Echocardiography, Lung Ultrasound and Cardiac Magnetic Resonance Findings in COVID-19: A Systematic Review

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Abstract

The manifestations of COVID-19 as outlined by echocardiography, lung ultrasound (LUS) and cardiac magnetic resonance (CMR) imaging are yet to be fully described. We conducted a systematic review of the current literature and included studies that described cardiovascular manifestations of COVID-19 using echocardiography, LUS and CMR. We queried PubMed, EMBASE and Web of Science for relevant articles. Original studies and case series were included. This review describes the most common abnormalities encountered on echocardiography, LUS and CMR in patients infected with COVID-19.

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Short title: *ECHO, LUS and CMRI in COVID-19*

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Abstract

The manifestations of COVID-19 as outlined by echocardiography, lung ultrasound (LUS) and cardiac magnetic resonance (CMR) imaging are yet to be fully described. We conducted a systematic review of the current literature and included studies that described cardiovascular manifestations of COVID-19 using echocardiography, LUS and CMR. We queried PubMed, EMBASE and Web of Science for relevant articles. Original studies and case series were included. This review describes the most common abnormalities encountered on echocardiography, LUS and CMR in patients infected with COVID-19.

Introduction

The pandemic caused by novel coronavirus infection (COVID-19) has completely transformed the way of life for both patients and physicians around the globe. Since its inception in December, 2019, COVID-19 has spiraled exponentially, with more than 105 million documented cases and over 2 million fatalities worldwide as of February, 2021[1]. Given its multifaceted cardiac manifestations and a fatality rate estimated at 10.5% for cardiovascular disease related complications, COVID-19 has had a disproportionate impact on the diagnosis and management of cardiovascular diseases. Our study aims to provide an overview of current findings and recommendations in cardiovascular imaging in patients with COVID-19.

Methods

We performed a systematic search of the PubMed, EMBASE and Web of science databases to identify relevant articles from the inception of the database to October 2nd, 2020. The search strategy used in each database is elaborated in Supplementary File 1. Extracted citations were imported into Mendeley reference manager and screened for relevance. Screening was performed at two levels. At the first level, articles and abstracts were screened for relevance. At the second level, articles identified by title and abstract screening were subjected to full text review. A second manual search was performed to identify articles published after the initial search until publication. The PRISMA flow chart for inclusion of studies is described in Figure 1.

Echocardiography in Patients with Covid-19

Indications for Echocardiography in COVID-19 patients

The American Society of Echocardiography (ASE) and other clinical societies have established appropriate criteria for the use of echocardiography (ECHO) in patients admitted to the hospital[2].

Given increasing evidence for cardiovascular manifestations of COVID-19, and the increasing role of bedside focused cardiac ultrasound (FoCUS) in clinical management, there may be utility in performing a focused bedside ECHO among patients with COVID-19, especially in the critically ill[3–5]. Although performing an ECHO solely based on troponin elevation is not recommended, there is an increasing body of data suggesting that elevated troponin (>99thpercentile on admission) is an important predictor of mortality and length of hospital stay in patients with COVID-19[6–10]. Similarly, NT-ProBNP has also been found to be elevated among a significant number of patients with COVID-19 and is an important predictor of mortality[11]. A prospective international survey of 1216 patients from 69 countries revealed that abnormalities on ECHO were found most in patients who had a combination of indications (72%) followed by patients with chest pain and ST segment elevation on ECG (71%), elevated cardiac biomarkers (69%) and clinical suspicion for left or right ventricular failure. In a third of patients who had abnormal ECHO (33%), it resulted in a change of management towards disease specific therapy (42%). In another retrospective study, ECHO changed clinical management in 24.2% of patients who had undergone cardiac imaging when there was concern for a major cardiovascular event[12].

Transthoracic and Transesophageal ECHO (TTE and TEE) in COVID-19 patients - safety constraints for health care personnel

It is prudent to consider the risks of exposure of healthcare personnel while performing TTE and TEE in patients with COVID-19. Despite studies demonstrating that health care workers have a significantly higher risk of acquiring COVID-19 due to increased workplace exposure to patients [13], the data regarding the incidence of COVID-19 among ECHO sonographers is scarce.

