis to adjust these goals.

Data collection

The following patient clinical data were collected: age; gender; height; actual body weight; BMI; comorbidities[24]; pre-ICU admission functional status assessed on the basis of the ability to perform basic activities of daily living[25]; admission severity assessed by the Simplified Acute Physiology Score 3 (SAPS 3)[26]; and the use of intensive care therapies, such as vasoactive drugs, IMV, and hemodialysis. In addition, data were collected on length of ICU stay, LPV settings, duration of LPV, length of hospital stay, ICU mortality, and overall in-hospital mortality.

Data on training tools were collected up to July 31, 2020, as were data on the number of views on the EEP-HCFMUSP platform, number of health care professionals registered on the SES-SP platform, and number of users who downloaded the mobile application. Discharge from the ICU and hospital discharge were monitored up to August 28, 2020 for all patients admitted up to July 31 of that year.

Statistical analysis

The Shapiro-Wilk test was used in order to assess the distribution of continuous variables. Because those variables had a nonparametric distribution, they were expressed as median and IQR. Categorical variables were expressed as absolute and relative frequency.

This study followed the 2016 Standards for Quality Improvement Reporting Excellence, the goal of which is to improve the quality of studies.[27] All analyses were performed using the R software (R Core Team, 2017).

RESULTS

Structuring of the Tele-ICU network for the care of patients with COVID-19 began in April of 2020. The cost for installing the equipment was approximately R$10,000 (approximately US$1,850 as per the exchange rate in November of 2020) per participating hospital. The monthly cost of operating the service, including teleconsultations and multidisciplinary training, was R$20,000 per participating hospital (approximately US$3,700).

Between April and July of 2020, a total of 105,486 views were recorded on the EEP-HCFMUSP free online platform, and 3,484 distance learning course registrations were made on the SES-SP platform. The mobile application was installed by more than 3,000 users up to July of that year.

During the study period, the cases of 454 patients were discussed. Among those patients, the COVID-19 diagnosis was confirmed by RT-PCR in 326 (74%) and was excluded in 113. For the remaining 15 patients, there was insufficient information for analysis. The patient inclusion flow chart is presented in Figure 1.

Table 1 shows the demographic, clinical, and biochemical data at ICU admission and on the first day of Tele-ICU discussion, for the 326 COVID-19 patients treated during the study period. Table 1 also shows data on IMV, rescue maneuvers for hypoxemia, and tracheostomy. Of those 326 patients, 273 (83.7%) required IMV. With regard to IMV settings on the first day of Tele-ICU discussion, we found that the median V_T per kg of predicted ideal body weight was 6.1 mL/kg (5.6-6.9 mL/kg), the median plateau pressure was 25 cmH_2O (21-28 cmH_2O), and the median driving pressure was 13 cmH_2O (11-15 cmH_2O).

During the study period, ICU mortality was 65% and overall in-hospital mortality was 68%. ICU mortality decreased from 73.2% in April to 58.7% in July, and overall in-hospital mortality decreased from 73.2% in April to 64.8% in July. Considering only the patients who underwent IMV, we found that ICU mortality and overall in-hospital mortality were 76% and 78%, respectively. ICU mortality decreased from 88% in April to 67% in July, whereas overall in-hospital mortality decreased from 88% in April to 71% in July. The median SAPS 3 was 55 (49-67) in April, 54 (46-65) in May, 53 (47-61) in June, and 53 (45-62) in July.

Figure 2 shows the rates of ICU mortality and overall in-hospital mortality over the months evaluated. Figure 3 shows the length of ICU stays and overall hospital stays during the same period.

DISCUSSION

In March of 2020, a Tele-ICU program was implemented at InCor-HCFMUSP to meet the high demand for specialized resources for treating patients with COVID-19. The provision of training facilitated standardization of care for patients with COVID-19, as did the rapid dissemination of the treatment and LPV protocols to health care professionals. Over the study period, severity at admission, as assessed by the SAPS 3, remained similar, whereas ICU mortality and overall in-hospital mortality decreased, suggesting that, in addition to factors such as increases in scientific information and in clinical experience in the management of COVID-19 during that period, factors related to the provision of training and to Tele-ICU support may have contributed to those decreases. Between April and July, length of ICU stay decreased by 1 day and length of hospital stay decreased by 5 days.

The Tele-ICU program found solutions to diversify the method of dissemination of the treatment protocol through video classes, discussion forums on the distance learning platform, classes offered during teleconsultations, and use of the mobile application. These measures may have improved health care professional adherence to the LPV strategy and the observed result, as was suggested in a study showing improved clinical outcomes, increased adoption of good practices, and even cost reduction after educational activities through Tele-ICU.[28]

