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Rapid screening for COVID-19 by applying artificial intelligence to chest computed tomography images: A feasibility study

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Abstract

Aim: The aim of the study was to present the results and impact of the application of artificial intelligence (AI) in the rapid diagnosis of COVID-19 by telemedicine in public health in Paraguay.

Methods: This is a descriptive, multi-centered, observational design feasibility study based on an AI tool for the rapid detection of COVID-19 in chest computed tomography (CT) images of patients with respiratory difficulties attending the country's public hospitals. The patients' digital CT images were transmitted to the AI diagnostic platform, and after a few minutes, radiologists and pneumologists specialized in COVID-19 downloaded the images for evaluation, confirmation of diagnosis, and comparison with the genetic diagnosis (reverse transcription polymerase chain reaction (RT-PCR)). It was also determined the percentage of agreement between two similar AI systems applied in parallel to study the viability of using it as an alternative method of screening patients with COVID-19 through telemedicine.

Results: Between March and August 2020, 911 rapid diagnostic tests were carried out on patients with respiratory disorders to rule out COVID-19 in 14 hospitals nationwide. The average age of patients was 50.7 years, 62.6% were male and 37.4% female. Most of the diagnosed respiratory conditions corresponded to the age group of 27–59 years (252 studies), the second most frequent corresponded to the group over 60 years, and the third to the group of 19–26 years. The most frequent findings of the radiologists/pneumologists were severe pneumonia, bilateral pneumonia with pleural effusion, bilateral pulmonary emphysema, diffuse ground glass opacity, hemidiaphragmatic paresis, calcified granuloma in the lower right lobe, bilateral pleural effusion, sequelae of tuberculosis, bilateral emphysema, and fibrotic changes, among others. Overall, an average of 86% agreement and 14% diagnostic discordance was determined between the two AI systems. The sensitivity of the AI system was 93% and the specificity 80% compared with RT-PCR.

Conclusion: Paraguay has an AI-based telemedicine screening system for the rapid stratified detection of COVID-19 from chest CT images of patients with respiratory conditions. This application strengthens the integrated network of health services, rationalizing the use of specialized human resources, equipment, and inputs for laboratory diagnosis.

Keywords

COVID diagnosis, artificial intelligence, telemedicine, rapid screening, telediagnosis, telehealth, ICTs in health, Paraguay

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Introduction

The coronavirus pandemic (COVID-19) is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that causes a severe acute respiratory syndrome.[1] It was identified in December 2019 in the city of Wuhan, capital of Hubei Province in Central China.[1,2] The World Health Organization (WHO) recognized it as a global pandemic on 11 March 2020.[3,4] On 31 March 2021, over 127.5 million cases of COVID-19 had been reported in over 215 countries, and this has resulted in over 2.8 million deaths and over 104 million cases that have recovered.[3–6]

The incubation period is about 5 days, varying between 2 and 14 days.[3–7] The most common symptoms are fever, dry cough, and dyspnea (difficulty in breathing).[7,8] Complications usually include pneumonia, acute respiratory syndrome, thrombosis, or sepsis.[7] There is currently no specific antiviral treatment.[7,8] Each country performs the diagnosis of COVID-19 based on genetic analysis (reverse transcription polymerase chain reaction (RT-PCR)) of samples in the laboratory obtained by nasopharyngeal swabs according to the WHO advice, but many countries around the world are using an antibody test as a key step of their plans to exit lockdown.[4,6–10] Antibody tests are used to identify antibodies in a person's blood sample and are important in detecting infections in people who are asymptomatic. However, the number of tests performed varies greatly from country to country, depending on the resources available and the containment strategies adopted.[4,9] In Paraguay, to date (31 March 2021), 212,691 cases of COVID-19 have been confirmed, 4,161 have died, and 173,994 have recovered, with an average infection rate of 1.5 during a period of 386 days of pandemic.

In order to strengthen the diagnostic and screening capacity of coronavirus, it has been proposed to use telemedicine tools for the detection of suspected cases through chest images by computed tomography (CT) of the patient suspected of being infected. That is to say, with the planned, appropriate, and systematic application of the diagnosis of COVID-19 by telemedicine, the aim is to reduce the workload of health personnel in specialized hospitals to attend to cases of COVID-19, thus making it possible to speed up the diagnostic processes and significantly increase the flow of patients suspected of carrying the coronavirus.[7–9]

In practical terms, adequate screening strategy should allow the detection of suspected cases of COVID-19 for their respective evaluation by the clinician, and a laboratory test by RT-PCR (if considered appropriate), thus defining the management of the patients (hospitalization or home quarantine) and their eventual treatment, avoiding unnecessary transfers of patients with suspected coronavirus, resulting in crowding in specialized centers.[4,9]

