

The role of technology platforms in Brazil as a strategy for pandemic preparedness and response

O papel das plataformas tecnológicas no Brasil como estratégia para preparação e resposta a pandemias

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ABSTRACT The COVID-19 pandemic highlighted the need for robust and integrated laboratory infrastructures and technologies to offer rapid responses to health emergencies. Technology platforms, or core facilities, centralize expensive and sophisticated equipment and rely on teams with high technical expertise. They played, during the pandemic, an essential role in the development and improvement of molecular diagnosis, genomic analysis, support for epidemiological surveillance and research into the natural history of the disease. This work discusses the importance of the Fiocruz Technology Platforms Network during the health crisis. Similar to what happened in other countries, core facility activities were quickly reorganized in support of the health emergency, temporarily replacing normal research support demands, which were heavily reduced due to isolation strategies. At Fiocruz, the genomics, bioinformatics and PCR platforms quickly joined the Surveillance Network and Reference Laboratories initiatives, allowing efficient monitoring of viral evolution and the identification of variants, optimizing fast and accurate diagnostic protocols and genomic analyses. They demonstrated a strategic role in dealing with public health emergencies, due to their expertise, set of permanent and operational infrastructures, and rapid mobilization to meet the voluminous demands for analysis.

KEYWORDS Technologies. Molecular diagnosis. Public health. Bioinformatics. Genomics.

RESUMO A pandemia de covid-19 evidenciou a necessidade de infraestruturas laboratoriais e tecnologias robustas e integradas para oferecer respostas rápidas a emergências sanitárias. As plataformas tecnológicas, ou core facilities, centralizam equipamentos caros e sofisticados e contam com equipes altamente qualificadas. Durante a pandemia, desempenharam papel essencial no desenvolvimento e no aprimoramento de diagnóstico molecular, análise genômica e suporte à vigilância epidemiológica e à pesquisa sobre a história natural da doença. Este trabalho discute a importância das instalações da Rede de Plataformas Tecnológicas da Fiocruz durante a crise sanitária. Semelhante ao ocorrido em outros países, as atividades das core facilities foram rapidamente reorganizadas em suporte à emergência sanitária, substituindo temporariamente as demandas normais de suporte à pesquisa, fortemente reduzidas devido às estratégias de isolamento. Na Fiocruz, as plataformas de genômica, de bioinformática e de PCR se juntaram rapidamente às iniciativas da Rede de Laboratórios de Vigilância, permitindo um monitoramento eficiente da evolução viral e da identificação de variantes, e otimizando protocolos de diagnóstico e análises genômicas rápidos e precisos. As plataformas demonstraram ter um papel estratégico para o enfrentamento a emergências em saúde pública por meio da expertise, conjunto de infraestruturas permanentes e operacionais, e agilidade frente à demanda voluminosa de análises.

PALAVRAS-CHAVE Tecnologias. Diagnóstico molecular. Saúde pública. Bioinformática. Genômica.

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Introduction

The SARS-CoV-2 pandemic has put the surveillance and mobilization capacity of health systems to the test through large-scale care, diagnosis, and vaccination in all regions of the world. There is consensus that new pandemics will occur, likely with an increased frequency, due to climate change, the continued expansion of large livestock monocultures close to populations of animal species susceptible to various viral infections, and the invasion of biomes, resulting in ecological imbalances that favor the emergence and spread of pathogens and reinforce the critical importance of One Health policies¹.

In Brazil, the National Network of Epidemiological Surveillance Laboratories and the National Network of Environmental Health Surveillance Laboratories make up the National System of Public Health Laboratories (Sislab), which, in turn, is an integral part of the Brazilian Unified Health System (SUS)². The Ministry of Health (MS), through the General Coordination of Public Health Laboratories (CGLAB), plays a crucial role in the coordination and technical assistance offered to the states and the Federal District in the implementation and maintenance of the National Network of Public Health Laboratories². This network is essential for the diagnosis, monitoring and control of diseases, in addition to collaborating with public health surveillance.

Furthermore, the MS and CGLAB are responsible for health promotion, among other responsibilities, carrying out ongoing education and training actions for health professionals, especially those involved in epidemiological surveillance. This promotion includes strengthening capabilities to ensure a faster and more effective response to outbreaks, epidemics, and other public health problems. In short, epidemiological surveillance is organized around Central Reference Laboratories (Lacen), which specialize in diagnosing a range of pathogens².

