

COVID-19 and cardiovascular imaging: a guide for the practising clinician

Ruchika Meel^{*}, Blanche Cupido^{#,‡}, Alfonso Pecoraro[†], Anton Doubell[†], Wayne Lubbe[‡] and Ntobeko A.B. Ntusi^{‡#,‡,∞}

^{*}Division of Cardiology, Department of Medicine, Chris Hani Baragwanath Academic Hospital and University of the Witwatersrand, Johannesburg, South Africa

[#]Division of Cardiology, Department of Medicine, Faculty of Health Sciences, University of Cape Town and Groote Schuur Hospital, Observatory, Cape Town, South Africa

[†]Division of Cardiology, Department of Medicine, Stellenbosch University and Tygerberg Hospital, Bellville, South Africa

[‡]St Dominics Private Hospital, Southernwood, East London, South Africa

[‡]Hatter Institute for Cardiovascular Research in Africa, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa

[∞]Cape Universities Body Imaging Centre, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa

Address for correspondence:

Dr Ruchika Meel
Division of Cardiology
Department of Medicine
Chris Hani Baragwanath Academic Hospital
PO Bertsham
Johannesburg
2013
South Africa

Email:

ruchikameel@gmail.com

INTRODUCTION

Coronavirus disease-2019 (COVID-19), caused by SARS-CoV-2, has been declared a global pandemic,⁽¹⁾ and numbers of new cases increase daily in Africa (Table 1 for abbreviations).⁽²⁾ From limited data, SARS-CoV-2 involves the cardiovascular system in multiple ways.⁽³⁾ As cardiologists we play a critical role in the management of these patients. Cardiovascular imaging such as echocardiography, cardiac computed tomography (CCT) and cardiovascular magnetic resonance (CMR) are central in the diagnosis and management of patients with cardiovascular disease (CVD) who may have COVID-19. As imagers we physically engage in the investigation and management of such patients, especially with echocardiography where close contact is inevitable, and this predisposes to increased risk of infection. In this review, we highlight the risks associated with various non-invasive cardiovascular imaging modalities,

ABSTRACT

In the ongoing COVID-19 pandemic, patients with cardiac disease have been the worst afflicted with a high mortality. Cardiac imaging forms an integral part of the armamentarium in the management of these patients. This review focuses on providing a general guide to cardiac imaging in the COVID-19 context for the practising clinician in Africa. These recommendations are likely to be modified as further data emerge on the effect of the SARS-CoV-2 virus on the cardiovascular system.

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revise indications for cardiovascular imaging in the COVID-19 context, and how risks associated with each modality may be mitigated based on current guidelines and recommendations from experts.

TRANSTHORACIC ECHOCARDIOGRAPHY: INDICATIONS, RISKS, RISK MITIGATION, PREPARATION OF ECHOCARDIOGRAPHY LABORATORY AND PERSONNEL

During the COVID-19 pandemic, indications for all special investigations and procedures have to be reconsidered due to the increased demand on healthcare resources and the risk of infection of healthcare workers (HCW). In terms of transtho-

TABLE 1: Abbreviations.

AGP	Aerosol generating procedure
CCT	Cardiac computed tomography
CMR	Cardiovascular magnetic resonance
COVID-19	Coronavirus disease-2019
CVD	Cardiovascular disease
HCWs	Healthcare workers
LA	Left atrium
LAA	Left atrial appendage
PPE	Personal protective equipment
PUI	Persons under investigation
SARS-CoV-2	Severe acute respiratory syndrome coronavirus-2
TEE	Transoesophageal echocardiography
TTE	Transthoracic echocardiography

racic echocardiography (TTE), this will imply that TTE should only be performed if it would influence or alter therapy in the short term. TTE should be limited to mostly inpatients, although a limited number of outpatients will have a clinical indication for TTE. No routine or follow-up TTE should be performed – except if there is a clear clinical indication.

In the outpatient services all patients entering the service from home should be screened for symptoms (preferably telephonically and ahead of time if your service can accommodate this, or else at the entrance to your service by a dedicated staff member).⁽⁴⁾ Anyone reporting concerning symptoms should have the echo postponed and the local institutional protocol for suspected COVID persons activated. Social distancing, of a minimum of 1.5m, should be adhered to in your waiting room. It is best to set your area up with designated marked areas where patients can sit. All patients should wear face masks. No companions/family are allowed in the waiting rooms or the echo room.

