**Name of Journal:** *World Journal of Clinical Cases*

**Manuscript NO:** 76613

**Manuscript Type:** REVIEW

**Cardiovascular disease and COVID-19, a deadly combination: A review about direct and indirect impact of a pandemic**

Vidal-Perez R *et al*. Cardiovascular disease and COVID-19

Rafael Vidal-Perez, Mariana Brandão, Michal Pazdernik, Karl-Patrik Kresoja, Myriam Carpenito, Shingo Maeda, Rubén Casado-Arroyo, Saverio Muscoli, Janine Pöss, Ricardo Fontes-Carvalho, Jose Manuel Vazquez-Rodriguez

**Rafael Vidal-Perez, Jose Manuel Vazquez-Rodriguez,** Servicio de Cardiología, Unidad de Imagen y Función Cardíaca, Complexo Hospitalario Universitario A Coruña Centro de Investigación Biomédica en Red-Instituto de Salud Carlos III, A Coruña 15006, Spain

**Mariana Brandão, Ricardo Fontes-Carvalho,** Department of Cardiology, Centro Hospitalar de Gaia, Gaia 4400-020, Portugal

**Michal Pazdernik,** Intensive Care Unit, Department of Cardiology, Institute for Clinical and Experimental Medicine Prague, Prague 14021, Czech Republic

**Karl-Patrik Kresoja, Janine Pöss,** Heart Center Leipzig, University of Leipzig, Leipzig 04289, Germany

**Myriam Carpenito,** Unit of Cardiac Sciences, Department of Medicine, Campus Bio-Medico University of Rome, Rome 00128, Italy

**Shingo Maeda,** Arrhythmia Advanced Therapy Center, AOI Universal Hospital, Kawasaki 210-0822, Japan

**Rubén Casado-Arroyo,** Department of Cardiology, Hôpital Erasme, Université Libre de Bruxelles, Brussels 1070, Belgium

**Saverio Muscoli,** Unit of Cardiology, Policlinico Tor Vergata, Rome 00133, Italy

**Ricardo Fontes-Carvalho,** Department of Surgery and Physiology, Faculty of Medicine of the University of Porto, Porto 4200-319, Portugal

**Author contributions:** Vidal-Perez R designed, edited, and wrote the final paper; Brandão M, Pazdernik M, Kresoja KP, Carpenito M, Maeda S, Casado-Arroyo R, Pöss J, and Fontes-Carvalho R performed the collection of the data and helped in writing the original draft; Vidal-Perez R and Vazquez-Rodriguez JM contributed to the critical revision and editing of the paper; all authors wrote, read, and approved the final manuscript.

**Corresponding author: Rafael Vidal-Perez, FACC, FESC, PhD, Reader (Associate Professor), Staff Physician,** Servicio de Cardiología, Unidad de Imagen y Función Cardíaca, Complexo Hospitalario Universitario A Coruña Centro de Investigación Biomédica en Red-Instituto de Salud Carlos III, As Xubias de Arriba - 84, A Coruña 15006, Spain. rafavidal@hotmail.com

**Received:** March 22, 2022

**Revised:** April 25, 2022

**Accepted:** August 24, 2022

**Published online:** September 26, 2022

**Abstract**

Coronavirus disease 2019 (COVID-19) is known to present with respiratory symptoms, which can lead to severe pneumonia and respiratory failure. However, it can have multisystem complications such as cardiovascular manifestations. The cardiovascular manifestations reported comprise myocarditis, cardiogenic shock, arrhythmias, pulmonary embolism, deep vein embolism, acute heart failure, and myocardial infarction. There is also an indirect impact of the pandemic on the management of cardiovascular care that has been shown clearly in multiple publications. In this review, we summarize the deadly relation of COVID-19 with cardiovascular events and the wider impact on several cardiovascular care areas by the pandemic situation

**Key Words:** COVID-19; Cardiovascular diseases; Pandemic; Heart failure; Telemedicine; Prognosis

**©The** **Author(s) 2022.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Citation:** Vidal-Perez R, Brandão M, Pazdernik M, Kresoja KP, Carpenito M, Maeda S, Casado-Arroyo R, Muscoli S, Pöss J, Fontes-Carvalho R, Vazquez-Rodriguez JM. Cardiovascular disease and COVID-19, a deadly combination: A review about direct and indirect impact of a pandemic. *World J Clin Cases* 2022; 10(27): 9556-9572

**URL:** https://www.wjgnet.com/2307-8960/full/v10/i27/9556.htm

**DOI:** https://dx.doi.org/10.12998/wjcc.v10.i27.9556

**Core Tip:** The pre-existing cardiovascular disease is an important risk factor for a severe clinical course of coronavirus disease 2019 (COVID-19) and is associated with adverse outcomes. Furthermore, COVID-19 may exacerbate underlying heart disease and is frequently aggravated by cardiovascular complications, such as thromboembolic events and myocardial injury between others. COVID-19 also has been associated with a direct damage of the cardiovascular system. In this review, we will focus on the direct and indirect impact of the pandemic in relation with cardiovascular diseases to show that cardiovascular disease and COVID-19really were a deadly combination.

**INTRODUCTION**

The complete impact of the pandemic has been much greater than what is indicated by reported deaths due to coronavirus disease 2019 (COVID-19) alone. Indirect effects of the pandemic have been present on cardiovascular disease management and could justify partially the excess of death related with COVID-19[1].

The prior presence of cardiovascular disease is an important risk factor for a severe clinical course of COVID-19 and is associated with unfavorable outcomes[2,3]. Furthermore, COVID-19 may aggravate underlying heart disease and is frequently worsened by cardiovascular complications, such as thromboembolic events, malignant arrhythmia, and myocardial injury[4]. COVID-19 also has been associated with a direct damage of the cardiovascular system[5].

In this review, we will focus on the direct and indirect impact of the pandemic in relation with cardiovascular diseases to show that cardiovascular disease and COVID-19 really were a deadly combination.

**Thromboembolic complications**

Arterial and venous thromboembolic events are frequently observed in COVID-19 patients and contribute to increased morbidity and mortality[4,6].

***Venous thrombotic events***

The incidence rates of venous thrombotic events (VTE) reach more than 30% in cohorts of critically ill patients despite pharmacological prophylaxis[7]. As evidence of the activated coagulation system, D-dimer plasma levels are elevated in a relevant proportion of COVID-19 patients, associated with an adverse outcome[8]. Numerous randomized controlled trials have evaluated the role of therapeutic doses of heparin in reducing VTE events or mortality in patients hospitalized due to COVID-19. In the intensive care unit (ICU) scenario, these studies showed that heparin at therapeutic doses did not reduce mortality but may be associated with a higher risk of bleeding events; consequently, this approach is not recommended. According to the current guidelines, hospitalized COVID-19 patients should receive at a minimum routine thromboprophylaxis. Therapeutic-dose heparin should be used for hospitalized COVID-19 patients who have a D-dimer level above the upper limit of normal, require low-flow oxygen, and have no increased bleeding risk. In the patients receiving ICU level of care, prophylactic-dose heparin is recommended[9].

***Arterial thrombotic events: Stroke and acute myocardial infarction***

COVID-19 is an independent risk factor for the occurrence of ischemic stroke, with a higher risk in patients with a severe clinical course[10]. The reported stroke rate of COVID-19 patients is approximately 1%. Notably, patients with COVID-19 seem to have an increased risk for cryptogenic and large vessel stroke[4].

Furthermore, COVID-19 has been descried as a relevant risk factor for the development of acute myocardial infarction (AMI)[11]. A large fraction of patients presenting with AMI and accompanying severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection has type II MI caused by the primary infection inducing respiratory and/or hemodynamic derangement. It remains controversial whether SARS-CoV-2 can trigger type I MI; the potential underlying mechanisms might be cytokine-related plaque instability, immune-thrombosis, and endothelitis[4,12]. Patients presenting with SARS-CoV-2 infection and concomitant ST elevation myocardial infarction (STEMI) have a high thrombus burden, a high risk for stent thrombosis, and an increased risk for a poor outcome[13]. Importantly, the COVID-19 pandemic should not compromise timely reperfusion in STEMI, and management of patients with non-ST-segment elevation acute coronary syndromes (ACS) should be guided by clinical risk stratification[14].

**Takotsubo syndrome**

Through the COVID-19 pandemic, a substantial increase in the incidence rate of Takotsubo syndrome was observed[15]. Notably, in one study, the majority of patients presenting with Takotsubo syndrome tested negative for SARS-CoV-2, potentially implying an increased level of stress in the general population due to the public health measure to reduce transmission rates (social distancing rules, self-isolation, and quarantine), economic stress, and fear of infection[4,15].

**ACUTE HEART FAILURE**

Progressive dyspnoea is both the hallmark symptom of acute heart failure (AHF) as well as severe COVID-19 and distinguishing these entities is challenging, as up to 12% of hospitalised COVID-19 patients might have an established diagnosis of chronic heart failure[16]. Natriuretic peptides might also be elevated in COVID-19 patients even in the absence of left ventricular systolic impairment, proving another challenge in differentiating both entities[14,17]. In line with this, COVID-19 might both trigger AHF in patients with a known history of heart failure as well as lead to a first episode of hospitalization in patients with occult heart failure[18]. Whether these factors are causative or just coincident is currently within the scope of scientific research. However, several factors induced by COVID-19 might be contributing to mechanisms of AHF such as acute myocardial injury defined as increase of circulating troponin levels (observed in 8% to 15% of COVID-19 patients), which has been described to be associated with disease severity[19]. Besides unspecific myocardial injury, the myocardium might also be deteriorated due to COVID-19 associated myocarditis, whereas both direct cardiomyocyte infection and autoimmune myocarditis have been described[20]. Acute respiratory distress syndrome (ARDS), hypoxemia, renal failure, volume expansion, increased sympathetic drive, fever, and systemic inflammatory response syndrome, factors that are commonly present in severe respiratory disease, might further induce or aggravate heart failure[21].

While AHF rates have consistently been reported to decline worldwide, there was an increase in symptom burdenas well as a higher in-hospital mortality rate as compared to historical data observed during the COVID-19 pandemic[14,19,22,23]. Among patients with known heart failure, one third of patients hospitalised with COVID-19 and up to 50% of those that developed AHF died within the in-hospital stay[8]. Patients with heart failure and COVID-19 that had to be admitted to an ICU had an even higher mortality rate of up to 75%[16].

Besides left sided heart failure, acute right heart failure, which might occur secondary to acute pulmonary hypertension or ARDS, has been described in patients with COVID-19[24]. Even in the absence of manifestations of right heart failure, right ventricular dysfunction appears in nearly 15% of patients with COVID-19 and might contribute to impaired outcomes, irrespective of heart failure state[25]. Moreover, there has been recent data that patients following SARS-CoV-2 infection are at increased risk of developing cardiovascular disease even after the acute phase of infection often referred to as “long COVID”[26].

**Effects of the Covid-19 pandemic on acute care of patients with cardiovascular disease**

In addition to the increased risk of an adverse outcome of SARS-CoV-2 infection and to the cardiovascular effects of COVID-19, patients with cardiovascular disease suffer from indirect consequences of the pandemic. Profound adaptations of health care systems were necessary to cope with the high number of severely ill patients with SARS-CoV-2 infection. This included a deferral of a substantial number of elective procedures and affected the acute care of patients with cardiovascular diseases[27]. The New York Times asked in April 2020: “Where have all the heart attacks gone?” Multiple reports from different European countries, the United States, and China show a marked reduction in hospital admissions due to ACS[28-32]. A meta-analysis of 27 international studies corroborated these results, showing a 40%-50% reduction of hospital admissions due to ACS[33]. The interval between symptom onset and admission to the hospital was increased most likely because patients waited longer until they called the emergency services. An observed increase of the door-to-device-times[34,35] might be partly attributable to the recommendations regarding protective measures for the staff as well as adapted reperfusion strategies including fibrinolysis in STEMI and conservative strategies in non-STEMI[36,37]. Hospital admissions due to other acute cardiovascular conditions were also reduced during the pandemic[35,38]. Reports on the effects of the pandemic on in-hospital mortality of AMI are heterogeneous[27]. Some studies describe increased rates of mortality; others show no difference[29, 34,39,40]. The above-mentioned meta-analysis showed an increased AMI mortality from March to May 2020[33]. The observed increase in prehospital deaths and out-of-hospital cardiac arrests implies a negative impact of the pandemic on total mortality rates of AMI[41,42]. Table 1 gives an overview on potential causes for chances in acute cardiac care during the COVID-19 pandemic.