The system must be able to identify new infectious agents, qualify and quantify the agent, and provide public health managers with accurate and current information for appropriate decisions. Additionally, several research laboratories in Science and Technology Institutions (STI) are accredited as National or Regional Reference Centers, assisting national surveillance agencies in monitoring the circulation of infectious agents in their specialty by clarifying unusual cases, and supporting the coordination of health actions to control outbreaks and epidemics. Monitoring the circulation of variants of infectious agents, such as variants of interest (VOI), variants under monitoring (VUM), and variants of concern (VOC), is essential because they may present antigenic variations, virulence, specificity or cellular tropism, or drug resistance with a possible direct impact on public health. For most known and widely circulating infectious agents, there are detection kits and systems commercially available in the international market, standardized and with quality certification.

Many actions were carried out by the Ministry of Health during the SARS-CoV-2 pandemic with the aim of accelerating the acquisition and distribution of these reagents and kits and promoting testing and the dissemination of data from the period through the 'Epidemiological Bulletins' issued by the Health Surveillance Secretariat of the Ministry of Health (SVS/MS)^{3,4}. However, during pandemics, the surveillance system is faced with the need to purchase, distribute and use diagnostic tests on a large scale in the international market, facing shortages, high prices, fierce competition and difficult logistics. There is often a need to adapt existing tests due to the regional evolution of agents through genetic modifications, demanding much research and accelerated development. There is also a need to bring together experts from the country's different STIs to share, analyze, and interpret data in order to transform it into information and knowledge of relevance to the population,

as well as guidelines and recommendations for the health system.

More recently, the World Health Organization (WHO) established a program called Preparedness for Emergencies, providing early warning mechanisms, open data and systems for detecting, reporting and responding to health emergencies⁵. It is understood that preparedness and surveillance also include risk management through the assessment of scenarios and possible prevention and mitigation responses, at national and subnational levels, in communities, rural and urban environments, in vulnerable or at special risk populations⁵.

Many countries include compulsory reporting systems, feeding epidemiological surveillance and reference laboratories with information and clinical samples necessary to confirm the diagnosis and characterization of pathogens. For example, in Brazil, Ordinance No. 356/GM/MS of March 11, 2020, mandated notification to the Ministry of Health of all results of diagnostic tests for COVID-19 detection performed by public, private, university, and other laboratories nationwide. Although, in practice, self-tests purchased in pharmacies were not included⁶, such measures are now essential for adequate surveillance, rapid coordination, and prioritized response, with the aim of reducing the impact of worsening conditions on the population.

In addition to local surveillance networks, many organizational structures, not only in STI but also in private entities, were established and aligned at various moments during the pandemic, contributing positively to the health system. In January 2020, the COVID-19 outbreak was declared a Public Health Emergency of International Concern (PHEIC) and three months later it was classified as a pandemic by the WHO⁷. In Brazil, at the beginning of February, a Public Health Emergency of National Importance (ESPIN) was considered, with the first case of COVID-19 being confirmed on February 26, 2020 in São Paulo (SP) and, in less than a month, it was declared

that the transmission of the new coronavirus was of a community nature throughout the national territory^{7,8}.

According to online monitoring of COVID-19 in Brazil⁹, more than 715 thousand deaths were recorded until February 2025. This scenario highlights the need for national strengthening in science, technology, and the production of health-related supplies. There are many arguments for this, starting with the difficulty of obtaining imported supplies, reagents, kits, drugs, and vaccines when there is high global demand. In a pandemic, the regional and local epidemiological situation and, often, the variants of the etiological agent are specific. Additionally, the natural history of the disease can be quite different due to factors such as the population's genetic makeup, seasonality, frequency of comorbidities, specific elderly care policies, and environmental factors, among others. Therefore, the search for solutions to mitigate or prevent its spread must consider these specificities, and the development of supplies, kits, and vaccines must receive attention and resources to ensure equity and specific solutions¹⁰.

The Economic-Industrial Complex for Health and Innovation (Ceis) for the SUS has the mission of involving the integration of various sectors of the national economy focused on the production of goods and services related to health and innovation^{11,12}. Pandemic preparedness should be seen as a state policy, in which strengthening epidemiological surveillance and implementing rapid responses depend on coordination between sectors.