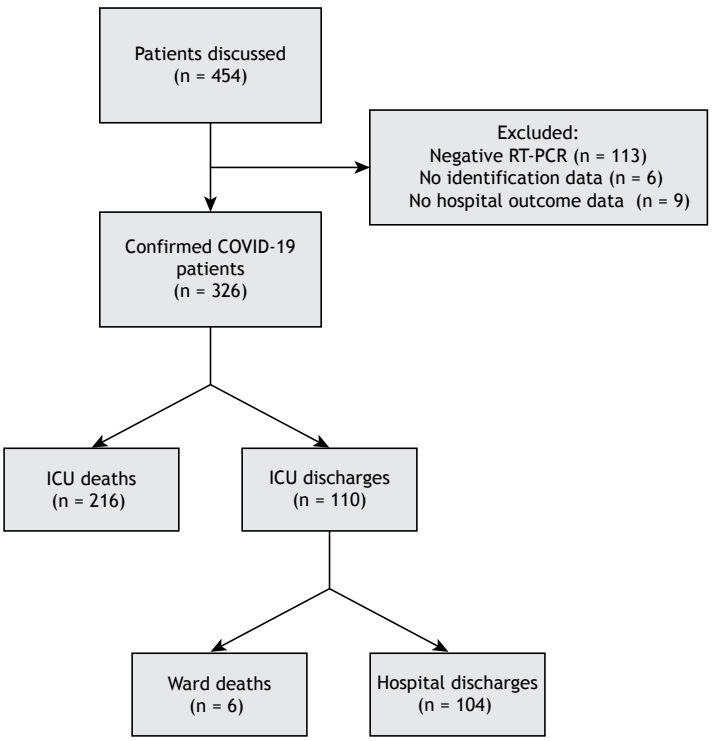

Figure 1. Flow chart of evaluation via the Tele-ICU program during the study period.

Table 1. Demographic, clinical, laboratory, and treatment characteristics, as well as data on the use of mechanical ventilation, at ICU admission and on the first day of Tele-ICU discussion, for the COVID-19 patients treated during the study period.[a]

Variable	N = 326
Age, years	60 [49-68]
Male gender	182 (56.0)
BMI, kg/m^2	27.7 [24.7-32.6]
Able to perform basic activities of daily living without assistance	265 (97.4)
SAPS 3	53 [47-64]
Comorbidities	
Hypertension	160 (49.1)
Diabetes	125 (38.4)
Obesity (BMI > 30 kg/m^2)	90 (27.6)
COPD	22 (6.7)
Heart disease	21 (6.4)
Dyslipidemia	11 (3.4)
Chronic kidney disease	12 (3.6)
None	32 (9.8)
Laboratory test results on the first day of Tele-ICU discussion	
Creatinine, mg/dL	1.1 [0.8-2.8]
pH	7.34 [7.26-7.42]
PO_2, mmHg	84 [69-115]
PCO_2, mmHg	48 [42-58]
Bicarbonate, mmol/L	26 [23-30]
Base excess, mmol/L	0.5 [−3.8 to 4.2]
IMV settings on the first day of Tele-ICU discussion	
Compliance, mL/cmH_2O	30 [25-37]
V_T, mL/kg of predicted ideal body weight	6.1 [5.6-6.9]
Plateau pressure, cmH_2O	25 [21-28]
Driving pressure, cmH_2O	13 [11-15]
PEEP, cmH_2O	12 [10-14]
FiO_2, %	60 [40-80]
PaO_2/FiO_2	148 [104-223]
Organ support therapies during the ICU stay	
Use of IMV	273 (83.7)
Duration of IMV, days	13 [8-20]
Hemodialysis	72 (22.1)
Vasopressors	170 (52.1)
Corticosteroids	211 (64.7)
Rescue maneuvers for respiratory failure	
Prone positioning	82 (30.0)
PEEP titration	120 (44.0)
Alveolar recruitment	19 (7.0)
Use of neuromuscular blockade	101 (37.0)
Tracheostomy	29 (10.6)

SAPS 3: Simplified Acute Physiology Score 3; and IMV: invasive mechanical ventilation. [a]Values expressed as median [IQR] or n (%).

In terms of demographic data, our results are comparable to those of cohort studies of critically ill patients with COVID-19.[29-32] Similar to what has been reported in other studies,[33,34] life support therapies, such as vasoactive drug therapy and renal replacement therapy, both of which are associated with increased overall in-hospital mortality, were widely used in our group of patients. Because the patients treated through our Tele-ICU program should preferably be on IMV, we found a higher rate of IMV use than that reported for ICUs at other public hospitals in Brazil (83.7% vs. 64.3%).[7] The median PaO_2/FiO_2 ratio for the patients treated through the program was low in general and was lower than that reported in a multicenter study conducted in Italy.[31]

The median PaO_2/FiO_2 ratio in our sample was consistent with moderate to severe ARDS.[35] The mortality rate of ARDS in Brazil ranges from 53%

