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Two years into the COVID-19 pandemic: implications for the cardiac catheterization laboratory and its current practices

Dois anos de pandemia da COVID-19: implicações para as salas de hemodinâmica e suas práticas atuais

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ABSTRACT - COVID-19 continues to overwhelm healthcare systems. During the peak of the pandemic, cardiac catheterization labs across the world observed a significant decrease in procedure volumes due to several reasons, including reallocation of medical resources, deployment of interventional cardiologists to the COVID-19 wards, and physician and patient concerns about viral transmission. In particular, structural heart disease interventions experienced a significant reduction in volume by more than 90%. To address these challenges, healthcare systems employed new safety measures and protocols, including COVID-19 rapid polymerase chain reaction pretesting, Personal Protective Equipment, and vaccination mandates to ensure safety of patients and healthcare workers. Although these measures partly addressed safety concerns, diagnosis and management of acute myocardial injury remained challenging throughout the pandemic. While the pathophysiological mechanisms leading to myocardial injury is not fully elucidated, most studies have suggested COVID-19 is a pro-inflammatory disease associated with a hypercoagulable state. Ongoing randomized studies are evaluating the efficacy of more aggressive antithrombic regimens in COVID-19. In addition, the presentation of acute coronary syndrome with concomitant COVID-19 infection is variable, more likely atypical, delayed, and is associated with higher rates of adverse cardiovascular events and death. It was necessary to implement protocols to expedite diagnosis, triage and management of patients with acute coronary syndrome, while minimizing the risk of viral transmission to hospital staff. Robotic percutaneous coronary intervention may offer in the future a potential solution to many of the safety concerns faced by interventional cardiologists during the COVID-19 era; however, it has its own set of limitations.

Keywords: COVID-19; Coronavirus infections; SARS-CoV-2; Hemodynamics; Acute coronary syndrome; Percutaneous coronary intervention; Robotic surgical procedures; Personal protective equipment; Personnel, hospital

RESUMO - A COVID-19 continua a sobrecarregar os sistemas de saúde. No auge da pandemia, os serviços de hemodinâmica do mundo todo tiveram redução significativa no volume de procedimentos devido a vários motivos, incluindo redistribuição de recursos médicos, alocação dos cardiologistas intervencionistas em alas da COVID-19 e preocupações dos médicos e pacientes com a transmissão viral. Em especial, as intervenções para doença cardíaca estrutural tiveram queda importante – de mais de 90% do volume. Para enfrentar esses desafios, os sistemas de saúde empregaram novas medidas de segurança e protocolos, incluindo pré-teste com reação em cadeia da polimerase para COVID-19, Equipamentos de Proteção Individuais e exigência de vacinação para garantir a segurança de pacientes e trabalhadores da saúde. Embora tais medidas tenham abordado parcialmente as questões de segurança, o diagnóstico e o tratamento da injúria miocárdica aguda permaneceram desafiadores durante a pandemia. Enquanto os mecanismos fisiopatológicos que causam injúria miocárdica não estão completamente elucidados, a maioria dos estudos sugere que a COVID-19 seja uma doença pró-inflamatória, associada a um estado de hipercoagulabilidade. Os estudos randomizados em andamento avaliam a eficácia de regimes antitrombóticos mais agressivos na COVID-19. Além disso, a apresentação de síndrome coronariana aguda junto da COVID-19 é variável, mais provavelmente atípica, tardia e está associada a altas taxas de eventos cardiovasculares adversos e óbito. É necessário implementar protocolos para agilizar diagnóstico, triagem e tratamento de

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pacientes com síndrome coronariana aguda, e também minimizar o risco de transmissão viral para os funcionários do hospital. A intervenção coronariana percutânea robótica oferece uma solução em potencial para as diversas questões de segurança enfrentadas pelos cardiologistas intervencionistas na era da COVID-19. Porém, ela também se apresenta com seu conjunto de limitações.