**MYOCARDITIS**

COVID-19-associated myocardial injury, defined as serum troponin level above the 99th percentile of the upper reference limit, was reported from the early days of the pandemic[43]. In several studies, myocardial injury was common among COVID-19 patients, with a very wide prevalence ranging from 8%-62% according to the study and the definition used[43,44]. Nevertheless, almost all studies have shown that these patients had a worse prognosis[44].

Interestingly, even after 2 years of the onset of the COVID-19 epidemic, the pathogenesis of myocardial injury remains unknown. Numerous authors have stated that it may be largely attributable to prominent systemic inflammation, rather than to direct viral infection of the heart[43,44]. This is concordant with the pathophysiology of severe forms of COVID-19, where a profound proinflammatory state, the so-called “cytokine storm”, is thought to take place[45]. In a systematic review comprising nearly 200 COVID-19 patients submitted to cardiac magnetic resonance imaging, myocarditis was the most common imaging diagnosis (40.2%). Evidence of diffuse myocardial edema (T1 and T2 mapping abnormalities) and fibrosis (late gadolinium enhancement) were amongst findings in these patients.

However, the ability of SARS-CoV-2 to directly cause cardiomyocyte infection and damage remains controversial. According to the current definition of myocarditis, proposed by the European Society of Cardiology (ESC) Working Group on Myocardial and Pericardial Diseases, a definitive diagnosis can only be made when a viral genome is proven in endomyocardial specimens along with the histological findings of active myocarditis[46]. In April 2020, a group from Padua University reported the first case of biopsy-proven viral myocardial involvement in a COVID-19 patient presenting with cardiogenic shock[47]. However, to this date, there have been limited reports with pathological evidence of COVID-19 direct myocardial invasion. The potential for long-term evolution into forms of inflammatory cardiomyopathy remains also unclear.

More recently, with the large-scale use of several COVID-19 vaccines, the attention shifted to COVID-19 vaccination-related myocarditis. Despite not being reported as an adverse event in the first vaccine clinical trials, several cases were observed soon after vaccination campaigns began, particularly with mRNA technology vaccines. In May 2021, the Centers for Disease Control and Prevention released a report stating a possible association between COVID-19 vaccination and myocarditis, regarding the BNT162b2 (Pfizer-BioNTech) and the mRNA-1273 (Moderna) vaccines[48]. Later, an analysis of 2.5 million vaccinated people from Israel expected the incidence of post-vaccination myocarditis to be 2.13 cases per 100000 vaccinated persons[49]. In this cohort of patients who received the BNT162b2 mRNA vaccine (Pfizer-BioNTech), the highest myocarditis incidence was among young male patients, and after the second vaccine dose[49]. Another large English study showed similar findings, namely, an increased risk of myocarditis in patients who received the 2nd dose, and in those aged below 40[50]. Across published reports, vaccine-associated myocarditis was mostly a self-limiting disease of mild to moderate severity[50,51]. It has been hypothesized that post-vaccination myocarditis, similarly to COVID-19 myocarditis itself, can result from immune-mediated, virus-independent immunopathologic mechanisms[50,52].

Although this topic gathered intense attention from the social media, it is known that SARS-CoV-2 infection in non-vaccinated people carries a much greater risk of hospitalization and death than the vaccine associated risks[51]. Vaccines have proved to be highly effective at preventing symptomatic and severe disease, and remain, to this moment, the most powerful instrument to halt the effect of this dramatic pandemic on public health and social and economic domains.

**CARDIAC ARRYTHMIAS**

Cardiac arrhythmias may be not only the consequence of direct effects of SARS-CoV-2 infection but also the effects of the adverse reactions to medications used for the treatment of the infection and systemic illness (Figure 1). A metanalysis of 17 retrospective cohort studies of almost 6000 patients showed that the incidence for cardiac arrhythmias (Table 2)was 9.3%[53,54]. Table 3 describes the main mechanism of arrhythmogenicity in this setting[55].

***Atrial fibrillation***

Atrial fibrillation was the most frequent cardiac arrhythmia detected in patients with SARS-CoV-2 infection. Virus-induced cardiac injury in the context of myocarditis, hypoxemia, systemic inflammatory response, and autonomic dysfunction are some of the mechanism implicated in the pathogenesis of ventricular fibrillation (VF) in this setting.

***Ventricular arrhythmias***

Ventricular arrhythmias (ventricular premature complexes, non-sustained and sustained ventricular tachycardia, polymorphic ventricular tachycardia, and ventricular fibrillation) may occur in the same context of the previous described AF, but also due to the proarrhythmic effects of COVID therapies. Ventricular arrhythmogenicity can be enhanced by acidosis, electrolyte disturbances, fever in Brugada patients, and pre-existing or acquired QT prolongation and induced by drugs.

In a retrospective cohort study of more than 1000 patients having a cTn level measured on admission, arrhythmias developed in 44 of the 170 (25.9%) that showed a high cTn level on admission, including six patients with ventricular tachycardia (VT) or VF. The mortality was 100% in this population[56].

Another report compared all the consecutive out-of-hospital cardiac arrests in 2 mo after the first documented case of COVID-19 in a region of Italy with those which occurred in the same time frame in 2019. The cumulative incidence of out-of-hospital cardiac arrest was 21 cases/100000 inhabitants, with a 52% rise as compared with the previous year (*P* < 0.001)[57]. Table 4 describes the main measures to prevent ventricular arrhythmias[2].

***Drug-induced prolongation of QTc interval***

Several agents used for potential prophylaxis and for treating SARS-CoV-2 infection prolong the QT interval and lead to polymorphic VT in the form of torsades de pointes (TDP) (Table 5)[2]. Some simple measures have been proposed to avoid TDP, like avoiding QT prolonging drugs in patients with baseline QTc > 500 ms or with known long QT syndrome, when QTc increases to > 500 ms or if QTc is prolonged by > 60 ms compared to baseline measurement, avoiding drugs of uncertain clinical effect against COVID-19 in patients with known risk factors such as prolonged QTc, and monitoring and avoiding hypomagnesemia, hypokalaemia, concomitant use of certain QT prolonging antiarrhythmic drugs, including class IA (procainamide and quinidine) and class III (sotalol and amiodarone), or bradycardia.

***Acute myocardial injury***

A meta-analysis analyzing more than 4600 patients showed that patients with newly occurring arrhythmias and cardiac injury were at higher risk of requiring ICU admission or developing severe disease (relative risk [*RR*]: approximately 13, *P* < 0.001)[58].

***Sinus tachycardia***

Sinus tachycardia is the most frequent heart rhythm disturbance during the acute infection, due to fever, respiratory insufficiency, hemodynamic compromise, anxiety, and pain, among others. In the chronic context, the origin of sinus tachycardia is mainly due to physical deconditioning and autonomic dysfunction[59].

***Conduction disturbances***

A study showed that the presence of atrial premature contractions, right bundle branch block, or intraventricular block increased the odds of death[60].

***Implantation of cardiac implantable electronic devices***

A German study showed that the pandemic was associated with an overall decline of device implantation rates of -2.6%, with a peak of almost -23%[61]. This situation was limited in time. The COVID-19 pandemic has led to a significant increase in the use of remote monitoring of cardiac implantable electronic devices[62].

**CHRONIC CORONARY SYNDROME**

Other pre-existing inflammatory conditions such as chronic coronary syndrome (CCS) may be associated with worse clinical outcomes in the context of COVID-19. In CCS, the cytokine storm triggered by SARS-CoV-2 infection may favour the rupture of a silent atheromatous plaque, leading to acute coronary syndrome and a sudden worsening of the patient's clinical condition[63].

CCS patients are generally at low risk of acute cardiovascular events, so diagnostic and/or interventional procedures can be deferred in most cases. In these patients, medical therapy should be optimized and/or intensified with the help of telemedicine. Remote clinical monitoring should be ensured to reassure patients and to detect possible changes in clinical status that may require hospitalization in selected patients with a high risk profile[14].

Therefore, during the first phase of the pandemic, it was necessary to continue follow-up in these patients, but with some restrictions.

Non-steroidal anti-inflammatory drugs may worsen the course of community-acquired pneumonia; on the contrary, their negative involvement in exacerbation of SARS-CoV-2 infections is not yet known. The possible effects of chronic aspirin therapy are not clearly understood. However, aspirin has only a very limited anti-inflammatory effect at the low dose administered in CCS. Therefore, CCS patients should not discontinue aspirin for secondary prevention[64].

In patients admitted with influenza or pneumonia, statin therapy has been variably associated with favorable outcomes. Alternatively, patients with COVID-19 have been reported to develop elevated liver enzymes or severe rhabdomyolysis and it may be advisable to temporarily suspend statin therapy[65,66].

During the initial phase of the COVID-19 pandemic, asymptomatic visits of patients with suspected CCS were often deferred as financial resources were allocated to the pandemic. In symptomatic patients with suspected coronary artery disease and a pre-test probability of 5%-15%, functional imaging examinations to detect myocardial ischaemia such as coronary computed tomography angiography were preferred to other imaging techniques such as stress echocardiography to avoid close contact between patients and medical staff[67].

After the initial phase, some changes were established in some local protocols, allowing cardiac testing of patients wearing facial masks, and this approach showed to be feasible, reaching the same levels of effort as in the prepandemic period for treadmill tests[68].

**CHRONIC HEART FAILURE**

Association between SARS-CoV-2 infection and chronic heart failure (HF) may manifest as follows: (1) Patients with HF are at increased risk for severe and complicated course of COVID-19; (2) SARS-CoV-2 infection can exacerbate chronic HF; and (3) The COVID-19 pandemic is linked with dramatic changes in the delivery of outpatient care of HF patients

Patients with SARS-CoV-2 infection and pre-existing HF are more likely to be critically ill, with increased rates of ICU admission, renal replacement therapy, and mechanical ventilation[69]. Pre-existing HF represented an independent risk factor for mortality during COVID-19 hospitalization, with an adjusted odds ratio of 1.88 (95% confidence interval: 1.27-2.78)[70]. A large retrospective cohort study in United States veterans in the ambulatory setting testing positive for SARS-CoV-2 described that patients with COVID-19 and previously diagnosed HF had a greater risk of 30-d mortality and hospital admissions[71]. Interestingly, most of the clinical presentations of COVID-19 on top of advanced HF were dyspnoea and worsening of haemodynamic status instead of fever and other signs and symptoms of infection[72].

COVID-19 may cause or worsen HF through multiple mechanisms including myocardial ischemia or infarction, activation of the sympathetic nervous system, neurohormonal activation precipitating volume retention, elevations in pulmonary pressures, myocarditis, pulmonary embolism, stress cardiomyopathy, and inflammation leading to myocardial depression. The above mentioned mechanisms play a pivotal role and may subsequently lead to arrhythmias, cardiogenic shock, and/or sudden cardiac death[69,18].