The Global Pandemic Preparedness Summit (GPPS), held in Rio de Janeiro, Brazil, in July 2024, was a science-driven event aimed at boosting pandemic preparedness and response to combat future infectious disease outbreaks more quickly and equitably. The Summit's proceedings, outcomes, and recommendations contribute to decision-making by world leaders on pandemic preparedness efforts. One of the main highlights of the meeting was

the importance of sustainable investments in global disease surveillance and the 100-Day Mission for vaccines, diagnostics and therapies¹³. A comprehensive health surveillance plan is crucial, also integrating the mobilization of STIs.

Added to this health-political scenario, the constant evolution, and scientific and technological advancement have resulted in the application of viral genomic analysis during outbreaks, replacing traditional methods with a more agile and almost real-time approach. Advances in genomic sequencing, facilitated by decreasing costs and increasing data generation and computing power, have become essential for clinical microbiology to detect pathogens, support infection control, and aid epidemiological investigations¹⁴. Furthermore, prospective analytical capacity, through metagenomic sequencing, allows the localization and identification of unknown infectious agents not only in clinical samples, but also in environmental samples, such as water, sewage or animal excreta, while transcriptomics allows the analysis of pathogen-host cell interactions¹⁵.

The contrast between the SARS (2002-2003) and COVID-19 epidemics illustrates this transformation. While viral genomics was limited during the SARS epidemic, with only 31 viral genomes available after three months, in the COVID-19 pandemic, metagenomic sequencing has allowed rapid identification of the pathogen and sharing of viral genome information, boosting the development of diagnostic tests and control strategies. In only six months, more than 60,000 complete SARS-CoV-2 genomes were analyzed and deposited in accessible databases, demonstrating the expanded capacity of sequencing to monitor and understand viral spread in real time. The Genomic Network portal¹⁶ clearly demonstrates the evolution of COVID-19 in Brazil.

The growing recognition of the potential of genomic sequencing in public health has encouraged investment in this technology. However, the high costs of installation,

maintenance and updating, the need for skilled staff and associated bioinformatics, and the operational work involved require a clear understanding of the expected benefits, the effective use of genomic data, and the ways to positively impact health and public policies. Furthermore, the equipment and technologies involved need to receive constant maintenance, need to operate practically full-time and require a continuous update strategy.

During the COVID-19 pandemic, technology platforms (core facilities) in STI contributed significantly to addressing the pandemic scenario, bringing technical-scientific knowledge, data analysis, training and resource optimization. In this context, this work aims to discuss the experience of the Technology Platforms Network (TPN) of the Oswaldo Cruz Foundation (Fiocruz), with a specific focus on the areas of genomics, bioinformatics and real-time PCR, during the COVID-19 pandemic, highlighting the impact of these structures, previously organized in a network, in facing the health crisis in Brazil.

Material and methods

Fiocruz Technology Platforms Network

This essay reports an experience and was supported by a non-systematic bibliographic review, carried out between January and February 2025. The non-exhaustive review was carried out on the Web of Science (WoS) platform, which includes several databases, and prioritized original articles, reviews and official documents relevant to the topic from 2015 to 2024, in Portuguese, English and Spanish. Duplicate documents, files without full-text access, and those deemed unrelated to the topic were excluded. Data such as year, country, type of study, objectives, results, and conclusion were organized on a spreadsheet. The analysis followed a critical

and interpretative approach, grouping references into articles, official documents such as reports, websites, ordinances, manuals, and guides. Because this was a non-systematic review, no meta-synthesis tools or flowcharts were used.

Fiocruz's TPN was created in 2004 and has 16 technological areas that unfold across 82 platforms distributed across nine Brazilian states, exemplifying the relevance of these multi-user structures (core facilities) in Brazil. Currently, the TPN integrates high complexity laboratories that provide and share equipment and specialized technical knowledge, not only for the use of researchers internal to the institution, but also for external users, from public and private institutions and companies.