Descritores: COVID-19; Infecções por coronavírus; SARS CoV-2; Hemodinâmica; Síndrome coronariana aguda; Intervenção coronária percutânea; Procedimentos cirúrgicos robóticos; Equipamento de proteção individual; Recursos humanos em hospital

INTRODUCTION

Coronavirus disease 2019 (COVID-19) continues to be a global pandemic with significant morbidity and mortality, which is affecting the healthcare system worldwide. In the United States alone, more than 73 million cases of infection and 850 thousand deaths due to COVID-19 had been reported up to February 2022.[1] At the peak of the pandemic, hospitals around the world were flooded with admissions due to COVID-19-related respiratory infection, forcing them to cease elective surgeries and procedures to prevent nosocomial infections, maximize hospital capacity for COVID-19 patients, and maintain medical resources. Interventional cardiology experienced a significant and unprecedented impact on operations in the cardiac catheterization laboratory. Like many other specialists, interventional cardiologists found themselves working outside their usual work environment to help care for COVID-19 patients.[2] Given the significant influence of COVID-19 on the cardiac catheterization laboratory, we review impacts on Interventional Cardiology procedure volume and outcomes, institutional protocols to protect staff and patients, pathogenesis of myocardial injury in COVID-19 patients, triage and management of patients with acute coronary syndromes (ACS) and the future of Interventional Cardiology in the era of COVID-19. Lastly, insights from our own experience at a single large volume catheterization laboratory located in Mount Sinai Hospital, New York City, will be provided.

IMPACT OF COVID-19 ON CARDIAC CATHETERIZATION LAB

During the peak of the pandemic, in the spring of 2020, there was a significant reduction in invasive procedure volumes, including coronary angiography and percutaneous coronary interventions (PCI) for stable coronary heart disease. The cardiac catheterization laboratory for ST-segment elevation myocardial infarction (STEMI) activation also decreased.[3-6] Patients were reluctant to come to the hospital due to fear of contracting coronavirus, which delayed presentations for ACS. Furthermore, cardiologists were concerned about the potential for viral transmission and increased morbidity/mortality.[3,7,8] Patients often presented late to the hospital, experienced longer ischemic times and had prolonged door-to-balloon times, which translated into more severe presentations and worse outcomes compared to the pre-pandemic era.[9-11] Structural heart disease interventions also experienced a reduction in volumes by more than 90%.[7] These procedures included transcatheter aortic valve replacement (TAVR), transcatheter mitral valve repair (MitraClip®) and left atrial appendage occlusion.[7]

SAFETY MEASURES

To ensure the safety of patients and hospital staff, multiple measures and new protocols have been developed at the institutional and personal levels. Most catheterization labs have established formal protocols for selecting and performing invasive procedures and placed moratoriums on non-urgent elective procedures. New safety measures included COVID-19 rapid polymerase chain reaction (PCR) pretesting; increased access to Personal Protective Equipment (PPE), such as FIT-tested N-95 masks, gowns, and safety eyewear; separate procedure rooms and wards for COVID-19 patients; specific donning and doffing procedures and protocols to screen patients that are potentially suitable for systemic thrombolysis instead of PCI to reduce the risk of viral transmission.[12] Adding to these measures was vaccination status, which helped control the spread of the disease and reduce illness severity. The Mount Sinai Hospital Cardiac Catheterization Laboratory has adopted strict protocols to prevent the spread of COVID-19. Hospital staff are required to be fully vaccinated against COVID-19 (including booster shots) and nasopharyngeal PCR testing is mandatory for patients a minimum of 72 hours prior to the procedure. The volume of coronary and structural heart disease procedures has risen steadily throughout the pandemic and is currently at pre-COVID era numbers.

PATHOGENESIS OF MYOCARDIAL INJURY IN COVID-19

COVID-19 has been reported to cause acute myocardial injury (AMI). The pathogenesis of this condition is poorly understood and likely multifactorial, involving patient-, disease-and treatment-specific factors.[13] Coronary atherosclerotic plaque rupture can occur during severe COVID-19 infection (type 1 myocardial infarction). Other causes of troponin release may also be present, including imbalances between blood and oxygen supply to the myocardium, Takotsubo cardiomyopathy, septic shock and right heart failure.[14] Additionally, analyses of histological specimens collected during autopsy have shown direct cellular viral injury of the myocardium, indicating myocarditis as one of the potential mechanisms underlying myocardial injury in COVID-19.[13] Increased arterial and venous thrombosis mediated by endothelial inflammatory response, microvascular dysfunction, sepsis, hypoxia, sympathetic nervous system overactivity, cytokines and bradykinin have all been hypothesized to play a role.[15] These mechanisms