The risk to HCW performing TTE is significant, although not as high as transoesophageal echocardiography (TEE), which is considered an aerosol-generating procedure (AGP).⁽⁵⁾ The risk to HCW performing TTE is a consequence of direct contact with the patient, the proximity to the upper respiratory tract of the patient, prolonged (>15 minutes) contact with the patient, and the contamination of equipment that poses a risk during future image acquisitions.

The TTE service in each hospital or practice should be set up to minimise the risk of infection to HCW by undiagnosed or asymptomatic patients. It is currently not feasible to test every patient for COVID-19 before performing an echocardiogram – even if it were possible the false negative rate will make this strategy ineffective. Infection with COVID-19 of HCW poses a risk to patients in terms of the availability of echocardiographic service and the potential risk of nosocomial transmission of the virus. Echocardiography skills are limited in South Africa and should a significant portion of echocardiographically competent HCW become infected with COVID-19, continuity of care will be interrupted. HCW at significant risk of developing severe COVID-19 infection should be considered for reporting or interpretation of images only and should limit and, where possible, avoid patient contact.

For inpatient services, all requests are to be reviewed and triaged by a senior clinician in the echo service (fellow or consultant) and prioritised according to medical need in establishing a definitive diagnosis and therapeutic intervention.⁽⁶⁾ These decisions are to be taken on a case-by-case basis rather than a prescribed list of conditions given the fluid nature of the pandemic at present. There is a need to review practices on a fortnightly basis to adapt protocols and workflow according to

the needs of the pandemic. Traffic and exposure in the echocardiography laboratory should be minimised as much as possible – telephonic and/or electronic requests are preferable. Establishing a system for timeously and efficiently transporting patients will minimise waiting time of inpatients and risk of exposure to staff. The following steps should be followed routinely when scanning the undifferentiated patient to mitigate the risk of patient to HCW transmission of COVID-19 during echocardiography:

- Review the indication for the study.
- All patients should wear a surgical or cloth mask.
- HCW should wear appropriate personal protective equipment (PPE).⁽⁵⁾
- If available, use hand-held echocardiography machines.
- The echocardiographer should continue to image from the side of the patient that enables them to get relevant images in the shortest period of time. Although scanning from the right side of the patient is advantageous, a switch from left to right side at this stage may prolong scan time.
- Acquire only the minimum data set, and minimise acquisition time.
- All measurements, post processing and reporting to be performed after patient leaves the room or offline if available.
- Echocardiography machines need to be regularly disinfected as per manufacturer's guidelines.^(7,8)
- Regular cleaning of the echocardiography suite.

For patients under investigation for COVID-19 (PUI) or confirmed COVID-19 infection, echocardiography should only be performed if the result will alter short-term management. Examples of indications include: Heart failure/myocarditis, significant or life threatening arrhythmias, cardiac tamponade and cardiogenic shock or haemodynamic instability. If not, echocardiography should be deferred until after recovery (usually 14 days). During echocardiography of PUI or confirmed COVID-19 patients, additional precautions are advised:

- HCW at high risk of developing severe COVID-19 infection should not perform echocardiography.
- The most skilled operator available should acquire images.
- Do not transport patients to the echocardiography suite; images to be acquired in isolation room (mobile).
- Use dedicated device for COVID-19 patients if possible.
- Use a handheld device, if possible, as disinfection is easier.
- Abbreviated image acquisition protocol to answer the clinical question – no minimum data set.

- Aim to answer the clinical question using the subcostal acoustic window only in ventilated patients.
- Do not attach ECG leads – use time gating.
- If possible, also use individual/disposable gel dispensing methods such as gel sachets or syringes. During the scan, if availability allows, use disposable plastic probe protectors and covers for the machine.⁽⁴⁾
- All post processing, measurements and reporting to be performed offline or after doffing.
- Donning and doffing as per protocol.
- Device to be cleaned as per manufacturer's guidelines.
- Ensure that the machine is stored in a dedicated area away from the other machines and equipment utilised for non-COVID patients.

During the early phase of the pandemic, it makes sense to have dedicated echocardiographic machines in COVID-19 areas to perform TTE. This lowers the risk of spread of the virus associated with the movement of equipment. As community spread of the virus increases, all patients should be considered COVID-19 positive – even if they had a recent negative nasopharyngeal and oropharyngeal swab, as the negative predictive value of these swabs is low.