Technologies

The analysis primarily considered activities involving the mobilization of technologies such as genomic sequencing, bioinformatics, and real-time PCR of the TPN. These platforms played a fundamental and direct role in the surveillance of the various phases of the pandemic due to their use in diagnostics and research, primarily in identifying circulating variants during the most critical period of the pandemic. Equally important are other technologies in the studies of the natural history of the disease are fundamental, such as microscopy, cytometry, bioassays, proteomics, nanotechnology, among others. In this scenario, it becomes clear the importance and relevance of robust structures that can provide access to this variety of technological groups for preparedness in facing health crisis situations.

Results and discussion

The arrival of the pandemic highlighted the strengths and vulnerabilities of the health system worldwide and in Brazil. The extraordinary challenges for the public health system required significant responses in a short time,

which included, among other actions, a) risk assessment during the pandemic involving epidemiological prognoses, identification of special risk groups, development of rules for social distancing, behavior in public spaces – circulation areas, schools, hospitals and service points –, decontamination methodologies, formulation of public policies; b) development and improvement of large-scale molecular diagnostics, mainly with real-time PCR, organization of diagnostic stations, even in drive-thru format, and development of alternative tests such as rapid antigen detection tests; c) organization of clinical care and development of better treatment or mitigation methodologies and protocols; d) study of the natural history of COVID-19 disease with the aim of improving treatments and other means of combating the viral infection and its aggravating factors and comorbidities; e) development and evaluation of vaccines through clinical trials; f) communication and information for the population about the pandemic and all its aspects, including combating fake news and misinformation, whether wrong or maliciously false; and g) organization of innovative aspects of society to deal with the pandemic such as remote work, expansion of home shopping delivery systems etc.

Fiocruz's participation in these various areas of combating the pandemic was notable. As evidence, the following macro-points can be cited: a) immunization and equity for the Brazilian population, from research and development to vaccine production; b) health surveillance related to the COVID-19 epidemic; c) medical care and assistance, i.e., hospital assistance to the population; d) information, communication and dissemination to society; f) education especially focused on COVID-19; g) global alliances to promote health equity; h) inclusion actions aimed at vulnerable populations; and i) innovation in institutional management to overcome the challenges imposed by the pandemic¹⁷.

In this essay, we focus on some aspects where TPN's participation was crucially

important, whether in the contribution of knowledge, the provision of equipment and teams, the contribution to data analysis or the mobilization of complex technologies and support for research and development. The objective is to contribute to improving genomic surveillance and diagnostic capacity, understanding and mitigating numerous aspects of the natural history of the disease, and formulating further appropriate public policies throughout the different phases of the pandemic. It was observed that genomic surveillance of the virus was crucial for rapid decision-making by health agencies, supported by the extremely high quality of sequencing.

While all health systems faced common challenges such as the need to rapidly expand hospital beds and implement mass vaccination campaigns, the specific impacts varied depending on the level of preparedness and health policies of each country. European nations and Canada, for example, have demonstrated the importance of well-structured universal health systems in addressing global crises, while the United States and Brazil have highlighted the effects of structural inequalities in public health¹⁸. The pandemic has shown that resilient systems, with rapid response capacity and centralized coordination, are essential to mitigating the impacts of health crises¹⁹.

The model of organizing complex infrastructures composed of specialized teams is present, with variations, in many institutions around the world²⁰ and has as one of its main objectives to offer support to research²¹, to the development of projects and technologies or, simply, to serve as a space for shared research between different groups or, even, as a unit for providing technology services.

In addition to these objectives, strategies for an organization, a Platform Network – Core Facilities – contribute to the selection, training and retention of talents, interaction with other STI, obtaining external resources for specialized projects or for the acquisition or renewal of infrastructure and to nucleate

new technologies and areas of knowledge, thus multiplying the original investments²¹. Added to this is the Network's beneficial participation in national and international initiatives with the exchange of technical and management experiences, such as the Core for Life networks and the Association of Biomolecular Resource Facilities (ABRF), among others^{21,22}.

In Brazil, at the beginning of the pandemic in 2020, there was a reorganization of research in all STIs. This reorganization was especially due to the immediate need for isolation, followed, by long periods of 'confinement' and, consequently, leading to a drastic decrease in demand for analyses on all platforms, including Fiocruz's TPN. This scenario was evident around the world as the pandemic progressed in different countries²³, which led to a rapid reduction in routine Research and Development (R&D) activities²⁴. On the other hand, many institutions have come to play a crucial role in tackling the pandemic and providing health support to the country's healthcare system. To achieve this, the entire institutional scientific community needed to reinvent itself to meet demands that arose daily and affected different areas.