Furthermore, it is not known whether the clinical course of COVID-19 differs depending on the left ventricular ejection fraction or background medication[73]. SARS-CoV-2 uses the angiotensin-converting enzyme (ACE)-2 receptors for cell entry and early data suggested that ACE inhibitors (ACEIs) and angiotensin receptor blockers (ARBs) may upregulate ACE2, hypothetically increasing susceptibility to infection[74]. However, there is no clinical evidence linking ACEI/ARB treatment and susceptibility to infection or clinical course. Moreover, the available data do not support the discontinuation of ACEI/ARB in HF patients with COVID-19, which could increase the risk of death[75]. Consequently, it could be recommended that HF patients continue to take all prescribed guideline-appropriate medications (including ACEI, ARB, or sacubitril/valsartan) regardless of COVID-19[76]. Pneumococcal and influenza vaccination, as well as COVID-19 vaccination, when available, should be considered in patients with HF[77].

During COVID-19 pandemics, healthcare institutions have been forced to reconfigure the day-to-day routine ambulatory care. Adoption of restraint measures as an indirect impact of COVID-19 pandemics resulted in decreased hospital admissions for AHF and reduced number of self-referred AHF patients[78,79]. Altered medical care delivery was also confirmed in the multicentre, multinational PCHF-COVICAV registry, which demonstrated that COVID-19 impacted referral and hospitalizations of patients with acute HF and that HF was linked with a high mortality[80].

With an aim to diminish COVID-19 transmission during unnecessary hospitalizations of HF patients, and to maintain a healthy hospital workforce, medical facilities have broadly transitioned to noncontact care delivery methods for out-patient clinical care[81]. Several studies confirmed that this approach was able to keep a low proportion of admissions due to HF decompensation, without an increase in mortality. Results of these studies supported the implantation of telehealth outpatient visits in patients with HF and their safe incorporation into clinical practice[82].

**IMPACT ON VALVULAR HEART DISEASE**

Over the past decade, structural cardiac intervention has been increased worldwide, particularly transcatheter aortic valve implantation (TAVI), transcatheter mitral edge-to-edge repair (TEER), left atrial appendage closure (LAAC), atrial septal defect (ASD) closure, and patent foramen ovale (PFO) closure. This increase in structural cardiology is due to progressive improvements in technology, scientific support from several randomized controlled trials, and life expectancy.

The global COVID-19 pandemic profoundly impacted the treatment of patients eligible for coronary and structural cardiology interventions, as many hospitals had to adjust their internal organization and reallocate economic resources[83].

Structural interventions are usually elective and rarely performed in urgent cases as they require careful clinical and imaging examination such as CT and transthoracic (TT) or transoesophageal (TE) echocardiography. Hospitals changed their management, especially for all procedures requiring ventilators or intensive care. This forced restructuring led to significant constraints, delays, and, in some cases, deletion of procedures, especially in the first phase of the pandemic. TAVI, TEER, and LAAC procedures were reserved for urgent or highly symptomatic patients, while PFO closure, a procedure performed in the elective regime, was almost entirely suspended[84].

In addition, valvular heart disease (VHD) can exacerbate the course of COVID-19 and complicate treatment. An excess of mortality has been reported, particularly in patients with VHD infected with SARS-CoV-2; of 136 elderly patients with severe VHD (54% with aortic stenosis), 84.6% were treated conservatively, and the mortality rate was 41.8% after 30 d[85].

The first peak of the pandemic in England led to a considerable decrease in surgical valve interventions, 73%-76% for aortic valve replacement and 84%-85% for mitral valve replacement, while TAVI was less affected, with 35% and 18% decreases in April and May 2020, respectively[86].

The priority of valve interventions should therefore weigh the need for treatment, the immediate and short-term prognosis, available resources, and the risk to patients and healthcare professionals (HCPs) of hospital-acquired infections.

The ESC, the Society of Cardiovascular Angiography EuroIntervention and Interventions, and the Canadian Association of Interventional Cardiology have published their position statements on the management of structural heart surgery during the pandemic COVID-19[14,87,88].

As the pandemic continues, many centers have adopted a “minimalist” approach to TAVI, which is next day discharge (NDD) following transfemoral TAVI. NDD is a safe strategy for both balloon-expandable and self-expanding implants in selected cases[89].

It allows rapid discharge and avoids the risk of COVID-19 transfer to the patient in the hospital while ensuring patient treatment and medical care at a time of limited resources. NDD is unfortunately not performed in many centers, and for structural procedures, there is likely to be a long waiting list and a high burden for patients with symptomatic aortic stenosis when the pandemic recedes. Long waiting times can have a significant social and clinical impact, even in patients initially considered being at low risk of cardiovascular events. A possible solution should be to avoid standard referral to the ICU in centers with a high volume of procedures and expertise of surgeons using NDD, reserving it only for necessary cases, with all post-procedural care provided in a cardiovascular ward[90].

Treatment of mitral regurgitation (MR) differs according to aetiology and presentation. Chronic primary MR is usually well tolerated. In contrast, secondary MR is more variable and can lead to unstable HF syndromes that do not respond to medical treatment, especially in acute infections. Therefore, in the context of the pandemic, priority should be given to the treatment of acute primary MR complications (AMI or IE) and those with severe primary or secondary MR, which are symptomatic despite optimal medical therapy (OMT) and require hospitalization[91].

TEER requires general anesthesia (unlike transfemoral TAVI) and a longer TE echocardiograpy, exposing healthcare workers to the risk of COVID-19 transmission.

In contrast to patients affected by severe and symptomatic aortic stenosis, the majority of patients with severe MR can be managed by OMT, and indeed TEER has been deferred or reserved only for special cases during the pandemic. A web-based survey sent to EAPCI members from April 1 to 15, 2020 showed that TEER was discontinued in 73% of cases. A web-based survey sent to EAPCI members from April 1 to 15, 2020 showed that TEER was discontinued in 73% of cases[92].

Some changes in the classical organization of procedural protocols have been proposed to manage TEER better and avoid long waiting lists, especially in the postoperative phase. Same-day discharge (SDD) is increasingly practiced in larger centers, as shown by an observational study in which 89 patients who had an uncomplicated MitraClip inserted under moderate conscious sedation were discharged the same day without significant complications[93].

Chowdhury *et al*[94] developed a SDD protocol for patients treated during the pandemic by TEER. SDD reduced length of stay, resource utilization, and nosocomial SARS-CoV-2 infection risk. Patients were admitted 1 day before TEER, extubated in the cath lab, transferred to the recovery ward, and treated as outpatients within 2 h; then a TT echocardiogram was performed to assess outcomes and rule out pericardial effusion. If there was no immediate postoperative complication, they were discharged 3-4 h after the procedure. The protocol also included a telephone follow-up the next day and a follow-up at 2 wk and 30 d[94].

A new option for severe mitral regurgitation is transcatheter mitral valve replacement. This is a new and promising technique. Initial case series suggest that it is feasible and can lead to improvement in symptoms[95]. Numerous devices have been suggested in recent years, but unfortunately the use of this treatment has declined dramatically during the pandemic.

Other structural heart procedures, such as closure of PFO and ASD and LAAC, were unaffected in 9%, while complete cessation of activities was reported in 79%[92].

Two years after the pandemic, we are returning to normality, mainly due to the spread of the vaccine. Nevertheless, we have learned lessons from the first months of the pandemic that we are currently applying, such as avoiding extended hospital stays and promoting early discharge, avoiding intensive care unless absolutely necessary, and focusing on frequent follow-up.

**IMPACT ON CARDIOVASCULAR IMAGING**

Cardiovascular imaging (CVI) plays a pivotal role in the diagnostic pathway of both acute and chronic cardiovascular disease. The devastating impact of the COVID-19 pandemic on the treatment of patients with cardiovascular disease extended also to all cardiac imaging modalities, and likely contributed to delayed diagnosis of cardiovascular (CV) disease. Given its key role as a bedside test, and the “close contact” with the patient, echocardiography was the most affected cardiac imaging modality at the beginning[96]. Given the uncertainties of the disease since the beginning of the pandemic, the European Association of Cardiovascular Imaging issued specific recommendations for the use of cardiac imaging in this setting. Recommendations for the use of CVI were limited only to situations where it was likely to substantially change patient management or be lifesaving[96]. At that time, it was proposed that routine follow-up examinations and elective non-urgent procedures should be postponed or even cancelledand that more focused point-of-care examinations should be performed to minimize exposure time[96,97].

The INCAPS COVID survey was designed to assess the impact of COVID-19 on the use of cardiac imaging during the first lockdown. This survey reported a large reduction (45%-69%) in the total number of procedures in March and April 2020 in European countries[98]. Although we know that these numbers steadily recovered from Spring 2020, these results raised concern that the underutilization of CVI testing may have disrupted the implementation of primary and secondary strategies for CV disease prevention[99]. Patients deprived from prescribed CVI examinations could later present with more severe forms of disease, since they were probably not provided with appropriate care that would improve their long-term prognosis.

Furthermore, the COVID-19 pandemic also had a major impact on the well-being of healthcare professionals. A recently reported survey showed that CVI specialists experienced very high levels of stress, anxiety, and burnout during the COVID-19 pandemic, which highlights the psychological burden that these healthcare professionals have confronted and the importance to address proactively this problem[100].

Nevertheless, the pandemic also had some positive impact in cardiovascular imaging. We observed a broadened and more widespread use of pocket echocardiography and especially an increased awareness for the importance of lung ultrasound (LUS). Due to its high sensitivity, bedside availability, and steep learning curve, LUS already had previously well-established value as an important diagnostic and prognostic tool in heart failure and other acute cardiac care scenarios[101]. However, its implementation in the clinical field was accelerated with the pandemic especially because it was also observed that in patients with a diagnosis of COVID-19, LUS could be useful to detect signs of pulmonary involvement, such as pleural thickening, B-lines, or lung consolidation[102]. Although LUS is valuable to diagnose and grade COVID-19 pneumonia, it requires more advanced expertise to recognize typical signs and patterns[102]. However, when used by experienced operators, it can aid clinical decision-making from simple monitoring to mechanical ventilation titration.

In summary, given the wide impact of the COVID-19 on cardiovascular imaging techniques, medium- and long-term consequences may be expected for some patients due to delayed diagnosis and treatment.

**TELeMEDICINE**

Today's technology, especially telemedicine, allows following patients with chronic cardiovascular diseases such as CCS and CHF. Some scientific societies focused on this approach due to the COVID-19 pandemic to suggest a better and wider use of telemedicine[103,104].

For known CCS patients, clinical follow-up should be conducted mainly *via* telemedicine. This would allow physicians to address most of the patient's concerns related to continuation or change of medical therapy. Possible occurrence/recurrence of unstable symptoms should be assessed as part of the patient's clinical history to weigh the need for hospitalization and diagnostic tests[14].

Several reports suggest a decrease in hospitalization rates for chronic HF in people without SARS-CoV-2 infection during the peak of the pandemic COVID-19 compared to 2019[22].

For the duration of the COVID-19 outbreak, patients with chronic HF should be advised to closely follow protective measures to prevent disease transmission. Outpatients with HF should avoid routine, non-urgent hospital visits, which has led to an increase in telemedicine and remote monitoring work. The increased use of telemedicine has been promoted to minimize infection risk and ensure continuity of care and timely optimization of medical treatment. Several papers have reported the effective use of this technology in medical consultation, treatment adjustment, and follow-up of outpatients HF during the COVID-19 outbreak[105]. Telemedicine has become an important tool for delivering of HF care to ensure continuity of care for the chronically ill while maintaining the safety of patients and HCPs[106].

The changes in hospitals during the pandemic have helped reduce barriers to telemedicine and facilitate its widespread adoption. The chronic heart failure-CePPORT (Canadian e-Platform to Promote Behavioral Self-Management in Chronic Heart Failure Trial) trial highlight an approach to supporting patients with chronic HF[107].

What this change represents for the future of HF management and the provision of HF services in outpatient scenarios worldwide remains warmly debated[108].

Nowadays, far-reaching projects have been proposed for the future management of HF to improve access to care by overcoming transport barriers, the excessive cost of clinical appointments, patient education, and remote home monitoring in more patients tailored ways[18].