Existing personnel should be risk stratified. Those at higher risk (age >60 years, immunocompromised state, cardiorespiratory disease, BMI >40) should ideally not be working in the front-line.⁽⁴⁾ All staff should be familiar with the protocols for scanning COVID-19 patients, the indications for various levels of personal protective equipment (PPE), know where to access the PPE, as well as how to doff and don the PPE.

There is a decrease in patients without COVID-19 accessing cardiac care, both as a result of the limited availability of the services and of patients with cardiac complaints seeking medical care. Several guideline documents highlight the need to balance essential cardiovascular services while preserving HCW resources during the peak of the COVID-19 pandemic. As the pandemic abates, there will be an opportunity to reintroduce routine cardiovascular care (of which TTE is an important component), with the appropriate safety measures in place.

We recommend a pragmatic approach to the reintroduction of outpatient echocardiography, and that outpatient appointments are preceded by a short telephonic consultation to ensure screening for COVID-19 symptoms and to aid with planning of the appointment. During these visits, the standard practice of mask wearing, hand sanitation and physical distancing should be adhered to.

TRANSOESOPHAGEAL ECHOCARDIOGRAPHY: INDICATIONS, RISKS, RISK MITIGATION, PREPARATION OF LABORATORY AND PERSONNEL

TEE poses a great risk to operators and their team.⁽⁹⁾ This is due to the inherent greater risk of aerosolisation of virus particles – especially during intubation. Urgent indications include patients with left-sided infective endocarditis, poor imaging quality on trans-thoracic echocardiography, suspected prosthetic valve thrombosis or endocarditis where TTE provides insufficient information. If there is an indication for TEE, all patients must be tested for COVID-19 prior to the exam. TEE should be avoided in a confirmed case of COVID-19. Recently, stroke has emerged as one of the complications related to COVID-19 infection. In this context, it is usually related to pro-thrombotic milieu and micro-angiopathy associated with COVID-19, and is unlikely related to an intra-cardiac shunt.⁽¹⁰⁾ Therefore, TEE should be deferred as it is unlikely to change diagnosis and management. A TTE bedside bubble study may be considered. If any doubt exists, the individual case must be discussed with the heart team.

In general, the diagnostic investigation should be deferred to an imaging modality that is associated with lesser risk, but with the similar ability to answer a clinical question as TEE.⁽¹¹⁾ A classic example would be that of a patient requiring cardioversion for dysrhythmia, such as atrial fibrillation. For exclusion of thrombus in the left atrium (LA) or left atrial appendage (LAA), cardiac computed tomography (CCT) may be utilised. Further elective procedures such as structural heart disease intervention that require guidance with TEE should be postponed unless there is urgency or emergency. In the African context, this constitutes mostly patients for balloon mitral valvuloplasty that present with acute heart failure while pregnant.

The echocardiography laboratory set-up, and PPE for TEE remains the same as for TTE described above. All TEE must be ideally performed in a dedicated echocardiography room with adequate ventilation and air exchanges. The room and the echocardiographic equipment must be cleaned and decontaminated post-procedure, according to a standardised protocol.

TEE must be performed by an experienced operator to limit the duration of the procedure. Only personnel required to do the TEE should be permitted in the room. All HCWs considered high-risk for getting infected must not be allowed in the area when scanning suspected or confirmed cases of COVID-19. All teaching of trainees must be postponed, and simulation and online videos can be used as substitutes. The procedure must be focused and should be terminated once the clinical question is answered. Unnecessary equipment at risk of contamination, such as electrocardiogram leads, pencil

probes, and carotid Doppler probes, must be removed from the machine. The machine can be covered with a cloth during the procedure to reduce contamination without compromising the operator's view.

CARDIAC COMPUTED TOMOGRAPHY: INDICATIONS, RISK ASSESSMENT AND MITIGATION

Patients must be ideally tested for COVID-19 prior to CCT examination. CCT may be indicated to diagnose coronary artery disease, aortic dissection, pulmonary embolism and left ventricular (LV), LA and LAA thrombus due to a hypercoagulable state⁽¹⁰⁾ associated with SARS-CoV-2. Coronary CT angiography may eliminate the need for invasive coronary catheterisation and reduces the risk to catheterisation laboratory personnel. Lately, Kawasaki's disease has emerged as a rare complication of COVID-19 infection in children, as part of the pro-inflammatory process⁽¹²⁾ and CCT may serve as a useful non-invasive imaging modality in this sub-group of patients to identify aneurysmal involvement of coronary arteries. Any incidental pulmonary finding seen on CCT suggestive of COVID-19 pneumonia in a patient who was not suspected of having the disease must be immediately reported and communicated to the referring physician.⁽¹³⁾ Due to the CT's ability to diagnose early onset pneumonia in an asymptomatic patient, a routine scan of the chest where a patient has an indication for CT is recommended.⁽¹⁴⁾