WHO defines screening as "the presumed identification of a disease not yet recognized by the application of tests, examinations or other procedures that can be performed rapidly." A screening test is not intended to replace diagnosis, but rather to prioritize those cases with signs and symptoms of the pathology of interest. Persons with a positive or suspected COVID-19 result should be referred to a physician for laboratory diagnosis by RT-PCR and timely treatment.[6–8]

It is essential that a screening has a high sensibility, that is, to be able to detect individuals suffering from the pathology, and a high specificity, that is to say, to be able to classify healthy individuals as such. Other important features are that the test has low cost and low complexity, that the lack of timely treatment does not have major consequences, that the disease detected early is adequately treated, that the test is safe, and that it is acceptable to both patients and health professionals.[3–9]

It should be noted that in order to carry out the screening by telemedicine, health personnel (radiological technician) are considered as non-medical professionals who will be responsible for taking digital images of the patient's chest through the tomography following a protocol developed by the specialists for this purpose.[11–13]

The artificial intelligence (AI) system offers many opportunities to improve diagnosis in medicine. A rapid and smart screening system for COVID-19 through AI could be beneficial to overcome limitations in specialized hospitals and RT-PCR Labs to attend coronavirus-infected patients. This study used two AI systems with deep learning (DL) methods to diagnose COVID-19 from chest CT images. Both AI systems have a detection algorithm of pneumological pathologies and the diagnosis algorithm of COVID-compatible pneumopathies. According to the results of many medical image diagnosis systems–related papers, AI-powered diagnosis with DL methods offers excellent results in analyzing medical images.[14–27]

With the terrible crisis, in all respects, resulting from the COVID-19 pandemic, it is essential to develop diagnostic alternatives for screening and subsequent laboratory diagnosis in order to make rational use of the country's capabilities and thus optimize the use of the scarce resources available.[4–13] In this context, the Institute of Health Sciences Research (Instituto de Investigaciones en Ciencias de la Salud: IICS), through the Department of Biomedical Engineering and Imaging, in collaboration with the Directorate of Telemedicine and the National Institute of Respiratory and Environmental Diseases (Instituto Nacional de Enfermedades Respiratorias y del Ambiente: INERAM) of the Ministry of Public Health and Social Welfare (MSPBS) has developed this study. The aim is to serve as an objective and independent source of information on the technical feasibility of implementing a screening system based on AI (machine learning) by telemedicine for the rapid detection of COVID-19 from CT chest images of patients with respiratory disorders[13–27] in public hospitals.