In a recent cross-sectional study that surveyed sonographers in major academic centers in New York (NY,USA), it was found that there was an infrequent use of plastic ECHO machine covers (9%), barriers between the patient and sonographer (11%) and probe covers (30%) during the procedure. In addition, about a quarter of respondents reported a lack of training in disinfection practices of ultrasound equipment[14]. Such findings highlight the need for more stringent adherence to the ASE and American Institute of Ultrasound in Medicine's guidelines for protection of patients and ECHO providers to safeguard this vulnerable population[15].

Key Echocardiographic findings in patients with COVID-19

Due to the multi-factorial nature of cardiac involvement in COVID-19, various studies have demonstrated diverse cardiac manifestations**[Table 1]** .

Right ventricular (RV) involvement

RV involvement seems to be the most common with multiple studies demonstrating RV dilatation and a range of systolic dysfunction from mild to severe including documented instance of an acute cor pulmonale like presentation [16–21]. Pulmonary artery systolic pressure (PASP) was also found to be significantly elevated in a large number of patients presenting with COVID-19[4,18]. These findings may in part be attributed to a hypercoagulable state associated with systematic inflammation , endothelial dysfunction of the pulmonary vasculature leading to pulmonary emboli or microthrombi affecting the smaller segmental pulmonary arteries, hypoxemia secondary to infection itself or adverse effects of positive pressure ventilation[4,18,22–25]. Further, tricuspid annular plane systolic excursion (TAPSE) was found to be significantly decreased in critically ill COVID-19 patients and was more profoundly affected in severe acute respiratory distress syndrome (ARDS) as compared to mild ARDS and was found to have the best inter-observer variability [26](51). A study by D'Alto et al. demonstrated that right ventricular-arterial uncoupling expressed as TAPSE/PASP is an independent predictor of mortality in COVID-19 patients [27].

Left ventricular (LV) involvement

LV systolic and diastolic dysfunction have also been reported in COVID-19 patients, especially in those with elevated troponin levels[28,29]. Interestingly, despite conventional ECHO studies demonstrating only mild LV systolic and diastolic dysfunction, a recent myocardial deformation analysis study revealed patients who had a normal LV ejection fraction (LVEF) measured by conventional ECHO had abnormal LV deformation. This was in the form of abnormal regional longitudinal deformation (rLS), regional radial strain (rRS) and regional circumferential strain (rCS) affecting predominantly the basal segments. Such a pattern is suggestive of a reverse basal takotsubo-like syndrome in patients with COVID-19, similar to what is seen in Fabry's or Friedrich's disease[30–32]. Myocardial involvement in the basal/mid infero-/anterolateral LV segments was thought to be partly a result of hydrostatic edema due to the supine position of the patient. Such reverse basal takotsubo-like syndrome picture could also be explained by the edema leading to abnormal basal rRS curves without significant alterations during systole[30]. Furthermore, COVID myocarditis exhibits a transmural myocardial involvement as evidenced by the severely impaired CS, as it is triggered by cytokine storm. This finding differs from typical viral myocarditis which often affects the epi-myopericardial segments.[30]. In a multicenter study by Giustino et al., patients with myocardial injury as defined by elevated cardiac biomarkers, had more wall motion abnormalities (WMAs) in apical and mid segments, while basal WMAs were numerically higher in patients with no myocardial injury. Furthermore, WMAs were more frequently observed in patients with regional ST-segment deviations[33].

Vascular changes

PASP was found to be elevated in several studies, presumably due to hypoxemia-mediated pulmonary vasoconstriction, pulmonary emboli and the effects of positive pressure ventilation[18,22–25]. Notably, there has also been a high incidence of deep venous thrombosis among COVID-19 patients. A recent meta-analysis highlighted an overall incidence of 20% which is disproportionately high when compared to patients admitted for other medical conditions[34]. A recent study also described a high rate of fluid responsiveness (82.9% of patients) based on an inferior vena cava (IVC) distensibility index >18% at the time of evaluation. This was thought to be due to third spacing of fluids because of sepsis, reduction of venous return to the RV due to high positive pressure ventilation and a natural tendency to maintain a negative fluid balance in patients with ARDS[18].