contribute to the known hypercoagulable state associated with COVID-19 infection, with an increased risk of spontaneous thrombosis and thromboembolism.[15] Prophylactic anticoagulation has been shown to reduce mortality in patients with COVID-19 infection. However, no benefits of therapeutic anticoagulation over prophylactic dosing have been noted so far.[16] The FREEDOM COVID (https://clinicaltrials.gov/ct2/show/NCT04512079) randomized controlled trial is an ongoing study to assess the efficacy of therapeutic anticoagulation with enoxaparin or apixaban and prophylactic anticoagulation with enoxaparin in treatment of hospitalized COVID-19 infection patients. Further research is needed to determine the efficacy of more aggressive antithrombotic regimens in patients with ACS and COVID-19, given their hypercoagulable state.

TRIAGE AND MANAGEMENT OF MYOCARDIAL INJURY IN THE ERA OF COVID-19

The diagnosis and management of myocardial injury during the pandemic presented with their own challenges. First, the presentation of AMI in COVID-19 infection is variable and more likely atypical.[11] Patients with severe COVID-19 infection frequently present with elevated cardiac troponin and variable electrocardiogram (ECG) abnormalities.[17,18] Second, COVID-19 patients with ST-segment elevation on ECG are sometimes noted to have an absence of obstructive coronary artery disease.[19] Third, patients with cardiovascular disease develop severe forms of COVID-19 and have a higher risk of death.[20] Among patients with STEMI, concurrent diagnosis of COVID-19 is associated with significantly higher rates of in-hospital mortality relative to patients without COVID-19.[18] COVID-19 STEMI cases have significantly higher thrombus burden, multivessel coronary thrombosis rates and incidence of in-stent thrombosis.[21] These unfavorable characteristics support the need to correctly identify all STEMI patients with concurrent COVID-19. Consequently, the classification and management of myocardial injury and ACS in the setting of COVID-19 have become the center of discussion during the pandemic to minimize unnecessary exposure to the virus and expedite the management of ACS.