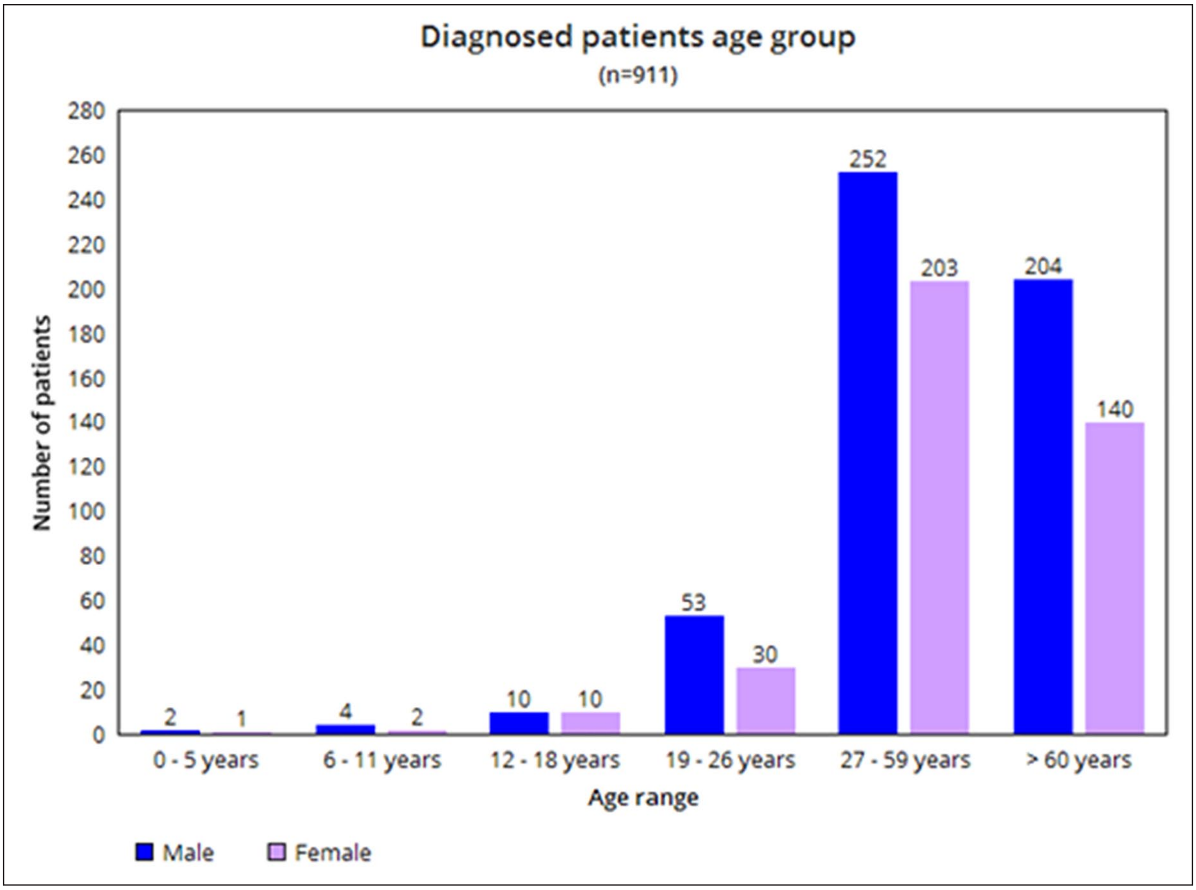

Figure 1. Age ranges of respiratory patients diagnosed with AI application for COVID ($n = 911$).

This article presents the results and potential impact of the application of AI for the rapid diagnosis of COVID-19 by telemedicine in public health in Paraguay.

Materials and methods

This descriptive, multi-center, observational study of the feasibility and implementation of an AI tool for the rapid diagnosis of COVID-19 by telemedicine was carried out between March and August 2020 in 14 regional, general, and specialized hospitals in the 18 health regions of the MSPBS. This study was approved by the Health Sciences Research Institute Scientific and Ethics Committee (approval no. P38/2020).

Sample size

The sample size calculation was at convenience, where we enrolled sequentially 911 patients with respiratory disorder and medical request for a chest CT scan, who were referred to 1 of the 14 widespread countryside hospitals during the study period. Chest CT scan was performed on all participants. The recruitment of patients with respiratory disorders was non-random and sequential. All patients provided a written informed consent prior to enrollment in the study. Patient data were consigned in a complete electronic fact sheet. The demographics of our enrolled patients set are showed in Figure 1.

Inclusion criteria

We enrolled patients having evidence of respiratory disorders with tachycardia and respiratory rate above 25 or higher, fever, myalgia, O_2 saturation below 93%, and cough.

Exclusion criteria

We excluded patients with another sign and symptoms as in the inclusion criteria and not compatible with COVID-19.

Sensitivity/specificity of the AI system

The sensitivity/specificity of the system was obtained by comparing the diagnosis performed by the two AI platforms with the *Gold Standard* RT-PCR performed in the laboratory and further confirmed through the diagnosis made by the image specialist or pneumologist. To assess the accuracy of AI diagnosis system, its outcomes have been compared with the results of the RT-PCR test and confirmed by the pneumologist in order to determine the rate (%) of the patients diagnosed with the disease or true positive (sensitivity = (a) / (a) + (c); (a) = true positives; (c) = false negatives) and the rate (%) diagnosed as true negative (specificity = (d) / (b) + (d); (d) = true negatives; (b) = false positives).

Selection of AI platform and technology

This study has selected at convenience two in the country available AI platform with DL methods to perform the rapid diagnosis of COVID-19. The DL technology used in both AI platforms is a deep convolutional neural network (DCNN) with stochastic pooling (SP), which replace traditional average pooling and improve the performance of the basic DCNN in order to strengthen the effectiveness of our algorithm in detecting COVID-19.

Two AI platforms were used in the telemedicine platforms. Each of them used a different amount of COVID-19's positive frame images; these had been introduced into the system to be used in learning COVID-19's patterns through the algorithm for both platforms. The different level of studies already processed to be used by these systems was used as a learning method in order to improve their sensitivity and specificity in their respective diagnostic results.

The AI system used includes a detection algorithm of pneumological pathologies and the diagnosis algorithm of COVID-compatible pneumopathies. The detection algorithm can locate the pulmonary pathology and the diagnosis algorithm can assist the diagnosis of patients according to CT lung images. The AI system used is called "deep learning technology," which is a computer-aided diagnosis.[15,17–20,25] In this study, we will use the AI system only as a tool to show its potentialities compared with the RT-PCR diagnosis and do not pretend to explain in detail how both algorithms are built. Both algorithms use data-driven methodology to optimize the diagnosis. Supplementary research regarding how many false positives and false negatives did each AI evaluation produce, compared with the polymerase chain reaction (PCR) and radiologist findings, will be addressed in further studies in order to validate the detection and diagnosis algorithm.