All elective cases must be postponed, as recommended by the Society for Cardiovascular CT (SCCT).⁽¹³⁾ Urgent CCT indications are described in Table II. Details of indications are discussed in the SCCT guidelines.⁽¹³⁾ In Africa, most cases of chest pain undergo invasive coronary angiography and the role of cardiac CT is limited.

CT scanner room equipment setup and patient transportation are described in the SCCT guidelines.⁽¹³⁾ Transport of a patient to and from the COVID-19 ward must be done as per standardised protocol of each institution. Patients must not wait outside in a general CT laboratory, to reduce infection to other personnel and patients.

TABLE II: Urgent Indications for cardiac computed tomography in the COVID-19 context.

Coronary artery disease assessment in high-risk patient
Left atrial appendage and ventricular thrombus
Pulmonary embolism
Aortic dissection
Cardiac tumours
Prosthetic valve thrombosis and endocarditis
Patient requiring urgent structural heart disease intervention

Staff education, personal protective equipment and decontamination must be done as per SCCT guidance.⁽¹³⁾ In health-care facilities with more multiple CT scanners, one scanner can be dedicated to COVID-19 cases. This is not possible in the majority of hospitals in Africa and thus strict decontamination measures and personal protective measures must be followed.

CARDIOVASCULAR MAGNETIC RESONANCE: INDICATIONS, RISK ASSESSMENT AND MITIGATION IN THE CONTEXT OF COVID-19

CMR is a remarkably powerful imaging modality, free of ionising radiation, with high spatial and temporal resolution, performed via excitation of hydrogen protons within a powerful magnetic field. The strong magnetic field aligns the nuclear magnetisation spin of the hydrogen protons, which are then excited by radiofrequency pulses. Fourier transformation is then used to convert frequencies into images. Signal from a given tissue (e.g. heart muscle) is determined by the proton density and 2 specific relaxation parameters: longitudinal relaxation and transverse relaxation times, which vary substantially for different tissues, and substantially within the same tissue from health to disease.⁽¹⁵⁾

A CMR scanner consists of a superconducting magnet, a radio-frequency transmitter and receiver connected to radio aerials, and gradient coils driven by powerful pulses of electricity to create transient magnetic fields. Scanning sequences are coordinated to the electrocardiographic complexes. Indications and contra-indications for CMR are included in Table III. CMR is extremely safe, and unequivocally advantageous compared with x-ray and scintigraphic techniques. Patients for CMR must be screened as ferromagnetic particles may act as potentially dangerous projectiles in the vicinity of the scanner. Although most metallic medical implants – including all prosthetic cardiac valves, stents, conduits, pacemakers and implantable-cardioverter defibrillators are MR compatible or conditional – care needs to be taken with certain implants like insulin drivers and cerebrovascular clips. Gadolinium-based contrast agents have proved extremely safe in tens of millions of patients. The risk of nephrogenic sclerosing fibrosis appears extremely low, particularly with the use of cyclic chelates.⁽¹⁶⁾

Healthcare workers in the MR suite are at increased risk of infection from contact with patients infected with SARS-CoV-2, as placement of leads puts them in very close physical contact with patients. COVID-19 is transmitted from person to person through small droplets from the nose or mouth, spread when a person with COVID-19 coughs or exhales. Droplets land on objects and surfaces around the person, and the virus may remain viable on hard surfaces for days (others may catch COVID-19 by touching these objects or surfaces).⁽¹⁷⁾ Importantly, asymptomatic individuals are still capable of transmitting

TABLE III: Indications and contra-indications for cardiovascular magnetic resonance.