Similarly, it quickly became clear that the organization of Fiocruz's TPN could contribute to facing this scenario in an agile and orderly manner, as it already had an established and robust initial structure, as well as qualified teams. Real-time PCR platforms were activated with the task of supporting the institutional Surveillance Network through large-scale analysis of clinical samples for the molecular diagnosis of the virus. In this context, the difficulty immediately detected concerned biosafety, both for intensive and on-site operation of laboratories and equipment, as well as for receiving samples and their processing with RNA extraction and real-time PCR itself.

To overcome this challenge, the Institutional Biosafety Technical Committee (CTBio-Fiocruz) worked to establish protocols and guidelines that met all safety requirements for

operating the platforms. Similarly, numerous consultations with the biosafety committees of different national and international institutes were launched to contribute to the safety of all adopted procedures, as well as the correct use of devices, clothing and decontamination protocols for classrooms, laboratory and hospital spaces and shared equipment²⁵⁻²⁷. At Fiocruz, technicians from the maintenance sector also collaborated to evaluate decontamination procedures and even developed UV-C devices for decontaminating physical spaces, hospital rooms and equipment.

With the advancement of the COVID-19 pandemic and the emergence of viral variants in circulation, the need to strengthen the surveillance system was imminent. At that time, the Fiocruz TPN genomics platforms were organized under the leadership of the Institutional Surveillance Network. The Fiocruz Genomic Surveillance Network¹⁶ was then established, contributing significantly to the national research effort to characterize the genome of SARS-CoV-2, the cause of COVID-19, in Brazil. Furthermore, the important work of monitoring the evolution of viral lineages and mapping and evaluating the functional impact of genetic mutations was being carried out. Once again, technical expertise and cutting-edge laboratory infrastructure were required to establish viral sequencing routines. Frequent primer set adjustments were also necessary to achieve complete genome variant coverage. Furthermore, bioinformatics pipelines were developed to analyze and annotate the obtained sequences. Thus, data quality allows for accurate interpretation of the results and the information to be deposited into an international database²⁸.

Such data is available online¹⁶ in the form of an infographic, where it is possible to follow the constant evolution of SARS-CoV-2 strains in Brazil. This virus has genetic simplicity when compared to other microorganisms such as bacteria and fungi, and is therefore classified into lineages based on small differences in its genetic material. The availability

and dissemination of these data in real time are thanks to the collaboration of Brazilian researchers from Genomic Surveillance Networks in various STIs and Lacen, and also to the Global Initiative on Sharing All Influenza Data (GISAID)²⁹.

At Fiocruz, there were five genomic platforms called NGS (Next Generation Sequencing) in operation at the beginning of the pandemic, as well as a Reference Laboratory with NGS capabilities. Over the course of the first year, five additional regional platforms were created, installed, and trained. After the pandemic, the set of infrastructures continues to operate in viral surveillance (Mpox, SARS, Influenza and Arbovirus) and some platforms are in the process of expanding surveillance to study bacteria, such as *M. tuberculosis* and drug resistance. Three platforms are being formed or expanded for human genome studies in cancer and genetic or rare diseases. Currently, ten platforms provide more general support for research and development projects in health, biodiversity, and biotechnology³⁰.

Naturally, as the pandemic progressed, Research, Development, and Innovation (R&D&I) efforts in research laboratories were resumed. With this resumption, so did the operational routines of the platforms, which are crucial in part for developing clinical and biological research on COVID-19. These activities included the search for new drugs and epidemiological studies. The Platform Network's full spectrum of analytical services, including proteomics, cytometry, microscopy, and bioassays, among others, was also resumed^{31,32}.

With the advancement of protocols and the results from genetic sequencing, the need arose for support to obtain, store and process data safely and with quality. In general, once a sample is sequenced and the appropriate metadata is collected, careful bioinformatic analysis is essential, combining computational power with the expertise of analysis, interpretation and programming of algorithms and interfaces. Additionally, the storage of clinical and research samples poses a significant

challenge. Many institutions, such as Fiocruz, have established specific biobanks for this purpose³³.