In our approach, we provide CT lung images of a patient, and if the patient is found to have COVID-compatible pneumopathies, the AI system will return a diagnosis answer in the form of a percentage value, which expresses the degree of compatibility with a COVID picture.

In addition, the results of the two AI systems used were also compared with each other, and the outcome of this comparison was represented in statistical terms as the average of diagnostic agreement and discordance in four probability ranges that were defined to stratify the severity of the patient's condition compatible with the pathology of interest (COVID-19).

Laboratory virus nucleic acid testing (RT-PCR assay)

Nasopharyngeal or oropharyngeal swab samples coming from the patients with respiratory symptoms were obtained. Trained healthcare personnel placed them immediately into sterile transport tubes and sent them to a hospital of reference, following the *Guidelines of the Centers for Disease Control and Prevention*.[28] Finally, the COVID-19 diagnostic was made by genetic analysis using an RT-PCR.

Patients

This study included 911 patients with respiratory conditions of varying severity that prompted a medical request for a chest CT scan. The study was conducted between March and August 2020 at 14 MSPBS regional, general, and specialized hospitals and the patient data were recorded on an electronic file. The images captured were processed and transmitted from the tomography areas to the specialist physician and then to a cloud with an AI application for the corresponding diagnosis via Internet. The sampling of patients was non-random and sequential, including 911 consecutive patients, without selecting for any previous characteristics. This is similar to clinical procedures.

To ensure the confidentiality of the information as well as its integrity and consistency, the telemedicine platform used mechanisms such as a controlled access to the system (user/password) and prioritized queries by type of user (secretary, technician, doctor, or system administrator). Encrypted databases, secure socket layer (SSL) type–encrypted communication, and encryption keys for the manipulation and modification of information using an encryption protocol that provides secure communication were also used.

Equipment and software used

The images were obtained through tomographs from different manufacturers using a capture protocol pre-established by radiologists from the national reference center for respiratory diseases. A single computer was used to manage the images where digital images were downloaded in *DICOM* format (Digital Imaging and Communications in Medicine) and then processed and stored through "proprietary software."

A web application was used to simplify the process of incorporating the images obtained by the tomographs into the patient electronic file database. The digital technology used for the transmission of the images in this study is called "store & forward," in which once the images are obtained, the electronic patient record module is executed (standalone or Web application). The "remote specialist" (radiologist doctor) when entering the diagnostic system of the telemedicine platform visualizes the clinical data of the patients and the attached images for diagnosis. Immediately after the specialist and the AI cloud application make the diagnosis, the report is available for printing and delivery to the patient and/or for e-mail referral to the physician requesting the CT study, depending on how it was requested.

Statistical analyses

According to our population under study, study design, factors of interest, and outcomes, we have adopted descriptive statistics to describe and summarize the basic features of the data in our study (frequency distribution, tendency, dispersion, average, comparison, etc.).

Results

Fourteen national hospitals were selected that do not have a specialized laboratory diagnostic service using RT-PCR, nor medical pneumologists who are specialists in the proper diagnosis of SARS-CoV-2. Twelve were regional hospitals, one general hospital, and one specialized hospital. These hospitals were connected via Internet to an AI application cloud for the rapid diagnosis of COVID-19 by telemedicine.

Between March and August 2020, 911 rapid diagnostic (screening) tests were performed on patients with respiratory disorders to rule out COVID-19 by comparing clinical characteristics and CT chest images through the application of AI. The non-random and sequential recruitment of patients with respiratory disorders for the study was carried out in the outpatient department (moderate pathologies) and the emergency department (severe pathologies) of those 14 hospitals connected to the telemedicine network of the Telemedicine Directorate of the MSPBS. Regarding the demographic characteristics of the selected patients, 911 cases (respiratory tracts) were adjusted to the purpose of the research (inclusion criteria), 57.6% were male and 42.4% female. The average age was 50.7 years. The diagnosis was based on chest CT scan, PCR test, and initial symptoms of COVID-19. Regarding clinical characteristics, most of the common patients' conditions were evidence of respiratory disorders with tachycardia and respiratory rate above 25 or higher, fever, myalgia, O_2 saturation below 93%, and cough. All patients underwent treatment protocols based on the respiratory pattern and clinical findings. The distribution of the patient age ranges is shown in Figure 1.