**CONCLUSION**

The prior presence of cardiovascular disease is an important risk factor for a severe clinical course of COVID-19 and is associated with adverse outcomes. COVID-19 also has been associated with a direct damage of the cardiovascular system.

Although the pandemic seems to be near to its end, an effort must be made to enable the diagnosis of non-COVID-19 conditions that were overlooked during this period as these non-COVID-19 conditions untreated could explain the excess of death during this dramatic period. This should be a priority for policymakers while planning the recovery from these hazardous times. The lessons learnt during this period should serve as preparation for future challenges or impending pandemics that could be again a deadly combination as the COVID-19 was with the cardiovascular diseases.

**REFERENCES**

1 **COVID-19 Excess Mortality Collaborators**. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020-21. *Lancet* 2022; **399**: 1513-1536 [PMID: 35279232 DOI: 10.1016/S0140-6736(21)02796-3]

2 **Driggin E**, Madhavan MV, Bikdeli B, Chuich T, Laracy J, Biondi-Zoccai G, Brown TS, Der Nigoghossian C, Zidar DA, Haythe J, Brodie D, Beckman JA, Kirtane AJ, Stone GW, Krumholz HM, Parikh SA. Cardiovascular Considerations for Patients, Health Care Workers, and Health Systems During the COVID-19 Pandemic. *J Am Coll Cardiol* 2020; **75**: 2352-2371 [PMID: 32201335 DOI: 10.1016/j.jacc.2020.03.031]

3 **Li B**, Yang J, Zhao F, Zhi L, Wang X, Liu L, Bi Z, Zhao Y. Prevalence and impact of cardiovascular metabolic diseases on COVID-19 in China. *Clin Res Cardiol* 2020; **109**: 531-538 [PMID: 32161990 DOI: 10.1007/s00392-020-01626-9]

4 **Burger AL**, Kaufmann CC, Jäger B, Pogran E, Ahmed A, Wojta J, Farhan S, Huber K. Direct cardiovascular complications and indirect collateral damage during the COVID-19 pandemic : A review. *Wien Klin Wochenschr* 2021; **133**: 1289-1297 [PMID: 34671829 DOI: 10.1007/s00508-021-01956-2]

5 **Rusu I**, Turlacu M, Micheu MM. Acute myocardial injury in patients with COVID-19: Possible mechanisms and clinical implications. *World J Clin Cases* 2022; **10**: 762-776 [PMID: 35127893 DOI: 10.12998/wjcc.v10.i3.762]

6 **Lodigiani C**, Iapichino G, Carenzo L, Cecconi M, Ferrazzi P, Sebastian T, Kucher N, Studt JD, Sacco C, Bertuzzi A, Sandri MT, Barco S; Humanitas COVID-19 Task Force. Venous and arterial thromboembolic complications in COVID-19 patients admitted to an academic hospital in Milan, Italy. *Thromb Res* 2020; **191**: 9-14 [PMID: 32353746 DOI: 10.1016/j.thromres.2020.04.024]

7 **Piazza G**, Campia U, Hurwitz S, Snyder JE, Rizzo SM, Pfeferman MB, Morrison RB, Leiva O, Fanikos J, Nauffal V, Almarzooq Z, Goldhaber SZ. Registry of Arterial and Venous Thromboembolic Complications in Patients With COVID-19. *J Am Coll Cardiol* 2020; **76**: 2060-2072 [PMID: 33121712 DOI: 10.1016/j.jacc.2020.08.070]

8 **Zhou F**, Yu T, Du R, Fan G, Liu Y, Liu Z, Xiang J, Wang Y, Song B, Gu X, Guan L, Wei Y, Li H, Wu X, Xu J, Tu S, Zhang Y, Chen H, Cao B. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet* 2020; **395**: 1054-1062 [PMID: 32171076 DOI: 10.1016/S0140-6736(20)30566-3]

9 Coronavirus Disease 2019 (COVID-19) Treatment Guidelines Bethesda (MD), 2021. [cited 20 April 2022]. Available from: https://www.covid19treatmentguidelines.nih.gov/

10 **Belani P**, Schefflein J, Kihira S, Rigney B, Delman BN, Mahmoudi K, Mocco J, Majidi S, Yeckley J, Aggarwal A, Lefton D, Doshi AH. COVID-19 Is an Independent Risk Factor for Acute Ischemic Stroke. *AJNR Am J Neuroradiol* 2020; **41**: 1361-1364 [PMID: 32586968 DOI: 10.3174/ajnr.A6650]

11 **Katsoularis I**, Fonseca-Rodríguez O, Farrington P, Lindmark K, Fors Connolly AM. Risk of acute myocardial infarction and ischaemic stroke following COVID-19 in Sweden: a self-controlled case series and matched cohort study. *Lancet* 2021; **398**: 599-607 [PMID: 34332652 DOI: 10.1016/S0140-6736(21)00896-5]

12 **Varga Z**, Flammer AJ, Steiger P, Haberecker M, Andermatt R, Zinkernagel AS, Mehra MR, Schuepbach RA, Ruschitzka F, Moch H. Endothelial cell infection and endotheliitis in COVID-19. *Lancet* 2020; **395**: 1417-1418 [PMID: 32325026 DOI: 10.1016/S0140-6736(20)30937-5]

13 **Hamadeh A**, Aldujeli A, Briedis K, Tecson KM, Sanz-Sánchez J, Al Dujeili M, Al-Obeidi A, Diez JL, Žaliūnas R, Stoler RC, McCullough PA. Characteristics and Outcomes in Patients Presenting With COVID-19 and ST-Segment Elevation Myocardial Infarction. *Am J Cardiol* 2020; **131**: 1-6 [PMID: 32732010 DOI: 10.1016/j.amjcard.2020.06.063]

14 **Task Force for the management of COVID-19 of the European Society of Cardiology**. ESC guidance for the diagnosis and management of cardiovascular disease during the COVID-19 pandemic: part 2-care pathways, treatment, and follow-up. *Eur Heart J* 2022; **43**: 1059-1103 [PMID: 34791154 DOI: 10.1093/eurheartj/ehab697]

15 **Jabri A**, Kalra A, Kumar A, Alameh A, Adroja S, Bashir H, Nowacki AS, Shah R, Khubber S, Kanaa'N A, Hedrick DP, Sleik KM, Mehta N, Chung MK, Khot UN, Kapadia SR, Puri R, Reed GW. Incidence of Stress Cardiomyopathy During the Coronavirus Disease 2019 Pandemic. *JAMA Netw Open* 2020; **3**: e2014780 [PMID: 32644140 DOI: 10.1001/jamanetworkopen.2020.14780]

16 **Sokolski M**, Reszka K, Suchocki T, Adamik B, Doroszko A, Drobnik J, Gorka-Dynysiewicz J, Jedrzejczyk M, Kaliszewski K, Kilis-Pstrusinska K, Konopska B, Kopec A, Larysz A, Lis W, Matera-Witkiewicz A, Pawlik-Sobecka L, Rosiek-Biegus M, Sokolska JM, Sokolowski J, Zapolska-Tomasiewicz A, Protasiewicz M, Madziarska K, Jankowska EA. History of Heart Failure in Patients Hospitalized Due to COVID-19: Relevant Factor of In-Hospital Complications and All-Cause Mortality up to Six Months. *J Clin Med* 2022; **11** [PMID: 35011982 DOI: 10.3390/jcm11010241]

17 **Zhang Y**, Coats AJS, Zheng Z, Adamo M, Ambrosio G, Anker SD, Butler J, Xu D, Mao J, Khan MS, Bai L, Mebazaa A, Ponikowski P, Tang Q, Ruschitzka F, Seferovic P, Tschöpe C, Zhang S, Gao C, Zhou S, Senni M, Zhang J, Metra M. Management of heart failure patients with COVID-19: a joint position paper of the Chinese Heart Failure Association & National Heart Failure Committee and the Heart Failure Association of the European Society of Cardiology. *Eur J Heart Fail* 2020; **22**: 941-956 [PMID: 32463543 DOI: 10.1002/ejhf.1915]

18 **DeFilippis EM**, Reza N, Donald E, Givertz MM, Lindenfeld J, Jessup M. Considerations for Heart Failure Care During the COVID-19 Pandemic. *JACC Heart Fail* 2020; **8**: 681-691 [PMID: 32493638 DOI: 10.1016/j.jchf.2020.05.006]

19 **Lippi G**, Lavie CJ, Sanchis-Gomar F. Cardiac troponin I in patients with coronavirus disease 2019 (COVID-19): Evidence from a meta-analysis. *Prog Cardiovasc Dis* 2020; **63**: 390-391 [PMID: 32169400 DOI: 10.1016/j.pcad.2020.03.001]

20 **Basso C**, Leone O, Rizzo S, De Gaspari M, van der Wal AC, Aubry MC, Bois MC, Lin PT, Maleszewski JJ, Stone JR. Pathological features of COVID-19-associated myocardial injury: a multicentre cardiovascular pathology study. *Eur Heart J* 2020; **41**: 3827-3835 [PMID: 32968776 DOI: 10.1093/eurheartj/ehaa664]

21 **Tomasoni D**, Italia L, Adamo M, Inciardi RM, Lombardi CM, Solomon SD, Metra M. COVID-19 and heart failure: from infection to inflammation and angiotensin II stimulation. Searching for evidence from a new disease. *Eur J Heart Fail* 2020; **22**: 957-966 [PMID: 32412156 DOI: 10.1002/ejhf.1871]

22 **Andersson C**, Gerds T, Fosbøl E, Phelps M, Andersen J, Lamberts M, Holt A, Butt JH, Madelaire C, Gislason G, Torp-Pedersen C, Køber L, Schou M. Incidence of New-Onset and Worsening Heart Failure Before and After the COVID-19 Epidemic Lockdown in Denmark: A Nationwide Cohort Study. *Circ Heart Fail* 2020; **13**: e007274 [PMID: 32482087 DOI: 10.1161/CIRCHEARTFAILURE.120.007274]

23 **Bromage DI**, Cannatà A, Rind IA, Gregorio C, Piper S, Shah AM, McDonagh TA. The impact of COVID-19 on heart failure hospitalization and management: report from a Heart Failure Unit in London during the peak of the pandemic. *Eur J Heart Fail* 2020; **22**: 978-984 [PMID: 32478951 DOI: 10.1002/ejhf.1925]

24 **Creel-Bulos C**, Hockstein M, Amin N, Melhem S, Truong A, Sharifpour M. Acute Cor Pulmonale in Critically Ill Patients with Covid-19. *N Engl J Med* 2020; **382**: e70 [PMID: 32374956 DOI: 10.1056/NEJMc2010459]

25 **Kim J**, Volodarskiy A, Sultana R, Pollie MP, Yum B, Nambiar L, Tafreshi R, Mitlak HW, RoyChoudhury A, Horn EM, Hriljac I, Narula N, Kim S, Ndhlovu L, Goyal P, Safford MM, Shaw L, Devereux RB, Weinsaft JW. Prognostic Utility of Right Ventricular Remodeling Over Conventional Risk Stratification in Patients With COVID-19. *J Am Coll Cardiol* 2020; **76**: 1965-1977 [PMID: 33092732 DOI: 10.1016/j.jacc.2020.08.066]

26 **Xie Y**, Xu E, Bowe B, Al-Aly Z. Long-term cardiovascular outcomes of COVID-19. *Nat Med* 2022; **28**: 583-590 [PMID: 35132265 DOI: 10.1038/s41591-022-01689-3]

27 **Zeymer U**, Gitt A, Thiele H. [COVID-19 pandemic : Effects on clinical care of cardiovascular patients in spring 2020]. *Herz* 2021; **46**: 115-119 [PMID: 33590283 DOI: 10.1007/s00059-020-05015-w]