It is evident that the pandemic posed to the institutions the need to reinvent themselves, in order to adapt their activities and, consequently, their deliverables. For Fiocruz's research, the impact was proportional to all the progress achieved during this period. During the pandemic, the organization of technology platforms within the TPN demonstrated the importance of this structure and the benefits that ordered public investment in core facilities can bring to science, development, and the country's independence, especially in times of crisis.

Fiocruz's experience through the TPN aligns with international initiatives that also mobilized scientific infrastructure during the COVID-19 pandemic. In the United Kingdom, for example, the COG-UK (COVID-19 Genomics UK) consortium³⁴ stood out for the rapid generation and sharing of genomic data, contributing significantly to the detection of the virus' variants. Similarly, the U.S. Centers for Disease Control and Prevention (CDC) has strengthened partnerships with public and private laboratories through the SPHERES³⁵ project to accelerate genomic monitoring. In South Africa, the KwaZulu-Natal Research Innovation and Sequencing Platform (KRISP) played a central role in the early detection of the Beta variant, highlighting the importance of robust local capabilities in bioinformatics and genomics³⁶. In India, the INSACOG (Indian SARS-CoV-2 Genomics Consortium) was also created to integrate research and health surveillance laboratories, focusing on the detection and tracking of variants³⁷.

At the international level, the WHO has acted as a coordinator for data sharing through platforms such as GISAID, fostering global scientific collaboration. These experiences, as well as that of Fiocruz, demonstrate how strengthening core facility networks, combined with genomic surveillance strategies, was crucial in guiding public health decisions in real time during the pandemic.

However, not all investment should be made solely in equipment and technology, but also in training and knowledge expansion. It is essential to encourage training³⁸, scientific dissemination, and interaction with public health management sectors at the municipal, state, and national levels.

Likewise, there is a need for interaction with research management departments within STIs. In this context, Artificial Intelligence (AI) can play a strategic role in strengthening structures such as Fiocruz's TPN, especially in response to health emergencies. AI-based tools can automate and accelerate the analysis of large volumes of data such as genome sequences, contributing to real-time monitoring of viral variants. Additionally, machine learning algorithms can be used to predict outbreaks, identify epidemiological patterns, and optimize the allocation of laboratory resources. These applications are already widely used for different initiatives within the institution, such as 'InfoGripe'⁹. AI integration can also support the operationalization of TPN user services, as well as management processes such as procurement. This entire AI scenario can be channeled to expand the responsiveness of the national scientific infrastructure in the face of pandemics and health crises.

In retrospect, all of Fiocruz's genomics platforms became part of the Fiocruz Genomic Surveillance Network during the pandemic, when five additional centers were established. All continue to operate within this Surveillance Network, demonstrating that the integration initiative has become robust and definitive.

Final considerations

The COVID-19 pandemic has reinforced the importance of core facilities in responding to health emergencies. The integration of genomic sequencing, bioinformatics, and real-time PCR has enabled effective monitoring of viral evolution and the implementation of containment strategies. Strengthening core

facilities requires sustainable investments, collaboration between institutions, and public policies that ensure adequate infrastructure. Organizing these platforms within shared networks, such as Fiocruz's TPN, is an efficient model for ensuring their full use in the country's health security.

A network of Platforms – Core Facilities – not only brings great benefits to an institution but also proves to be a structure of great state, regional and national relevance by concentrating analytical and technological capacity to support research and technological development projects. Furthermore, these structures have the know-how and relevance to act as a buffer for expansion and speed of coordinated responses in times of emergency, thus proving to be essential as elements of preparedness, which is why they must be included as critical infrastructures for coping, resilience and response.

After a period that had a death toll of more than 700,000 lives in Brazil, it is clear that strengthening core facilities is crucial to ensuring an agile and effective response to future public health emergencies, requiring continuous investment in infrastructure and personnel training. Additionally, the need for national

response strategies is highlighted, creating State policies that strengthen the country's scientific and technological response, in addition to the integration of these infrastructures into pandemic preparedness plans.

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Collaborators

Pereira CD (0009-0003-6000-5903)* contributed to the design, data search, editing and review of the manuscript. Boniatti J (0000-0003-0510-9323)* contributed to the data search, editing and review of the manuscript. Lima Júnior MSC (0000-0003-0146-7123)* contributed to the final review of the manuscript. Degraive WMS (0000-0003-3533-4580)* contributed to the design, data search, writing and final review of the manuscript. ■

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