As can be seen in Figure 1, the largest number of remote diagnosed patients with respiratory disorders corresponds to the age group between 27 and 59 years (with 252 chest CT studies performed). The second most frequent corresponds to the group over 60 years and the third to the group between 19 and 26 years.

As we have already pointed out, the 911 cases diagnosed through the application of AI in the 14 hospitals of the National Telemedicine Network were introduced in a parallel way in both platforms (AI1 and AI2). The result of the comparability between both platforms by range of diagnosed probability can be seen in Figure 2. They were grouped in four probability ranges (%) according to their compatibility with COVID-19. As shown in Figure 2, in the range of 0%–25%, 686 patients were diagnosed through the AI1 system, and 643 patients with the AI2, with a difference of comparability of 6% between both platforms. In this range (0%–25%), 351 results were diagnosed by both platforms with probability of COVID "zero" or "undefined" in the scale of probabilities, of which 236 corresponded to the system AI1 and 115 to AI2. To define the diagnosis of these patients, images from studies with "zero" or "undefined" probability for COVID-19 were submitted for evaluation by pneumologists and radiologists, resulting in different pneumological pathologies. The distribution of the type of pathology and the number of cases are represented in Figure 3. The most frequent cases detected by the pulmonologists/radiologists (Figure 3) as studies with "zero" or "undefined" probability for COVID-19 corresponded 71.8% to pathologies that should be evaluated by a pneumologist, 6.8% to viral pneumopathies, 5.9% with no apparent or normal pathology, 5.4% to pathologies of other etiologies, and 2.6% to pulmonary emphysema and pleural effusion. The results of the successive evaluation of the undefined pathologies (71.8%) made by the pneumologist corresponded mainly to respiratory pathologies or abnormalities that a doctor would also label as a disease like asthma, chronic obstructive pulmonary disease (COPD), chronic bronchitis, cystic fibrosis, and so on.

The most frequent diagnoses made in the 0%–25% range were severe pneumonia, bilateral pneumonia with pleural effusion, bilateral pulmonary emphysema, diffuse ground glass opacity, hemidiaphragmatic paresis, calcified granuloma in the lower right lobe of the lung, bilateral pleural effusion, sequelae of tuberculosis, and bilateral emphysematous and fibrotic changes.

In the 25%–50% range, 67 patients in AI1 and 151 patients in AI2 were categorized as patients with a possibility of COVID-19, which represent a difference in the comparability of results between both platforms of 56%. The most frequent pathologies in this range were pulmonary emphysema, unspecific features in the lung parenchyma, and calcified granuloma nodules in the lower right lung lobe.

In the 50%–75% range, the AI1 system diagnosed 43 patients and the AI2 system 85 patients, with a difference of comparability of 49% between both platforms. The most frequent findings in this range were viral pneumopathies