28 **Garcia S**, Albaghdadi MS, Meraj PM, Schmidt C, Garberich R, Jaffer FA, Dixon S, Rade JJ, Tannenbaum M, Chambers J, Huang PP, Henry TD. Reduction in ST-Segment Elevation Cardiac Catheterization Laboratory Activations in the United States During COVID-19 Pandemic. *J Am Coll Cardiol* 2020; **75**: 2871-2872 [PMID: 32283124 DOI: 10.1016/j.jacc.2020.04.011]

29 **Mafham MM**, Spata E, Goldacre R, Gair D, Curnow P, Bray M, Hollings S, Roebuck C, Gale CP, Mamas MA, Deanfield JE, de Belder MA, Luescher TF, Denwood T, Landray MJ, Emberson JR, Collins R, Morris EJA, Casadei B, Baigent C. COVID-19 pandemic and admission rates for and management of acute coronary syndromes in England. *Lancet* 2020; **396**: 381-389 [PMID: 32679111 DOI: 10.1016/S0140-6736(20)31356-8]

30 **Mohammad MA**, Koul S, Olivecrona GK, Gӧtberg M, Tydén P, Rydberg E, Scherstén F, Alfredsson J, Vasko P, Omerovic E, Angerås O, Fröbert O, Calais F, Völz S, Ulvenstam A, Venetsanos D, Yndigegn T, Oldgren J, Sarno G, Grimfjärd P, Persson J, Witt N, Ostenfeld E, Lindahl B, James SK, Erlinge D. Incidence and outcome of myocardial infarction treated with percutaneous coronary intervention during COVID-19 pandemic. *Heart* 2020; **106**: 1812-1818 [PMID: 33023905 DOI: 10.1136/heartjnl-2020-317685]

31 **Solomon MD**, McNulty EJ, Rana JS, Leong TK, Lee C, Sung SH, Ambrosy AP, Sidney S, Go AS. The Covid-19 Pandemic and the Incidence of Acute Myocardial Infarction. *N Engl J Med* 2020; **383**: 691-693 [PMID: 32427432 DOI: 10.1056/NEJMc2015630]

32 **Xiang D**, Xiang X, Zhang W, Yi S, Zhang J, Gu X, Xu Y, Huang K, Su X, Yu B, Wang Y, Fang W, Huo Y, Ge J. Management and Outcomes of Patients With STEMI During the COVID-19 Pandemic in China. *J Am Coll Cardiol* 2020; **76**: 1318-1324 [PMID: 32828614 DOI: 10.1016/j.jacc.2020.06.039]

33 **Kiss P**, Carcel C, Hockham C, Peters SAE. The impact of the COVID-19 pandemic on the care and management of patients with acute cardiovascular disease: a systematic review. *Eur Heart J Qual Care Clin Outcomes* 2021; **7**: 18-27 [PMID: 33151274 DOI: 10.1093/ehjqcco/qcaa084]

34 **De Luca G**, Algowhary M, Uguz B, Oliveira DC, Ganyukov V, Zimbakov Z, Cercek M, Jensen LO, Loh PH, Calmac L, Roura-Ferrer G, Quadros A, Milewski M, Scotto di Uccio F, von Birgelen C, Versaci F, Ten Berg J, Casella G, Wong ASL, Kala P, Diez Gil JL, Carrillo X, Dirksen MT, Becerra-Muñoz VM, Kang-Yin Lee M, Juzar DA, de Moura Joaquim R, Paladino R, Milicic D, Davlouros P, Bakraceski N, Zilio F, Donazzan L, Kraaijeveld AO, Galasso G, Lux A, Marinucci L, Guiducci V, Menichelli M, Scoccia A, Yamac A, Ugur Mert K, Flores Rios X, Kovarnik T, Kidawa M, Moreu J, Flavien V, Fabris E, Lozano Martìnez-Luengas I, Boccalatte M, Bosa Ojeda F, Arellano-Serrano C, Caiazzo G, Cirrincione G, Kao HL, Sanchis Fores J, Vignali L, Pereira H, Manzo-Silberman S, Ordonez S, Özkan AA, Scheller B, Lehtola H, Teles R, Mantis C, Ylitalo A, Brum Silveira JA, Zoni R, Bessonov I, Savonitto S, Kochiadakis G, Alexopoulos D, Uribe C, Kanakakis J, Faurie B, Gabrielli G, Gutiérrez A, Bachini JP, Rocha A, Tam FC, Rodriguez A, Lukito A, Saint-Joy V, Pessah G, Tuccillo B, Cortese G, Parodi G, Bouraghda MA, Kedhi E, Lamelas P, Suryapranata H, Nardin M, Verdoia M; ISACS-STEMI COVID-19; Collaborators. COVID-19 pandemic, mechanical reperfusion and 30-day mortality in ST elevation myocardial infarction. *Heart* 2022; **108**: 458-466 [PMID: 34711661 DOI: 10.1136/heartjnl-2021-319750]

35 **Kwok CS**, Gale CP, Kinnaird T, Curzen N, Ludman P, Kontopantelis E, Wu J, Denwood T, Fazal N, Deanfield J, de Belder MA, Mamas M. Impact of COVID-19 on percutaneous coronary intervention for ST-elevation myocardial infarction. *Heart* 2020; **106**: 1805-1811 [PMID: 32868280 DOI: 10.1136/heartjnl-2020-317650]

36 **Chieffo A**, Stefanini GG, Price S, Barbato E, Tarantini G, Karam N, Moreno R, Buchanan GL, Gilard M, Halvorsen S, Huber K, James S, Neumann FJ, Möllmann H, Roffi M, Tavazzi G, Ferré JM, Windecker S, Dudek D, Baumbach A. EAPCI Position Statement on Invasive Management of Acute Coronary Syndromes during the COVID-19 pandemic. *EuroIntervention* 2020; **16**: 233-246 [PMID: 32404302 DOI: 10.4244/EIJY20M05\_01]

37 **Welt FGP**, Shah PB, Aronow HD, Bortnick AE, Henry TD, Sherwood MW, Young MN, Davidson LJ, Kadavath S, Mahmud E, Kirtane AJ; American College of Cardiology’s Interventional Council and the Society for Cardiovascular Angiography and Interventions. Catheterization Laboratory Considerations During the Coronavirus (COVID-19) Pandemic: From the ACC's Interventional Council and SCAI. *J Am Coll Cardiol* 2020; **75**: 2372-2375 [PMID: 32199938 DOI: 10.1016/j.jacc.2020.03.021]

38 **Bollmann A**, Hohenstein S, Meier-Hellmann A, Kuhlen R, Hindricks G. Emergency hospital admissions and interventional treatments for heart failure and cardiac arrhythmias in Germany during the Covid-19 outbreak: insights from the German-wide Helios hospital network. *Eur Heart J Qual Care Clin Outcomes* 2020; **6**: 221-222 [PMID: 32502261 DOI: 10.1093/ehjqcco/qcaa049]

39 **Woolf SH**, Chapman DA, Sabo RT, Weinberger DM, Hill L, Taylor DDH. Excess Deaths From COVID-19 and Other Causes, March-July 2020. *JAMA* 2020; **324**: 1562-1564 [PMID: 33044483 DOI: 10.1001/jama.2020.19545]

40 **Scholz KH**, Lengenfelder B, Thilo C, Jeron A, Stefanow S, Janssens U, Bauersachs J, Schulze PC, Winter KD, Schröder J, Vom Dahl J, von Beckerath N, Seidl K, Friede T, Meyer T. Impact of COVID-19 outbreak on regional STEMI care in Germany. *Clin Res Cardiol* 2020; **109**: 1511-1521 [PMID: 32676681 DOI: 10.1007/s00392-020-01703-z]

41 **Rashid Hons M**, Gale Hons CP, Curzen Hons N, Ludman Hons P, De Belder Hons M, Timmis Hons A, Mohamed Hons MO, Lüscher Hons TF, Hains Hons J, Wu J, Shoaib A, Kontopantelis E, Roebuck C, Denwood T, Deanfield J, Mamas MA. Impact of Coronavirus Disease 2019 Pandemic on the Incidence and Management of Out-of-Hospital Cardiac Arrest in Patients Presenting With Acute Myocardial Infarction in England. *J Am Heart Assoc* 2020; **9**: e018379 [PMID: 33023348 DOI: 10.1161/JAHA.120.018379]

42 **Wu J**, Mamas MA, Mohamed MO, Kwok CS, Roebuck C, Humberstone B, Denwood T, Luescher T, de Belder MA, Deanfield JE, Gale CP. Place and causes of acute cardiovascular mortality during the COVID-19 pandemic. *Heart* 2021; **107**: 113-119 [PMID: 32988988 DOI: 10.1136/heartjnl-2020-317912]

43 **Nishiga M**, Wang DW, Han Y, Lewis DB, Wu JC. COVID-19 and cardiovascular disease: from basic mechanisms to clinical perspectives. *Nat Rev Cardiol* 2020; **17**: 543-558 [PMID: 32690910 DOI: 10.1038/s41569-020-0413-9]

44 **Cenko E**, Badimon L, Bugiardini R, Claeys MJ, De Luca G, de Wit C, Derumeaux G, Dorobantu M, Duncker DJ, Eringa EC, Gorog DA, Hassager C, Heinzel FR, Huber K, Manfrini O, Milicic D, Oikonomou E, Padro T, Trifunovic-Zamaklar D, Vasiljevic-Pokrajcic Z, Vavlukis M, Vilahur G, Tousoulis D. Cardiovascular disease and COVID-19: a consensus paper from the ESC Working Group on Coronary Pathophysiology & Microcirculation, ESC Working Group on Thrombosis and the Association for Acute CardioVascular Care (ACVC), in collaboration with the European Heart Rhythm Association (EHRA). *Cardiovasc Res* 2021; **117**: 2705-2729 [PMID: 34528075 DOI: 10.1093/cvr/cvab298]

45 **Pirzada A**, Mokhtar AT, Moeller AD. COVID-19 and Myocarditis: What Do We Know So Far? *CJC Open* 2020; **2**: 278-285 [PMID: 32691024 DOI: 10.1016/j.cjco.2020.05.005]

46 **Caforio AL**, Pankuweit S, Arbustini E, Basso C, Gimeno-Blanes J, Felix SB, Fu M, Heliö T, Heymans S, Jahns R, Klingel K, Linhart A, Maisch B, McKenna W, Mogensen J, Pinto YM, Ristic A, Schultheiss HP, Seggewiss H, Tavazzi L, Thiene G, Yilmaz A, Charron P, Elliott PM; European Society of Cardiology Working Group on Myocardial and Pericardial Diseases. Current state of knowledge on aetiology, diagnosis, management, and therapy of myocarditis: a position statement of the European Society of Cardiology Working Group on Myocardial and Pericardial Diseases. *Eur Heart J* 2013; **34**: 2636-2648

47 **Tavazzi G**, Pellegrini C, Maurelli M, Belliato M, Sciutti F, Bottazzi A, Sepe PA, Resasco T, Camporotondo R, Bruno R, Baldanti F, Paolucci S, Pelenghi S, Iotti GA, Mojoli F, Arbustini E. Myocardial localization of coronavirus in COVID-19 cardiogenic shock. *Eur J Heart Fail* 2020; **22**: 911-915 [PMID: 32275347 DOI: 10.1002/ejhf.1828]

48 **Boehmer TK**, Kompaniyets L, Lavery AM, Hsu J, Ko JY, Yusuf H, Romano SD, Gundlapalli AV, Oster ME, Harris AM. Association Between COVID-19 and Myocarditis Using Hospital-Based Administrative Data - United States, March 2020-January 2021. *MMWR Morb Mortal Wkly Rep* 2021; **70**: 1228-1232 [PMID: 34473684 DOI: 10.15585/mmwr.mm7035e5]