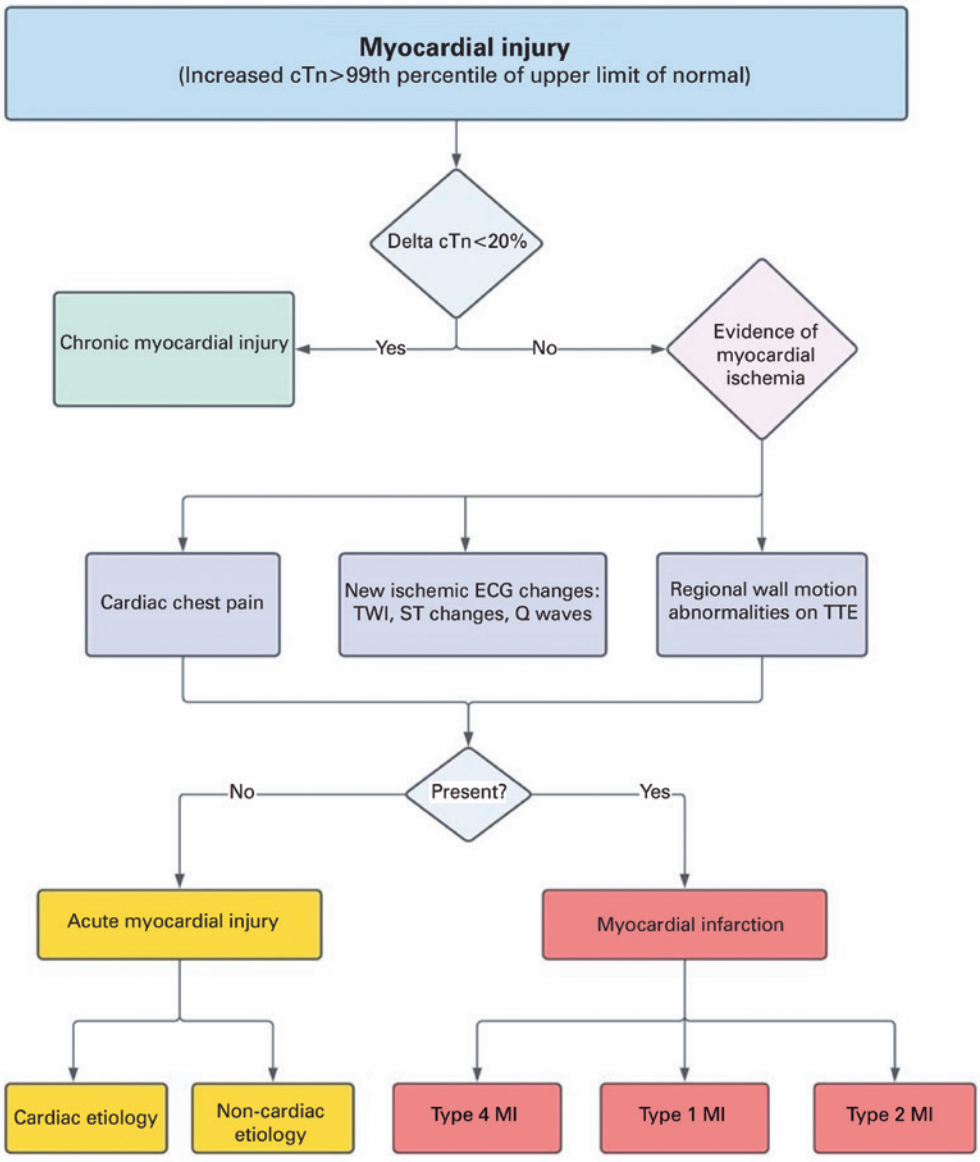
Myocardial injury (defined as increased cardiac troponin above the 99th percentile of normal) is highly prevalent among patients with COVID-19.[22,23] In the Mount Sinai healthcare system, 31% of patients with COVID-19 also had myocardial injury and, of these, 78% had AMI.[24] The presence of myocardial injury was associated with higher morbidity and mortality, especially if concurrent transthoracic echocardiogram (TTE) abnormalities were found.[17,24-29] COVID-19 patients with myocardial injury can be risk-stratified, according to cardiac troponin values and changes in troponin levels in the context of cardiovascular disease history and other risk factors (Figure 1).[30] In younger patients (<65 years) and in those without coronary artery disease, AMI has been reported to significantly worsen prognosis, which likely represents inflammation and thrombosis as key mechanisms.[24] Patients with COVID-19 and myocardial injury have a higher incidence of echocardiographic abnormalities, including left ventricular dysfunction, left ventricular wall motion abnormalities, grade II or III diastolic dysfunction, right ventricular dysfunction and pericardial effusion, which have been shown to carry a poorer prognosis.[29] In the era of COVID-19, the classification of myocardial injury as true ACS, non-ischemic myocardial injury or chronic myocardial injury is particularly important to reduce unnecessary exposure in the cardiac catheterization laboratory. Protocols to identity true ACS include increased utilization of point of care cardiac ultrasound to detect focal wall motion abnormalities, serial ECGs and monitoring of cardiac troponin level changes.[24]

Increases in cardiac troponin are categorized as chronic myocardial injury, acute myocardial injury (non-ischemic) or acute myocardial infarction. Delta is defined as maximum cardiac troponin changes 48 and 72 hours after the diagnosis of COVID-19.

Primary PCI (i.e., within 90 minutes of first medical contact) has been the standard of care for patients presenting to PCI centers with STEMI. However, during the COVID pandemic, hospitals have adopted algorithms to triage cardiovascular emergencies into different risk strata to balance the timeliness of treatment and the safety of patients and medical personnel.[31] A consensus statement by the Society of Cardiovascular Angiography and Interventions (SCAI®), the American College of Cardiology (ACC) and the American College of Emergency Physicians (ACEP) has outlined multiple protocols for ACS management during COVID-19 pandemic, such as out of hospital STEMI and referral hospital STEMI.[12] The Mount Sinai Hospital's Cardiac Catheterization Laboratory has developed its own protocols to manage different ACS scenarios, such as in-hospital STEMI (Figure 2).