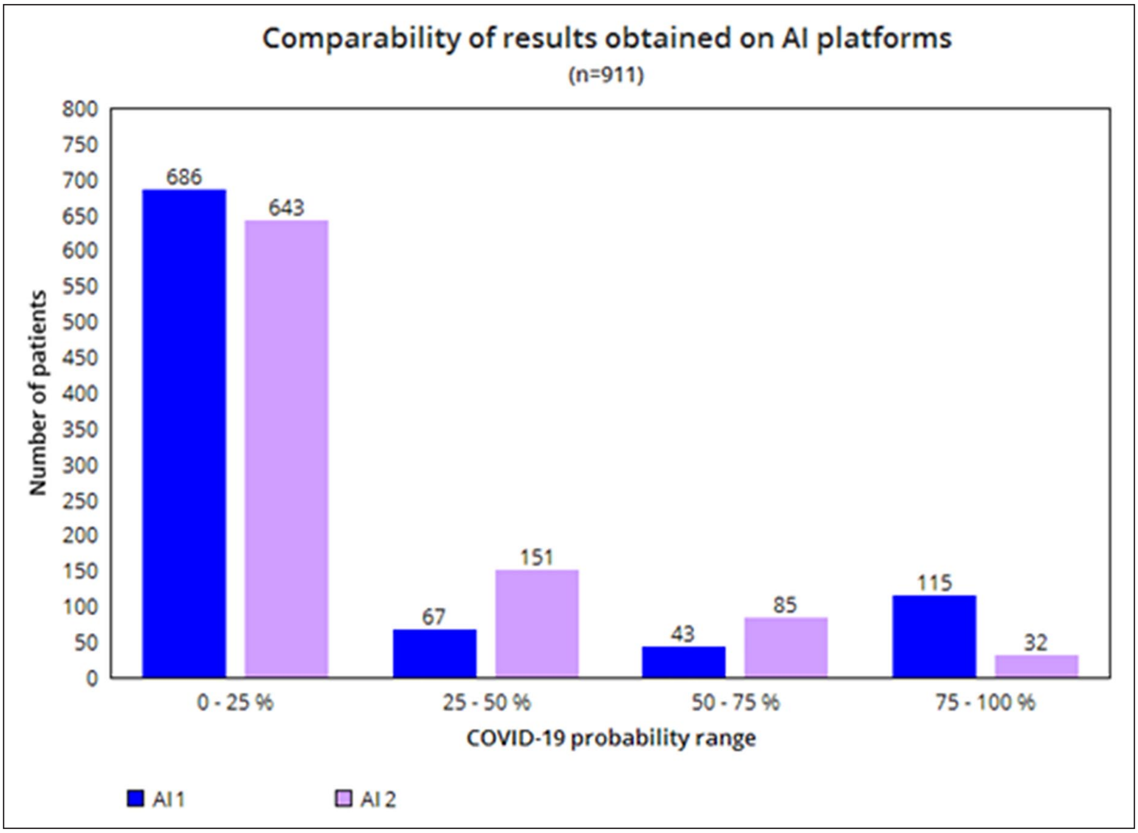

Figure 2. Comparison of the results diagnosed by the two AI platforms, with different degrees of learning of the COVID-19 parameters ($n = 911$).

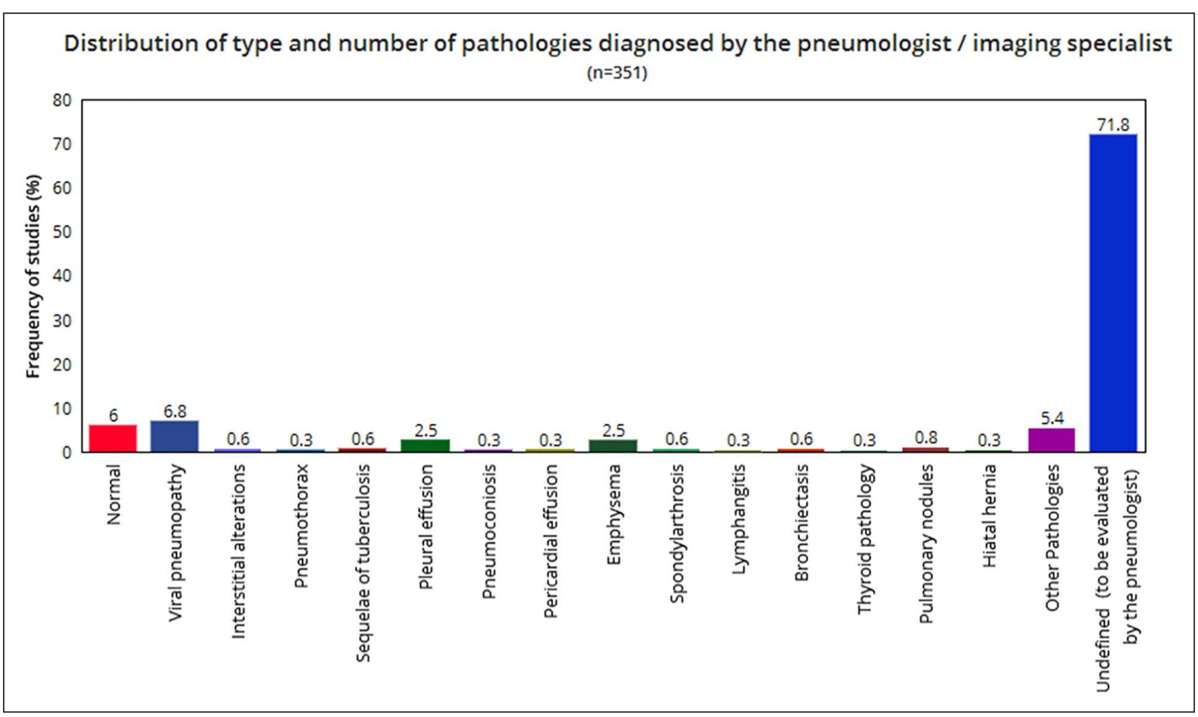

Figure 3. Diagnostic results of studies with "zero" or "undefined" probability for COVID that needed to be evaluated by the pneumologist ($n = 351$).

compatible with COVID-19, atypical viral pneumonia, and bilateral lung inflammatory process.