49 **Witberg G**, Barda N, Hoss S, Richter I, Wiessman M, Aviv Y, Grinberg T, Auster O, Dagan N, Balicer RD, Kornowski R. Myocarditis after Covid-19 Vaccination in a Large Health Care Organization. *N Engl J Med* 2021; **385**: 2132-2139 [PMID: 34614329 DOI: 10.1056/NEJMoa2110737]

50 **Patone M**, Mei XW, Handunnetthi L, Dixon S, Zaccardi F, Shankar-Hari M, Watkinson P, Khunti K, Harnden A, Coupland CAC, Channon KM, Mills NL, Sheikh A, Hippisley-Cox J. Risks of myocarditis, pericarditis, and cardiac arrhythmias associated with COVID-19 vaccination or SARS-CoV-2 infection. *Nat Med* 2022; **28**: 410-422 [PMID: 34907393 DOI: 10.1038/s41591-021-01630-0]

51 **Heymans S**, Cooper LT. Myocarditis after COVID-19 mRNA vaccination: clinical observations and potential mechanisms. *Nat Rev Cardiol* 2022; **19**: 75-77 [PMID: 34887571 DOI: 10.1038/s41569-021-00662-w]

52 **Dorward DA**, Russell CD, Um IH, Elshani M, Armstrong SD, Penrice-Randal R, Millar T, Lerpiniere CEB, Tagliavini G, Hartley CS, Randle NP, Gachanja NN, Potey PMD, Dong X, Anderson AM, Campbell VL, Duguid AJ, Al Qsous W, BouHaidar R, Baillie JK, Dhaliwal K, Wallace WA, Bellamy COC, Prost S, Smith C, Hiscox JA, Harrison DJ, Lucas CD. Tissue-Specific Immunopathology in Fatal COVID-19. *Am J Respir Crit Care Med* 2021; **203**: 192-201 [PMID: 33217246 DOI: 10.1164/rccm.202008-3265OC]

53 **Lavelle MP**, Desai AD, Wan EY. Arrhythmias in the COVID-19 patient. *Heart Rhythm O2* 2022; **3**: 8-14 [PMID: 35043098 DOI: 10.1016/j.hroo.2022.01.002]

54 **Kunutsor SK**, Laukkanen JA. Cardiovascular complications in COVID-19: A systematic review and meta-analysis. *J Infect* 2020; **81**: e139-e141 [PMID: 32504747 DOI: 10.1016/j.jinf.2020.05.068]

55 **Lazzerini PE**, Boutjdir M, Capecchi PL. COVID-19, Arrhythmic Risk, and Inflammation: Mind the Gap!. *Circulation* 2020; **142**: 7-9 [PMID: 32286863 DOI: 10.1161/CIRCULATIONAHA.120.047293]

56 **Si D**, Du B, Ni L, Yang B, Sun H, Jiang N, Liu G, Massé S, Jin L, Nanthakumar J, Bhaskaran A, Yang P, Nanthakumar K. Death, discharge and arrhythmias among patients with COVID-19 and cardiac injury. *CMAJ* 2020; **192**: E791-E798 [PMID: 32586839 DOI: 10.1503/cmaj.200879]

57 **Baldi E**, Sechi GM, Mare C, Canevari F, Brancaglione A, Primi R, Klersy C, Palo A, Contri E, Ronchi V, Beretta G, Reali F, Parogni P, Facchin F, Rizzi U, Bussi D, Ruggeri S, Oltrona Visconti L, Savastano S; Lombardia CARe researchers. COVID-19 kills at home: the close relationship between the epidemic and the increase of out-of-hospital cardiac arrests. *Eur Heart J* 2020; **41**: 3045-3054 [PMID: 32562486 DOI: 10.1093/eurheartj/ehaa508]

58 **Li X**, Pan X, Li Y, An N, Xing Y, Yang F, Tian L, Sun J, Gao Y, Shang H, Xing Y. Cardiac injury associated with severe disease or ICU admission and death in hospitalized patients with COVID-19: a meta-analysis and systematic review. *Crit Care* 2020; **24**: 468 [PMID: 32723362 DOI: 10.1186/s13054-020-03183-z]

59 **Chen Q**, Xu L, Dai Y, Ling Y, Mao J, Qian J, Zhu W, Di W, Ge J. Cardiovascular manifestations in severe and critical patients with COVID-19. *Clin Cardiol* 2020; **43**: 796-802 [PMID: 32562427 DOI: 10.1002/clc.23384]

60 **McCullough SA**, Goyal P, Krishnan U, Choi JJ, Safford MM, Okin PM. Electrocardiographic Findings in Coronavirus Disease-19: Insights on Mortality and Underlying Myocardial Processes. *J Card Fail* 2020; **26**: 626-632 [PMID: 32544622 DOI: 10.1016/j.cardfail.2020.06.005]

61 **Schwab JO**, Wiese J, Hauser T. The influence of the 2020 COVID-19 pandemic on the implantation rates of cardiac implantable electronic devices in Germany: changes between 2020 Q1-Q3 and 2019 Q1-Q3. *Eur Heart J Qual Care Clin Outcomes* 2022; **8**: 104-112 [PMID: 34849668 DOI: 10.1093/ehjqcco/qcab091]

62 **Simovic S**, Providencia R, Barra S, Kircanski B, Guerra JM, Conte G, Duncker D, Marijon E, Anic A, Boveda S. The use of remote monitoring of cardiac implantable devices during the COVID-19 pandemic: an EHRA physician survey. *Europace* 2022; **24**: 473-480 [PMID: 34410364 DOI: 10.1093/europace/euab215]

63 **Buicu AL**, Cernea S, Benedek I, Buicu CF, Benedek T. Systemic Inflammation and COVID-19 Mortality in Patients with Major Noncommunicable Diseases: Chronic Coronary Syndromes, Diabetes and Obesity. *J Clin Med* 2021; **10** [PMID: 33916917 DOI: 10.3390/jcm10081545]

64 **Basille D**, Plouvier N, Trouve C, Duhaut P, Andrejak C, Jounieaux V. Non-steroidal Anti-inflammatory Drugs may Worsen the Course of Community-Acquired Pneumonia: A Cohort Study. *Lung* 2017; **195**: 201-208 [PMID: 28005149 DOI: 10.1007/s00408-016-9973-1]

65 **Douglas I**, Evans S, Smeeth L. Effect of statin treatment on short term mortality after pneumonia episode: cohort study. *BMJ* 2011; **342**: d1642 [PMID: 21471172 DOI: 10.1136/bmj.d1642]

66 **Xu L**, Liu J, Lu M, Yang D, Zheng X. Liver injury during highly pathogenic human coronavirus infections. *Liver Int* 2020; **40**: 998-1004 [PMID: 32170806 DOI: 10.1111/Liv.14435]

67 **Task Force for the management of COVID-19 of the European Society of Cardiology**. European Society of Cardiology guidance for the diagnosis and management of cardiovascular disease during the COVID-19 pandemic: part 1-epidemiology, pathophysiology, and diagnosis. *Cardiovasc Res* 2021 [PMID: 34864874 DOI: 10.1093/cvr/cvab342]

68 **Barbeito-Caamaño C**, Bouzas-Mosquera A, Peteiro J, López-Vázquez D, Quintas-Guzmán M, Varela-Cancelo A, Martínez-Ruiz D, Yañez-Wonenburger JC, Piñeiro-Portela M, Vázquez-Rodríguez JM. Exercise testing in COVID-19 era: Clinical profile, results and feasibility wearing a facemask. *Eur J Clin Invest* 2021; **51**: e13509 [PMID: 33548060 DOI: 10.1111/eci.13509]

69 **Pillai A**, Lawson B. Coronavirus disease 2019 and cardiovascular diseases: collateral damage? *Curr Opin Anaesthesiol* 2022; **35**: 5-11 [PMID: 34839301 DOI: 10.1097/ACO.0000000000001076]

70 **Bhatt AS**, Jering KS, Vaduganathan M, Claggett BL, Cunningham JW, Rosenthal N, Signorovitch J, Thune JJ, Vardeny O, Solomon SD. Clinical Outcomes in Patients With Heart Failure Hospitalized With COVID-19. *JACC Heart Fail* 2021; **9**: 65-73 [PMID: 33384064 DOI: 10.1016/j.jchf.2020.11.003]

71 **Rumery K**, Seo A, Jiang L, Choudhary G, Shah NR, Rudolph JL, Wu WC, Erqou S. Outcomes of coronavirus disease-2019 among veterans with pre-existing diagnosis of heart failure. *ESC Heart Fail* 2021; **8**: 2338-2344 [PMID: 33728800 DOI: 10.1002/ehf2.13291]

72 **Bocchi EA**, Lima IGCV, Biselli B, Salemi VMC, Ferreira SMA, Chizzola PR, Munhoz RT, Pessoa RS, Cardoso FAM, Bello MVO, Hajjar LA, Gomes BR. Worsening of heart failure by coronavirus disease 2019 is associated with high mortality. *ESC Heart Fail* 2021; **8**: 943-952 [PMID: 33498096 DOI: 10.1002/ehf2.13199]

73 **Vaduganathan M**, Vardeny O, Michel T, McMurray JJV, Pfeffer MA, Solomon SD. Renin-Angiotensin-Aldosterone System Inhibitors in Patients with Covid-19. *N Engl J Med* 2020; **382**: 1653-1659 [PMID: 32227760 DOI: 10.1056/NEJMsr2005760]

74 **Furuhashi M**, Moniwa N, Mita T, Fuseya T, Ishimura S, Ohno K, Shibata S, Tanaka M, Watanabe Y, Akasaka H, Ohnishi H, Yoshida H, Takizawa H, Saitoh S, Ura N, Shimamoto K, Miura T. Urinary angiotensin-converting enzyme 2 in hypertensive patients may be increased by olmesartan, an angiotensin II receptor blocker. *Am J Hypertens* 2015; **28**: 15-21 [PMID: 24842388 DOI: 10.1093/ajh/hpu086]

75 **Lafaurie M**, Martin-Blondel G, Delobel P, Charpentier S, Sommet A, Moulis G. Outcome of patients hospitalized for COVID-19 and exposure to angiotensin-converting enzyme inhibitors and angiotensin-receptor blockers in France: results of the ACE-CoV study. *Fundam Clin Pharmacol* 2021; **35**: 194-203 [PMID: 33111329 DOI: 10.1111/fcp.12613]

76 **Seferovic PM**, Ponikowski P, Anker SD, Bauersachs J, Chioncel O, Cleland JGF, de Boer RA, Drexel H, Ben Gal T, Hill L, Jaarsma T, Jankowska EA, Anker MS, Lainscak M, Lewis BS, McDonagh T, Metra M, Milicic D, Mullens W, Piepoli MF, Rosano G, Ruschitzka F, Volterrani M, Voors AA, Filippatos G, Coats AJS. Clinical practice update on heart failure 2019: pharmacotherapy, procedures, devices and patient management. An expert consensus meeting report of the Heart Failure Association of the European Society of Cardiology. *Eur J Heart Fail* 2019; **21**: 1169-1186 [PMID: 31129923 DOI: 10.1002/ejhf.1531]

77 **Indolfi C**, Barillà F, Basso C, Ciccone MM, Curcio A, Mancone M, Mercuro G, Muscoli S, Nodari S, Pedrinelli R, Romeo F, Sinagra G, Filardi PP. [Position paper of the Italian Society of Cardiology (SIC) on COVID-19 vaccine priority in patients with cardiovascular diseases]. *G Ital Cardiol (Rome)* 2021; **22**: 363-375 [PMID: 33960979 DOI: 10.1714/3592.35745]