FUTURE OF THE CARDIAC CATHETERIZATION LAB

More than ever, novel challenges of COVID-19 add to the traditional risks of PCI, which have dictated the need to refine PCI approaches. Robotic PCI (R-PCI) offers a potential solution to many of the safety concerns faced by interventional cardiologists in the COVID-19 era. With regard to traditional risks, R-PCI decreases exposure to ionizing radiation by up to 97%, allows more accurate assessment of lesion length and enables precise deployment of coronary balloons and stents.[32] Robotic PCI can reduce the risk of exposure to COVID-19 by enabling social distancing in the catheterization lab, especially when the patient is COVID-19 positive. The safety and efficacy of R-PCI have been evaluated in the PRECISE (Percutaneous Robotically Enhanced Coronary Intervention) and the CORA-PCI (Complex Robotically Assisted Percutaneous Coronary Intervention) trials.[33,34] Although these studies did not include emergency cases of ACS, R-PCI provides a clear benefit to the operator in terms of radiation exposure while maintaining



Source: The Mount Sinai Hospital Cardiac Catheterization Laboratory.

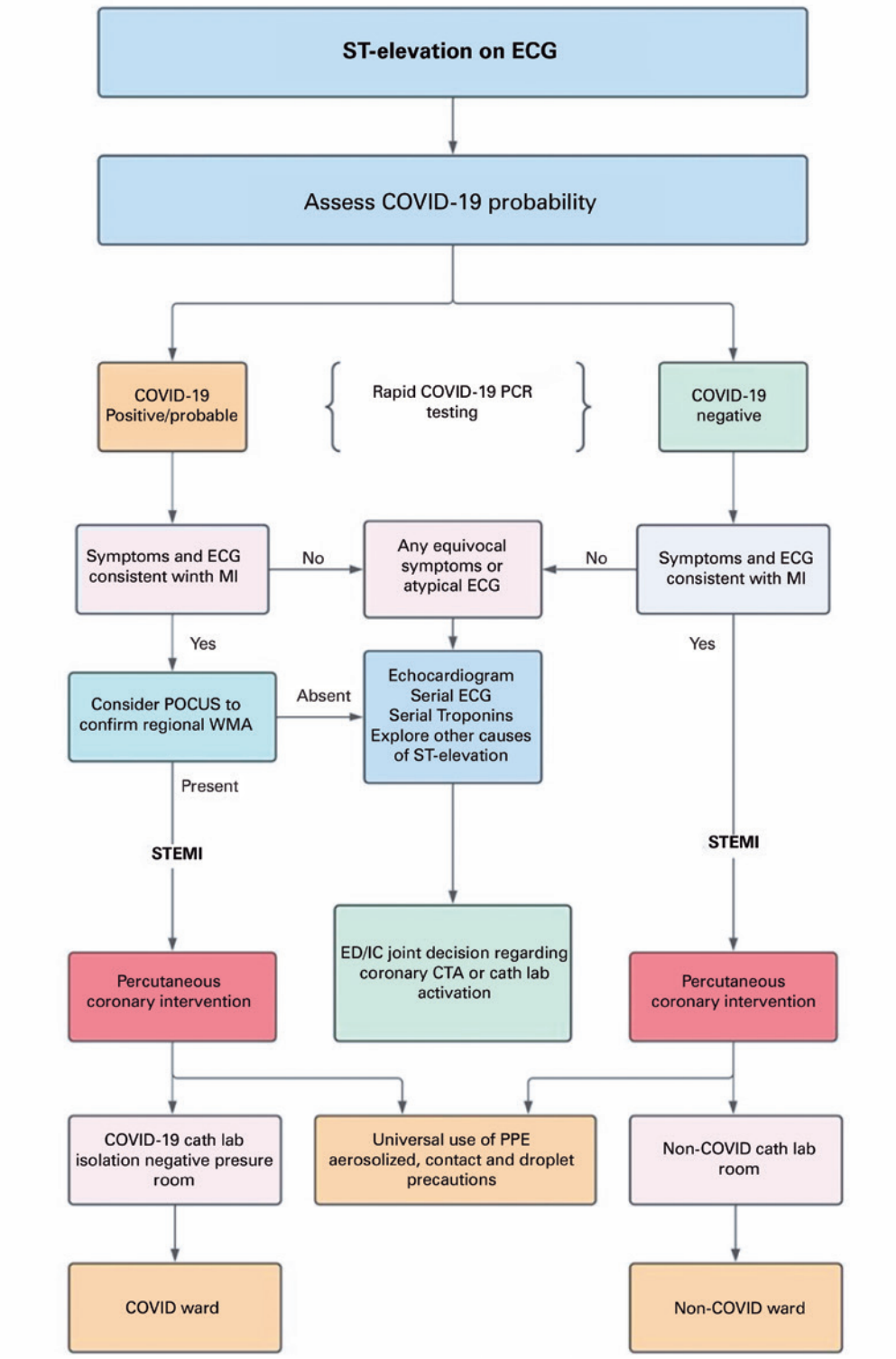
cTn: cardiac troponin; ECG: electrocardiogram; TWI: T-wave inversion; TTE: transthoracic echocardiogram; MI: myocardial infarction.