Common indications	Contraindications
Accurate assessment of LV function	Absolute
Cardiac function and anatomy for device implantation	Non-MR compatible implantable devices
Myocardial viability	Severe claustrophobia
Detection of intraventricular thrombus	
Myocarditis	Relative
Myocardial inflammation/oedema	Dysrhythmia affecting ECG gating
Interstitial fibrosis (dilated and infiltrative/restrictive cardiomyopathies)	Severe renal impairment (risk of nephrogenic systemic fibrosis)
Congenital heart disease	
RV quantification	
Evaluation for ARVC	
Post OHT cardiac surveillance	
Constrictive pericarditis	
Quantification of valvular function	
Aortic and vascular assessments	
Iron overload quantification	

ARVC = Arrhythmogenic right ventricular cardiomyopathy, ECG = electrocardiogram, LV = left ventricle, MR = magnetic resonance, OHT = orthotopic heart transplantation.

the virus. The Society for Cardiovascular Magnetic Resonance (<https://scmr.org/page/COVID19>), European Association of Cardiovascular Imaging (<https://www.escardio.org/The-ESC/Press-Office/Press-releases/ESC-Guidance-for-the-Diagnosis-and-Management-of-Heart-Disease-during-COVID-19>), and American College of Radiology [ACR] (<https://www.acr.org/Clinical-Resources/Radiology-Safety/MR-Safety/COVID-19-and-MR-Use>) recommend that CMR should be avoided in patients with COVID-19, or in persons under investigation, to minimise risk to healthcare workers, unless the test is absolutely necessary and is the only diagnostic tool that can be used, and imaging is likely to impact imminent clinical management.⁽¹¹⁾ All other studies should be delayed or alternative imaging methods such as point-of-care or portable ultrasound or CT considered.

If patients do have a CMR study, appropriate PPE should be worn by imaging staff and patients should also wear a standard surgical or cloth mask, and shortened protocols should be used.⁽¹⁸⁾ Whenever possible, the imaging department should dedicate a specific area (including waiting space) and specific equipment (e.g. MR scanner) to the evaluation of patients with suspected or confirmed COVID-19, to minimise the risk of contamination of other patients and to concentrate the protective material availability.

The ACR has also recommended for the following:

- **Cleaning of MR machines:** while instructions and strategies for cleaning and disinfecting MR machines (with water and soap or alcohol-based disinfectants) will vary by loca-

tion and the availability of PPE, the ACR recommends 60 minutes of down-time between patients and after all surfaces have been thoroughly cleaned.

- **PPE:** powered air-purifying ventilators should not be brought into the vicinity of the scanner, as these contain ferromagnetic components.
- **Masks:** inpatients who have metal strips on masks should be fitted with MRI-safe alternatives, and metallic strips should be removed from face masks and replaced with tape.

In some hospitals, the use of a mobile CT unit close to the location where clinical triage is performed at the entrance to the hospital might be considered, depending on the availability of access to standard CT equipment.

The approach to cardiac imaging in COVID-19 is summarised in Figure 1.

CONCLUSIONS

Cardiac imaging is an essential service in patient care, not only in patients presenting with cardiac conditions, but across the spectrum of medicine. This holds true in the COVID-19 pandemic as well, albeit tainted by the real risks to HCWs when performing cardiac imaging. The overarching principle when performing cardiac imaging in COVID-19 patients is to perform imaging only when the information will impact on the