78 **Kubica J**, Ostrowska M, Stolarek W, Kasprzak M, Grzelakowska K, Kryś J, Kubica A, Adamski P, Podhajski P, Navarese EP, Anielska-Michalak E, Brycht O, Curzytek A, Dudek A, Gromadziński L, Grzelakowski P, Kamiński L, Kleinrok A, Kostkiewicz M, Koziński M, Król P, Kulawik T, Minczew G, Mindykowski M, Pawlak A, Prokopczuk J, Skonieczny G, Sobkowicz B, Sowiński S, Stankala S, Szymański P, Wester A, Wilczewski P, Bartuś S, Budaj A, Gąsior M, Gruchała M, Drożdż J, Jaguszewski M, Jankowski P, Legutko J, Lesiak M, Leszek P, Mitkowski P, Nessler J, Tomaszuk-Kazberuk A, Tycińska A, Zdrojewski T, Kaźmierczak J. Impact of COVID-19 pandemic on acute heart failure admissions and mortality: a multicentre study (COV-HF-SIRIO 6 study). *ESC Heart Fail* 2022; **9**: 721-728 [PMID: 34786869 DOI: 10.1002/ehf2.13680]

79 **Severino P**, D'Amato A, Saglietto A, D'Ascenzo F, Marini C, Schiavone M, Ghionzoli N, Pirrotta F, Troiano F, Cannillo M, Mennuni M, Rognoni A, Rametta F, Galluzzo A, Agnes G, Infusino F, Pucci M, Lavalle C, Cacciotti L, Mather PJ, Grosso Marra W, Ugo F, Forleo G, Viecca M, Morici N, Patti G, De Ferrari GM, Palazzuoli A, Mancone M, Fedele F. Reduction in heart failure hospitalization rate during coronavirus disease 19 pandemic outbreak. *ESC Heart Fail* 2020; **7**: 4182-8 [PMID: 33094929 DOI: 10.1002/ehf2.13043]

80 **Sokolski M**, Trenson S, Sokolska JM, D'Amario D, Meyer P, Poku NK, Biering-Sørensen T, Højbjerg Lassen MC, Skaarup KG, Barge-Caballero E, Pouleur AC, Stolfo D, Sinagra G, Ablasser K, Muster V, Rainer PP, Wallner M, Chiodini A, Heiniger PS, Mikulicic F, Schwaiger J, Winnik S, Cakmak HA, Gaudenzi M, Mapelli M, Mattavelli I, Paul M, Cabac-Pogorevici I, Bouleti C, Lilliu M, Minoia C, Dauw J, Costa J, Celik A, Mewton N, Montenegro CEL, Matsue Y, Loncar G, Marchel M, Bechlioulis A, Michalis L, Dörr M, Prihadi E, Schoenrath F, Messroghli DR, Mullens W, Lund LH, Rosano GMC, Ponikowski P, Ruschitzka F, Flammer AJ. Heart failure in COVID-19: the multicentre, multinational PCHF-COVICAV registry. *ESC Heart Fail* 2021; **8**: 4955-4967 [PMID: 34533287 DOI: 10.1002/ehf2.13549]

81 **Oseran AS**, Afari ME, Barrett CD, Lewis GD, Thomas SS. Beyond the stethoscope: managing ambulatory heart failure during the COVID-19 pandemic. *ESC Heart Fail* 2021; **8**: 999-1006 [PMID: 33506638 DOI: 10.1002/ehf2.13201]

82 **Afonso Nogueira M**, Ferreira F, Raposo AF, Mónica L, Simões Dias S, Vasconcellos R, Proença G. Impact of telemedicine on the management of heart failure patients during coronavirus disease 2019 pandemic. *ESC Heart Fail* 2021; **8**: 1150-1155 [PMID: 33560597 DOI: 10.1002/ehf2.13157]

83 **Cammalleri V**, Muscoli S, Benedetto D, Stifano G, Macrini M, Di Landro A, Di Luozzo M, Marchei M, Mariano EG, Cota L, Sergi D, Bezzeccheri A, Bonanni M, Baluci M, De Vico P, Romeo F. Who Has Seen Patients With ST-Segment-Elevation Myocardial Infarction? First Results From Italian Real-World Coronavirus Disease 2019. *J Am Heart Assoc* 2020; **9**: e017126 [PMID: 32901560 DOI: 10.1161/JAHA.120.017126]

84 **Wood DA**, Sathananthan J. "Minimalist" transcatheter aortic valve implantation during the COVID-19 pandemic: previously optional but now a necessity. *EuroIntervention* 2020; **16**: e451-e452 [PMID: 32763865 DOI: 10.4244/EIJV16I6A82]

85 **Dvir D**. Severe valvular heart disease and COVID-19: results from the multicenter international valve disease registry. [cited 20 April 2022]. Available from: https://www.tctmd.com/news/valve-disease-plus-covid-19-often-lethal-combination-registry-shows

86 **Mohamed MO**, Banerjee A, Clarke S, de Belder M, Patwala A, Goodwin AT, Kwok CS, Rashid M, Gale CP, Curzen N, Mamas MA. Impact of COVID-19 on cardiac procedure activity in England and associated 30-day mortality. *Eur Heart J Qual Care Clin Outcomes* 2021; **7**: 247-256 [PMID: 33079204 DOI: 10.1093/ehjqcco/qcaa079]

87 **Shah PB**, Welt FGP, Mahmud E, Phillips A, Kleiman NS, Young MN, Sherwood M, Batchelor W, Wang DD, Davidson L, Wyman J, Kadavath S, Szerlip M, Hermiller J, Fullerton D, Anwaruddin S. Triage considerations for patients referred for structural heart disease intervention during the COVID-19 pandemic: An ACC/SCAI position statement. *Catheter Cardiovasc Interv* 2020; **96**: 659-663 [PMID: 32251546 DOI: 10.1002/ccd.28910]

88 **Wood DA**, Sathananthan J, Gin K, Mansour S, Ly HQ, Quraishi AU, Lavoie A, Lutchmedial S, Nosair M, Bagai A, Bainey KR, Boone RH, Liu S, Krahn A, Virani S, Mehta SR, Natarajan MK, Velianou JL, Dehghani P, Wijeysundera HC, Asgar AW, Virani A, Welsh RC, Webb JG, Cohen EA. Precautions and Procedures for Coronary and Structural Cardiac Interventions During the COVID-19 Pandemic: Guidance from Canadian Association of Interventional Cardiology. *Can J Cardiol* 2020; **36**: 780-783 [PMID: 32299781 DOI: 10.1016/j.cjca.2020.03.027]

89 **Costa G**, Barbanti M, Picci A, Todaro D, La Spina K, Di Simone E, D'Arrigo P, Criscione E, Valvo R, Reddavid C, Deste W, Sgroi C, Tamburino C, Giuffrida A, Garretto V, Privitera G, Cannizzaro MT, Inserra C, Veroux P. Predictors and safety of next-day discharge in patients undergoing transfemoral transcatheter aortic valve implantation. *EuroIntervention* 2020; **16**: e494-e501 [PMID: 32091404 DOI: 10.4244/EIJ-D-19-01080]

90 **Sathananthan J**, Webb JG, Polderman J, Achtem L, Hensey M, Murdoch D, Moss R, Shook A, Bruce S, Blanke P, Bancroft C, Andrews H, Leipsic J, Wood D, Lauck S. Safety of Accelerated Recovery on a Cardiology Ward and Early Discharge Following Minimalist TAVR in the Catheterization Laboratory: The Vancouver Accelerated Recovery Clinical Pathway. *Structural Heart* 2019; **3**: 229-235 [DOI: 10.1080/24748706.2019.1592268]

91 **Ponikowski P**, Voors AA, Anker SD, Bueno H, Cleland JGF, Coats AJS, Falk V, González-Juanatey JR, Harjola VP, Jankowska EA, Jessup M, Linde C, Nihoyannopoulos P, Parissis JT, Pieske B, Riley JP, Rosano GMC, Ruilope LM, Ruschitzka F, Rutten FH, van der Meer P; ESC Scientific Document Group. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: The Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur Heart J* 2016; **37**: 2129-2200 [PMID: 27206819 DOI: 10.1093/eurheartj/ehw128]

92 **Roffi M**, Capodanno D, Windecker S, Baumbach A, Dudek D. Impact of the COVID-19 pandemic on interventional cardiology practice: results of the EAPCI survey. *EuroIntervention* 2020; **16**: 247-250 [PMID: 32490825 DOI: 10.4244/EIJ-D-20-00528]

93 **Marmagkiolis K**, Kilic ID, Ates I, Kose G, Iliescu C, Cilingiroglu M. Feasibility of Same-Day Discharge Approach After Transcatheter Mitral Valve Repair Procedures. *J Invasive Cardiol* 2021; **33**: E123-E126 [PMID: 33443488]

94 **Chowdhury M**, Buttar R, Rai D, Tahir MW, Tan BE, Thakkar S, Ali H, Patel HP, Bhatt DL, Depta JP. Same-day discharge after transcatheter mitral valve repair using MitraClip in a tertiary community hospital: a case series. *Eur Heart J Case Rep* 2021; **5**: ytab397 [PMID: 34693199 DOI: 10.1093/ehjcr/ytab397]

95 **Romeo F**, Cammalleri V, Ruvolo G, Quadri A, De Vico P, Muscoli S, Marchei M, Meloni S, Conti F, Ussia GP. Trans-catheter mitral valve implantation for mitral regurgitation: clinical case description and literature review. *J Cardiovasc Med (Hagerstown)* 2016; **17**: 85-91 [PMID: 26556446 DOI: 10.2459/JCM.0000000000000328]

96 **Skulstad H**, Cosyns B, Popescu BA, Galderisi M, Salvo GD, Donal E, Petersen S, Gimelli A, Haugaa KH, Muraru D, Almeida AG, Schulz-Menger J, Dweck MR, Pontone G, Sade LE, Gerber B, Maurovich-Horvat P, Bharucha T, Cameli M, Magne J, Westwood M, Maurer G, Edvardsen T. COVID-19 pandemic and cardiac imaging: EACVI recommendations on precautions, indications, prioritization, and protection for patients and healthcare personnel. *Eur Heart J Cardiovasc Imaging* 2020; **21**: 592-598 [PMID: 32242891 DOI: 10.1093/ehjci/jeaa072]

97 **Fazzari F**, Mantovani R, Donghi V, Curzi M, Bragato RM. From EACVI recommendations to the real-world experience: safety of performing echocardiography in the pandemic era. *Eur Heart J Cardiovasc Imaging* 2021; **22**: e82-e83 [PMID: 33491077 DOI: 10.1093/ehjci/jeab010]

98 **Williams MC**, Shaw L, Hirschfeld CB, Maurovich-Horvat P, Nørgaard BL, Pontone G, Jimenez-Heffernan A, Sinitsyn V, Sergienko V, Ansheles A, Bax JJ, Buechel R, Milan E, Slart RHJA, Nicol E, Bucciarelli-Ducci C, Pynda Y, Better N, Cerci R, Dorbala S, Raggi P, Villines TC, Vitola J, Malkovskiy E, Goebel B, Cohen Y, Randazzo M, Pascual TNB, Dondi M, Paez D, Einstein AJ; INCAPS COVID Investigators Group. Impact of COVID-19 on the imaging diagnosis of cardiac disease in Europe. *Open Heart* 2021; **8** [PMID: 34353958 DOI: 10.1136/openhrt-2021-001681]

99 **Dondi M**, Milan E, Pontone G, Hirschfeld CB, Williams M, Shaw LJ, Pynda Y, Raggi P, Cerci R, Vitola J, Better N, Villines TC, Dorbala S, Pascual TNB, Giubbini R, Einstein AJ, Paez D; INCAPS COVID Investigators Group. Reduction of cardiac imaging tests during the COVID-19 pandemic: The case of Italy. Findings from the IAEA Non-invasive Cardiology Protocol Survey on COVID-19 (INCAPS COVID). *Int J Cardiol* 2021; **341**: 100-106 [PMID: 34478789 DOI: 10.1016/j.ijcard.2021.08.044]