Figure 1. Classification of myocardial injury in COVID-19.

equivalent patient safety measures compared to manual PCI. Despite these benefits, R-PCI is far from perfect. There is a lack of compatibility with over-the-wire devices and the ability to manipulate multiple devices simultaneously during cases of complex PCI, which may become challenging, with up to 10% of cases requiring manual assistance. Additionally, R-PCI has longer procedure times than manual PCI, which could increase door to balloon time, making it a less attractive option in emergency scenarios. Despite these challenges, R-PCI represents an exciting development in the field of Interventional Cardiology, especially in the era of a highly contagious and virulent agent such as the virus implicated in COVID-19.

COMMENTARY

Cardiologists and catheterization labs across the world were impacted by the COVID-19 pandemic. Nonetheless, with the implementation of strict safety protocols and large vaccination campaigns, the volume of cases is steadily rising to pre-pandemic levels. Although poorly understood, COVID-19 is commonly associated with myocardial injury, adverse cardiovascular events and death. COVID-19 is a prothrombotic and proinflammatory viral illness, with evidence suggesting a benefit of more aggressive antithrombotic regimens in acutely ill patients, though more data from large scale randomized trials are needed.



Source: The Mount Sinai Hospital Cardiac Catheterization Laboratory.

ECG: electrocardiogram; PCR: polymerase chain reaction; MI: myocardial infarction; POCUS: point of care ultrasound; WMA: wall motion abnormality; STEMI: ST-elevation myocardial infarction; ED: emergency department; IC: Interventional Cardiology; CTA: computed tomography angiography; PPE: Personal Protective Equipment.

Figure 2. Triage protocol for ST-segment elevation in the electrocardiogram at primary percutaneous coronary intervention centers. In patients with confirmed or likely diagnosis of COVID-19 and classic symptoms and electrocardiogram findings consistent with myocardial infarction, bedside ultrasound for assessment of regional wall motion abnormalities is considered. If the ultrasound is consistent with ST-elevation myocardial infarction, percutaneous coronary intervention should be considered. Otherwise, further testing (transthoracic echocardiogram, serial electrocardiograms and chest radiography) should be carried out to determine the need of percutaneous coronary interventions. Rapid COVID-19 polymerase chain reaction testing should be done if available, to help determine the use of a dedicated catheterization lab and postprocedural hospital unit placement.

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None.

CONFLICTS OF INTEREST

The authors declare there are no conflicts of interest.

CONTRIBUTION OF AUTHORS

Conception and design of the study: AS, VR and GDD; data collection: AS and VR; data interpretation: AS and VR; text writing: AS, VR, JN and FB; approval of the final version to be published: GDD.

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