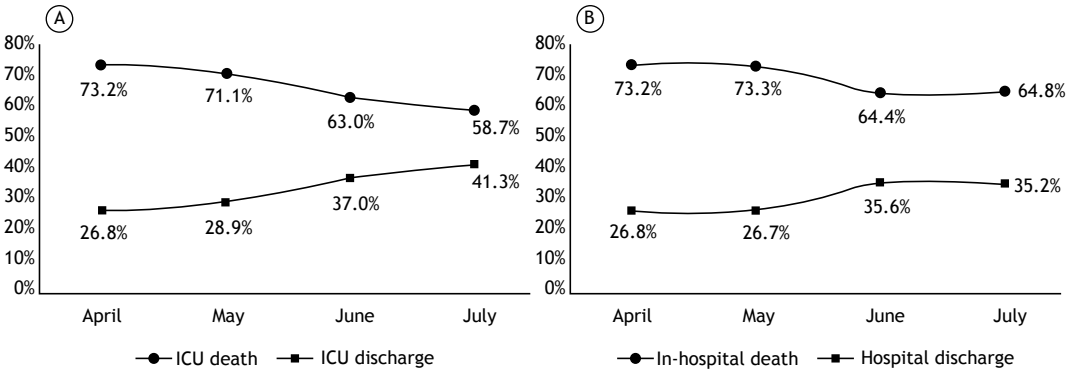

Figure 2. ICU mortality (in A) and overall in-hospital mortality (in B) during the study period.

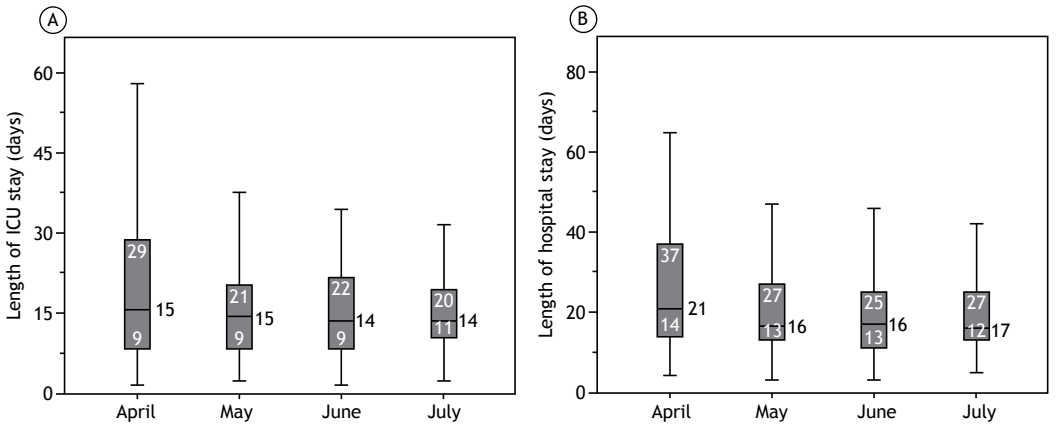

Figure 3. Length of ICU stay (in A) and length of hospital stay (in B) during the study period.

to 60%,[7] and a randomized clinical trial of patients with COVID-19 ARDS reported a 28-day mortality of up to 61.5%,[36] similar to that observed in the present study.

It is known that LPV reduces mortality, increases the number of IMV-free days,[17,37] and increases long-term survival.[38] Despite those benefits, it has been demonstrated that up to two thirds of patients do not receive LPV.[18] A study involving 45 ICUs in Brazil reported a 30% rate of ARDS and a higher median V_T than that delivered to the patients treated through our Tele-ICU program.[19] Adherence to the LPV protocol[39] was emphasized on a daily basis, and we succeeded in having 75% of the patients in our sample receive protective V_T (< 7 mL/kg of ideal body weight), protective plateau pressure, and protective driving pressure.[37,40] These protective settings were maintained during the first 3 days of monitoring (Table S2).

According to the database of the Brazilian ICU network, overall in-hospital mortality among COVID-19 patients on IMV in public ICUs was 69.3% up to November of 2020.[7] The sample of COVID-19 patients on IMV whose cases were discussed through our Tele-ICU program suffered from a selection bias on the part of the ICU team at the hospital of origin, who prioritized cases on the basis of severity and complexity. We found that overall in-hospital mortality was highest in the first two months of operation of the program, decreased in the third month, and remained stable in the fourth month.

One limitation of the present study is that not all cases of patients with COVID-19 admitted to ICUs were discussed through our Tele-ICU program; that is, we treated a subset of more severe cases selected by the physician at the hospital of origin. The exchange of information during teleconsultations was not always ideal, because patient medical records were sometimes unavailable and the data on the REDCap form could be incomplete. In addition, daily case discussions were sometimes ended because of complications at the hospital of origin or the overwhelming workload of health care professionals.

To our knowledge, this is the first Tele-ICU program to combine the provision of training/education with the provision of care in a statewide public health care network during the COVID-19 pandemic in Brazil. The effectiveness of the implementation of our Tele-ICU program is evidenced by the finding that the LPV protocol was actually used for cases of severe respiratory failure. With these data, we hope to encourage the creation of similar projects

that combine evidence-based practices, protocols, training, and teleconsultations.

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AUTHOR CONTRIBUTIONS

BRM, MVFG, MLG, MLAS, TFA, PGS, PC, and CRRC: conception and planning of the study, as well as interpretation of evidence; BRM, MVFG, MLG, MV, MLAS, TFA, MAG, APB, PGS, PC, and CRRC: drafting/revision of preliminary and final versions; and BRM, MVFG, MLG, MV, MLAS, TFA, MAG, APB, PGS, PC, and CRRC: approval of the final version.

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