100 **Joshi SS**, Stankovic I, Demirkiran A, Haugaa K, Maurovich-Horvat P, Popescu BA, Cosyns B, Edvardsen T, Petersen SE, Carvalho RF, Cameli M, Dweck MR. EACVI survey on burnout amongst cardiac imaging specialists during the 2019 coronavirus disease pandemic. *Eur Heart J Cardiovasc Imaging* 2022; **23**: 441-446 [PMID: 35061874 DOI: 10.1093/ehjci/jeac002]

101 **Picano E**, Scali MC, Ciampi Q, Lichtenstein D. Lung Ultrasound for the Cardiologist. *JACC Cardiovasc Imaging* 2018; **11**: 1692-1705 [PMID: 30409330 DOI: 10.1016/j.jcmg.2018.06.023]

102 **Gargani L**, Soliman-Aboumarie H, Volpicelli G, Corradi F, Pastore MC, Cameli M. Why, when, and how to use lung ultrasound during the COVID-19 pandemic: enthusiasm and caution. *Eur Heart J Cardiovasc Imaging* 2020; **21**: 941-948 [PMID: 32515793 DOI: 10.1093/ehjci/jeaa163]

103 **Barrios V**, Cosín-Sales J, Bravo M, Escobar C, Gámez JM, Huelmos A, Ortiz Cortés C, Egocheaga I, García-Pinilla JM, Jiménez-Candil J, López-de-Sá E, Torres Llergo J, Obaya JC, Pallares-Carratalá V, Sanmartín M, Vidal-Pérez R, Cequier Á. Telemedicine consultation for the clinical cardiologists in the era of COVID-19: present and future. Consensus document of the Spanish Society of Cardiology. *Rev Esp Cardiol (Engl Ed)* 2020; **73**: 910-918 [PMID: 32921586 DOI: 10.1016/j.rec.2020.06.032]

104 **Gorodeski EZ**, Goyal P, Cox ZL, Thibodeau JT, Reay RE, Rasmusson K, Rogers JG, Starling RC. Virtual Visits for Care of Patients with Heart Failure in the Era of COVID-19: A Statement from the Heart Failure Society of America. *J Card Fail* 2020; **26**: 448-456 [PMID: 32315732 DOI: 10.1016/j.cardfail.2020.04.008]

105 **Kerr B**, Pharithi RB, Barrett M, Halley C, Gallagher J, Ledwidge M, McDonald K. Changing to remote management of a community heart failure population during COVID-19 - Clinician and patient perspectives'. *Int J Cardiol Heart Vasc* 2020; **31**: 100665 [PMID: 33106775 DOI: 10.1016/j.ijcha.2020.100665]

106 **Sayer G**, Horn EM, Farr MA, Axsom K, Kleet A, Gjerde C, Latif F, Sobol I, Kelley N, Lancet E, Halik C, Takeda K, Naka Y, Yuzefpolskaya M, Kumaraiah D, Colombo PC, Maurer MS, Uriel N. Transition of a Large Tertiary Heart Failure Program in Response to the COVID-19 Pandemic: Changes That Will Endure. *Circ Heart Fail* 2020; **13**: e007516 [PMID: 32894988 DOI: 10.1161/CIRCHEARTFAILURE.120.007516]

107 **Nolan RP**, Ross HJ, Farkouh ME, Huszti E, Chan S, Toma M, D'Antono B, White M, Thomas S, Barr SI, Perreault S, McDonald M, Zieroth S, Isaac D, Wielgosz A, Mielniczuk LM. Automated E-Counseling for Chronic Heart Failure: CHF-CePPORT Trial. *Circ Heart Fail* 2021; **14**: e007073 [PMID: 33464959]

108 **Giacalone A**, Marin L, Febbi M, Franchi T, Tovani-Palone MR. eHealth, telehealth, and telemedicine in the management of the COVID-19 pandemic and beyond: Lessons learned and future perspectives. *World J Clin Cases* 2022; **10**: 2363-2368 [PMID: 35434056 DOI: 10.12998/wjcc.v10.i8.2363]

**Footnotes**

**Conflict-of-interest statement:** All the authors declare that they have no conflict of interest that may affect the content of this article.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: https://creativecommons.org/Licenses/by-nc/4.0/

**Provenance and peer review:** Invited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review started:** March 22, 2022

**First decision:** April 13, 2022

**Article in press:** August 24, 2022

**Specialty type:** Medicine, research and experimental

**Country/Territory of origin:** Spain

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): B

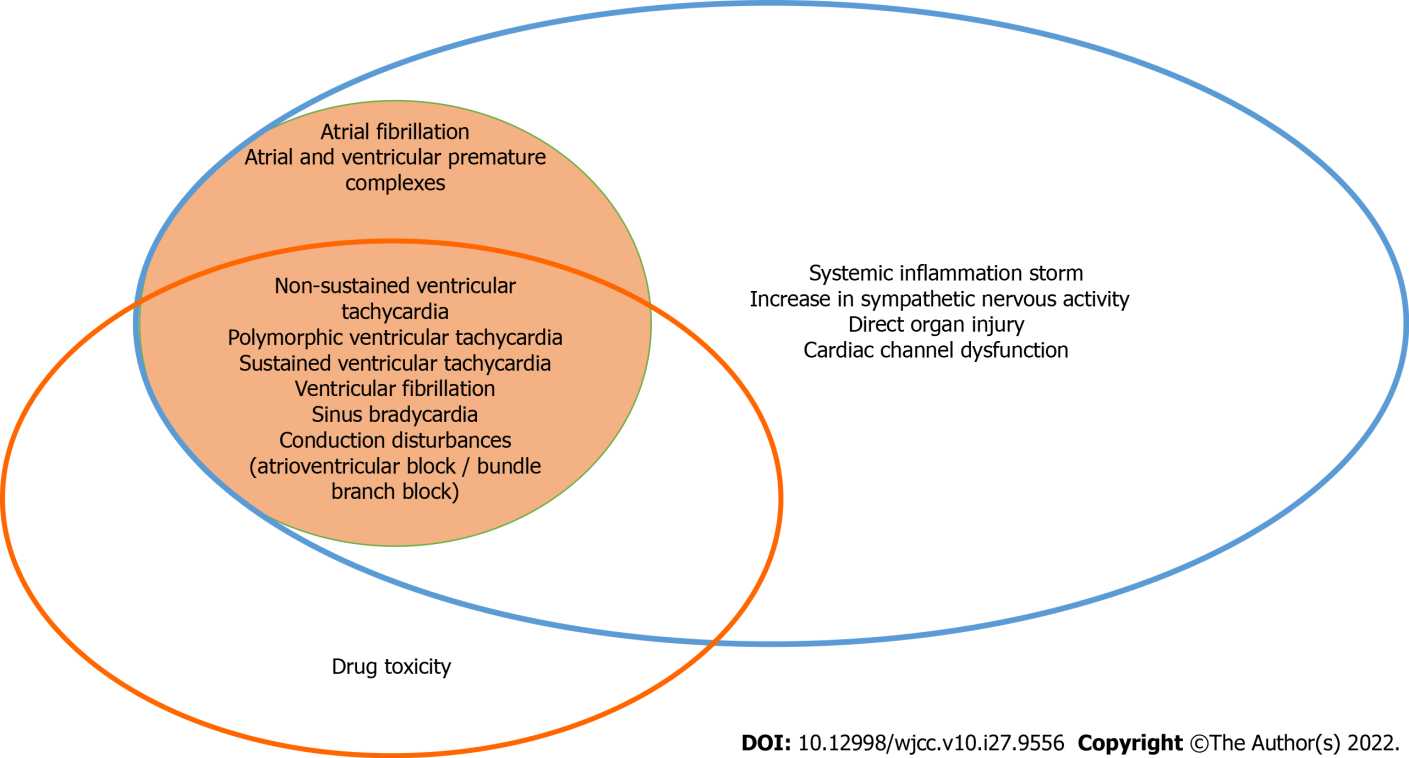
Grade C (Good): C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** El Sayed S, Egypt; Sun XD, China **S-Editor:** Wang LL **L-Editor:** Wang TQ **P-Editor:** Wang LL

**Figure Legends**



**Figure 1 Proposed mechanism of cardiac arrhythmias described in patients with SARS-CoV-2 infection.**

**Table 1 Potential causes for changes in acute cardiac care during the coronavirus disease 2019 pandemic**

|  |
| --- |
| **Potential causes for changes in acute cardiac care during the coronavirus disease 2019 pandemic** |
| Patients were afraid of infection with severe acute respiratory syndrome coronavirus-2 during hospitalization |
| Misinterpretation of thoracic complaints and/or dyspnea as non-cardiac by patients and doctors |
| Changed approach of AMI care with longer door-to-device times and adaption of reperfusion strategies |
| Planned reduction of elective procedures in order to keep resources for care of COVID**-**19 patients |

AMI: Acute myocardial infarction; COVID-19: Coronavirus disease 2019.

**Table 2 Cardiac arrhythmias described in patients with severe acute respiratory syndrome coronavirus-2 infection[53]**

|  |  |  |
| --- | --- | --- |
| **Supraventricular arrhythmias** | **Ventricular arrhythmias** | **Bradycardias** |
| +Atrial fibrillation | +Ventricular premature complexes | +Sinus bradycardia |
| +Sinus tachycardia | +Non-sustained ventricular tachycardia | +Conduction disturbances (atrioventricular block / bundle branch block) |
| +Supraventricular tachycardia | +Polymorphic ventricular tachycardia (Torsade des pointes) |  |
| +Atrial premature complexes | +Sustained ventricular tachycardia |  |

**Table 3 Mechanisms of arrhythmogenicity[55]**

|  |
| --- |
| **Mechanisms of arrhythmogenicity** |
| QT prolonging drugs (anti-coronavirus disease 2019 pharmacotherapies/antibiotic-associated diarrheas/other agents) |
| Drug-drug interactions |
| Previous heart rhythm conditions (long QT and Brugada syndrome) |
| Acute myocardial injury/myocarditis |
| Hypoxia |
| Systemic inflammation |
| Autonomic dysfunction (sympathetic/parasympathetic) |
| Electrolyte abnormalities |
| Cardiovascular comorbidities (hypertension, coronary artery disease, and cardiomyopathy) |

**Table 4 Measures to prevent ventricular arrhythmias[58]**

|  |
| --- |
| **Measures to prevent ventricular arrhythmias** |
| Stop QT prolonging drugs in patients with baseline QTc > 500 ms or with known LQTS |
| Stop QT prolonging drugs when QTc increases to > 500 ms or if QTc is prolonged by > 60 ms compared to baseline measurement |
| Control effectively fever in Brugada patients |
| Avoid the use of chloroquine/hydroxychloroquine, macrolides, fluoroquinolones, and protease inhibitors in patients with known risk factors such as prolonged QTc and electrolyte abnormalities (hypokalemia and hypomagnesemia) |
| Avoid concomitant use of QT prolonging antiarrhythmic drugs, including class IA and class III agents |
| Avoid hypokalaemia and hypomagnesemia |
| Monitor QT *via* ECG or kardia mobile application |

LQTS: Long QT syndrome.

**Table 5 QT prolonging drugs to avoid during severe acute respiratory syndrome coronavirus-2 infection[58]**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Antiarrhythmics** | **Antibiotics** | **Antiviral agents** | **Antiemetics** | **Antipsychotics** |
| +Class IA: Quinidine; Procainamide; +Class III: Amiodarone, Sotalol | +Chloroquine/Hydroxychloroquine; +Macrolides (Azithromycin); +Quinolones | +Lopinavir/Ritonavir; +Favipiravir; +Tocilizumab | +Domperidone | +Haloperidol |



Published by **Baishideng Publishing Group Inc**

7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA

**Telephone:** +1-925-3991568

**E-mail:** bpgoffice@wjgnet.com

**Help Desk:** https://www.f6publishing.com/helpdesk

https://www.wjgnet.com



**© 2022 Baishideng Publishing Group Inc. All rights reserved.**