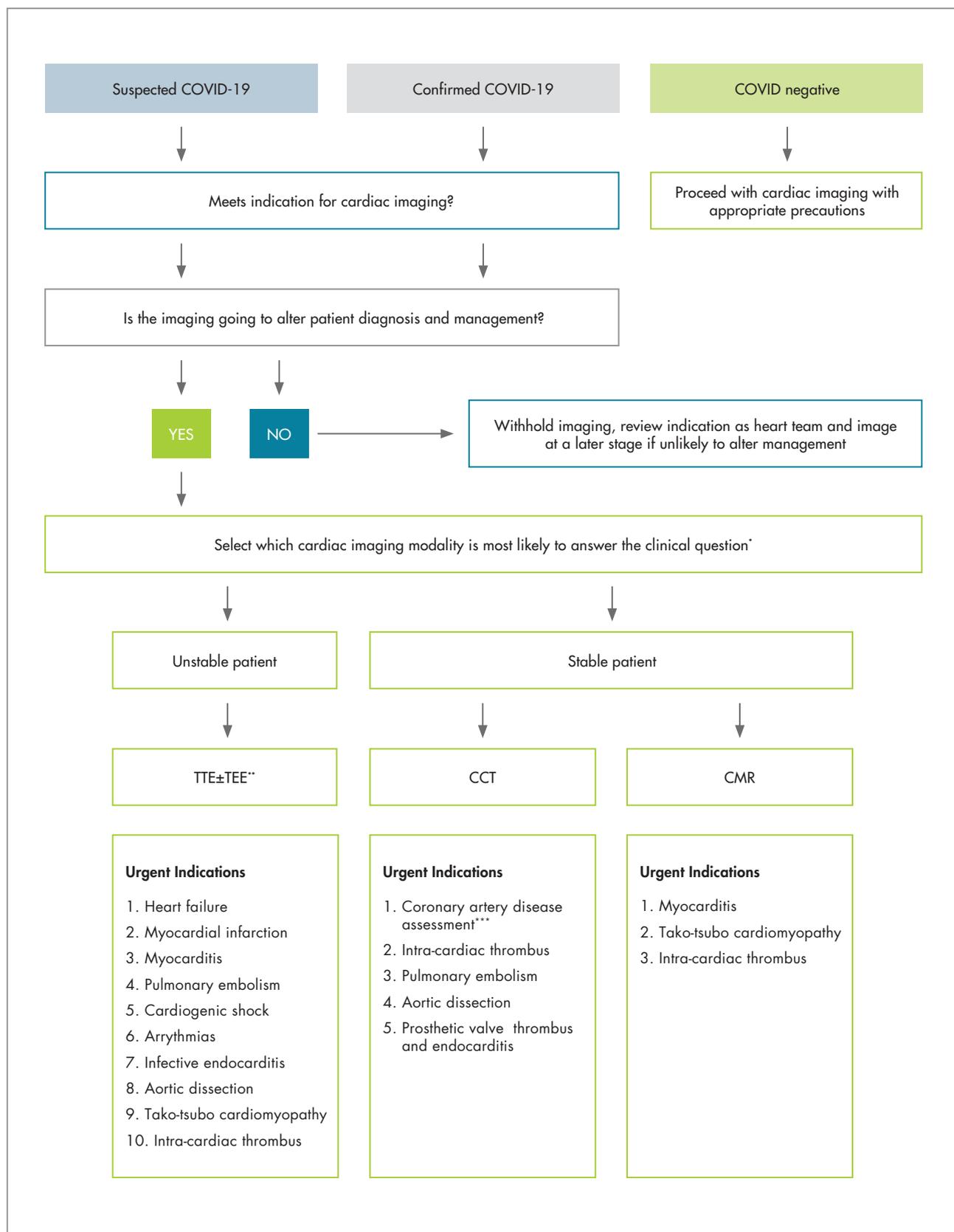


FIGURE 1: Approach to cardiac imaging in COVID-19 context.

*Avoid using multiple imaging modalities and use the imaging modality that is readily available and has the most expertise.
 **TEE should be deferred as far as possible and if absolutely necessary should be done with guideline recommended PPE.
 ***High risk for coronary artery disease.

immediate management of the patient and to obtain only the information required to make the decision.

Echocardiography remains the mainstay of cardiac imaging in these patients and CCT and CMR are limited to several specific indications. CT in COVID-19 patients is often done for pneumonia. When performed, it also creates an opportunity to obtain cardiac information (e.g. the presence or absence of thrombi in the LAA or LV). Dedicated CCT imaging should be reserved for cardiac emergencies such as aortic dissection or pulmonary embolism. CMR is a remarkably powerful imaging tool, but is generally not recommended in COVID-19 patients who are shedding the virus. Its unique ability to provide tissue characterisation is arguably a property sought after in the management of patients with suspected COVID-19 myocarditis, but as it will not affect immediate management, it is not included in most current management protocols. Mobility, versatility and utility of TTE has earned the echocardiographer the dubious honour of being the preferred source of imaging information in COVID-19 patients. Given the risk of aerosolisation accompanying TEE, it is to be avoided in COVID-19 patients as far as possible.

Where possible, the imaging service should aim to retain a "clean service" dedicated to non-COVID-19 patients, with a limited imaging service dedicated to COVID-19 patients – the latter preferably being provided in the COVID-19 areas of hospitals, so avoiding transport of patients. At all times, strict protocols emphasising physical distancing, mask wearing by patients, appropriate PPE utilisation by medical staff, and meticulous cleaning practises for staff, equipment and service areas, must be practised.

This article provides the reader with compact information and a sound approach to delivering a safe cardiovascular imaging service during the pandemic.

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