In the 75%–100% range, 115 patients with AI1 and 32 patients with AI2 were diagnosed, with a comparability difference of 72% between both. The most frequent findings in this range were viral pneumopathies, bilateral pneumonia with pleural effusion, upper right lobe with a frosted glass pattern, and non-specific infectious process.

Overall, across the four probability ranges of chest CTs, full comparability (averaging 86%) of diagnostic results for COVID-19 was found when analyzing the values of the probabilities diagnosed by the two platforms applied (AI1 and AI2). In addition, it is important to highlight that it was possible to differentiate in the images the severity (pleural effusion, bronchiectasis, etc.) and the extension of the pneumonia caused by SARS-CoV-2 in all the positive cases for COVID-19 and confirmed by RT-PCR depending on the viral load and virulence. On the contrary, it was determined that the average overall diagnostic discrepancy between platforms AI1 and AI2 was only 14% for the four ranges of probabilities (Figure 2) of assessment of chest CTs.

During the implementation phase of this study, a sensitivity of 93% and a specificity of 80% were obtained, when comparing the diagnosis made by the AI platform with the *Gold Standard RT-PCR*, which were further confirmed through the diagnosis made by the image specialist or pneumologist. We understand that the 7% discrepancy of sensitivity and 20% of specificity can be attributed to the AI platform expertise or to the cases in which the acquisition of the chest CT image did not comply with the protocol established for the effect (image slice or quality was not suitable for the analysis), patients' underlying chronic condition affecting the chest radiography, or discrepancy in the various devices' performance and therefore were not conclusive as positive COVID-19. No significant discrepancy in both AI tools evaluation was found attributable to the type (manufacturer) of device (tomographs) used to produce the chest images, which means device performance parameters like resolution, image quality, and so on were comparable for the various devices used in this study.

Discussion

The results of the present work show that the screening based on AI (machine learning) by telemedicine for the rapid detection of COVID-19 launched by the MSPBS offers a favorable perspective and potentialities and can be considered as a promising tool that contributes significantly to the increase of diagnostic alternatives for the screening, previous to the laboratory diagnosis (RT-PCR). This feature of the tool can in turn facilitate the optimization and rationalization of the use of the few and valuable resources (specialized professionals, installed capacity, laboratories with RT-PCR, supplies, and reagents) available in the country.[13,15–24]

In this sense, the results of this study show that a telemedicine platform with Information and Communication Technologies (ICTs)-based tools can strengthen and promote the strategy of the public health model based on equity and universality for access to high-impact diagnostic technologies in public health according to the epidemiological profile of each country.[13,29–32] However, the key to the proper functioning of the remote diagnosis system is to have trained health personnel in remote hospitals (health technicians) and the required technological infrastructure and a working protocol.[13,31–33]

In the absence of specific pharmacological treatment or an effective and reliable vaccine against COVID-19,[1–9] early detection and immediate sanitary isolation of the infected patient are essential.[1,3,4,15–20] According to the latest guidelines published by WHO, the diagnosis of COVID-19 must be confirmed in the laboratory by the RT-PCR method or genetic sequencing of the nasopharyngeal swab or blood samples as a key indicator for hospitalization. However, limitations in sample collection, sample transport, and availability of the necessary reagent kits have meant that only 30%–60% of all suspect cases can be confirmed by RT-PCR.[1,3–10] Early diagnosis is essential for the treatment and control of the disease. Thus, recent studies have suggested that thoracic images performed by CT could be a more reliable, practical, and fast method to diagnose and evaluate the COVID-19,[15–24] especially in epidemic areas.

Chest CT is a routine method for diagnosing pneumonia because it is quick and easy to perform through an image acquisition protocol. Recent studies of other authors[15–24] have shown that the sensitivity of CT images to detect COVID-19 was 98% compared with 71% sensitivity of the RT-PCR method. The sensitivity determined with the results of our study was 93% and the specificity 80%, which were obtained by comparing the diagnosis made by the AI platform with the *Gold Standard RT-PCR* and further confirmed through the diagnosis made by our image specialist or pneumologist. The 7% discrepancy in sensitivity and 20% of specificity may be probably attributed to the insufficient number of studies previously included on AI platforms (sample size) to learn from those studies and gain greater expertise for sensitivity/specificity, to cases where the acquisition of the chest CT image has not conformed to the established protocol for the effect (image slice or quality was not suitable for the analysis), to patients' underlying chronic condition affecting the chest radiography, or to discrepancy in the various devices' performance. In general, these differences in the results in terms of average values of comparability (86%), discrepancies (14%), sensitivity (93%), and specificity (80%) of the diagnoses made by the AI1 and AI2 platforms coincide with similar studies by other authors,[17–21] and we also attribute them to the number of images that both systems had as a background to learn "patterns from COVID-19 images."

In these uncertain times during the pandemic, decision-making in health services is a major challenge for health authorities around the world. In that context, AI and machine learning applications such as those used in our study in a pilot assay can facilitate such decisions efficiently, reliably, and quickly according to scientific evidence-based models to facilitate diligent measures to control the COVID-19 pandemic.[15–27] The results of this work, using the AI platform for COVID-19 screening in parallel to the laboratory diagnosis by RT-PCR, allow us to propose, in agreement with other similar investigations, a very efficient method. The measurement of the agreement of our results with other similar researches was made comparing our method with other AI-based COVID-19 diagnostic approaches.[15–24]

In this sense, this tool based on AI and machine learning can mitigate the deficient availability of highly trained imagers (radiologists) for the diagnosis of CT images (COVID, etc.) in regional, district, and some specialized hospitals saturated in their image-processing capacity during the avalanche caused by the pandemic. It can also act as a triage to rationalize the use of scarce specialized human resources and RT-PCR in low-income countries such as Paraguay. That means, through rational use of a validated AI diagnosis system, it is possible to establish a countrywide triage net in order to identify in a diligent manner suspected coronavirus-infected patients and separate from other respiratory diseases, thus serving as a filter to refer and at the same time reduce the workload in specialized hospitals and RT-PCR-Labs for COVID-19. With the fast diagnosis made by AI system (3–5 min), it will be possible to speed up the diagnostic processes and significantly increase the flow of patients suspected of carrying the coronavirus at the few specialized hospitals in low setting countries like Paraguay.[7–9]

Furthermore, our results show that AI and machine learning technologies such as those performed here can be used, once validated with the radiologist and RT-PCR diagnosis, as a diagnostic platform for COVID-19 and other respiratory pathologies such as those detected in the 0%–25% probability range on the AI diagnostic scale and detailed in Figure 3. However, in current practice, chest CT is not yet a routine diagnostic test for COVID-19,[19–23] although it can help to exclude other COVID-19-like symptoms and monitor patient progress during treatment in severe cases of the disease, such as the cases diagnosed in our study in the four probability ranges as shown in Figure 2. In that sense, the scale of assessment of the chest CT used by our platform of diagnosis with AI and expressed as probability can be applied to evaluate the severity and extension of the pneumonia caused by the coronavirus, and consequently indirectly measures the viral load that is reflected in the severity and extension of the COVID-19.[20] In this context, the severity (pleural effusion, bronchiectasis, distortions in the structure, etc.) and extension of pneumonia caused by SARS-CoV-2, according to its viral load and virulence, could be fully differentiated in our study according to our radiologist findings and other similar studies.[20] This differentiation could be observed in the images of the four established probability ranges (Figure 2) for the assessment of the chest CT of the 911 patients with respiratory pictures captured in our study.

There are some limitations in our study like small sample size (conditioned by the inclusion/exclusion criteria used in the study), selection of the AI technology (conditioned by the budget and available technology in the country during the study), description in detail how AI algorithms used are built (conditioned by the scope of the study), how many false positives and false negatives did each AI evaluation produce compared with the PCR findings, and detailed discussions of the results that we pretend to strengthen in further studies.

Conclusion

We can conclude with the first-stage results of our study that the application of AI for the rapid detection (screening) of COVID-19 by telemedicine is feasible, but our study has some limitations regarding how many false positives and false negatives did each AI evaluation produce compared with the PCR findings, which must be addressed in further research in order to validate the detection and diagnosis algorithm. This tool can improve imaging diagnosis by stratifying (probability ranges) the severity and extent of the pathology (COVID, influenza, etc.) and serves to monitor the evolution of patients during treatment of severe cases of the disease. With the implementation of this technology based on ICTs and AI, benefits can be achieved such as reduction of diagnostic costs, improvement in the quality of medical care and diagnosis, reduction of the average time for diagnosis, and extension of remote diagnostic screening services to locations with few specialized professionals and equipment, as has been shown in other countries.[13,29,33]

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Author contributions

P.G. contributed to conceptualization, methodology, investigation, formal analysis, and writing—original draft preparation. J.F. contributed to conceptualization, methodology, investigation, and formal analysis. F.G. contributed to methodology, investigation, formal analysis. O.V. contributed to methodology, investigation, formal analysis. L.R. and R.R. contributed to investigation and formal analysis. J.O. contributed to investigation, formal analysis, and validation. J.P. contributed to investigation and supervision. J.M. contributed to investigation and project administration. E.H. contributed to investigation, formal analysis, and writing—review & editing.

Declaration of conflicting interests

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