Other findings

In addition, there have been multiple studies that have described diverse findings such as pericarditis, moderate to severe pericardial effusion causing cardiac tamponade and acute myocarditis causing global hypokinesia on ECHO[35–43].

Echocardiographic predictors of mortality in COVID-19

As mentioned earlier, elevated PASP has been found to be associated with higher in-hospital mortality[18]. Studies have consistently shown RV dysfunction to be a predictor of disease severity. Mortality rate has been found to be increased in patients with moderate/severe dilation of the RV as compared to patients with mild/no RV dilation[21]. One study showed RV dilatation correlates with high sensitivity troponins, and d-Dimer levels [44]. Decrease in RV global longitudinal strain (GLS) and TAPSE were found to be strong predictive factors of mortality in COVID-19 patients[45,46]. Of note, decreased RVGLS and RV free wall longitudinal strain (RVFWLS) have been found to predict mortality independent of respiratory parameters, LV function or markers of multi-organ failure[19,45,47]. In addition, oxygen need, higher d-Dimer and C-reactive protein (CRP) correlated with lower RVGLS [19,45,47]. A cut-off of -23% was found to have a sensitivity of 94 % for predicting mortality[45]. In another study of 35 patients, those with RVGLS less than -20% had significantly higher 30 day mortality [48].

With regards to LV parameters, mortality was found to be increased in patients who had reduced LV longitudinal strain (LS), left ventricular stroke volume index (LVSVi), cardiac index and tissue Doppler S' (systolic wave) velocity[46]. In addition, Giustino et al. demonstrated that the mortality rate in patients with myocardial injury, defined as elevated cardiac biomarkers, was higher in patients with evidence of WMAs as compared to those without WMAs[33].

Transthoracic echo (TTE) in prone patients with COVID-19

In a case series involving 15 patients on prone ventilation, it was found that raising the patient's left arm and placing a pillow or a folded sheet underneath the mid-thoracic wall to maintain the left hemithorax slightly elevated to allow a comfortable transducer manipulation resulted in successful apical four and five chamber views and related measurements in 14 out of 15 patients who were studied[49]. In another case series involving 8 patients, an alternative method has been proposed for obtaining adequate TTE windows in prone patients. Rather than extending the patient's left arm above the head, the lower thoracic section of the patient's air mattress was temporarily deflated, taking advantage of the gravitational effect of the heart and its shift toward the chest wall while obtaining an apical four chamber view\sout. In addition to the traditional apical four chamber view, the apical five chamber view was also obtainable by tilting the probe in this position. These views were adequate to estimate the left ventricular ejection fraction (LVEF), mitral annular plane systolic excursion, mitral valve and annular Doppler velocities, aortic valve Doppler velocity, TAPSE and PASP from the tricuspid regurgitation peak Doppler velocity. Adequate measurements were possible in seven out of eight patients who were included in this case series[50].

Contrast echocardiography in COVID-19 patients

There have not been many studies that have examined the use and safety of ultrasound enhancing agents (UEA) in patients with COVID-19 despite contrast ECHO generally having a higher diagnostic yield when compared with non-contrast ECHO [51,52]. In a retrospective study of 33 patients, including 14 on mechanical ventilation, it was found that 82% of the ECHO studies were technically difficult (with technical difficulty defined as more than two LV myocardial segments not visualized from any acoustic window). However, after administration of a UEA, it was found that adequate LV opacification was achieved in 97% of patients and adequate RV assessment was possible in 91% of patients. Contrast opacification was particularly beneficial in visualization of RV contours. The UEAs used in this study were Definity (perflutren lipid microsphere; Lantheus Medical Imaging, North Billerica, MA) and Optison (perflutren protein type-A microspheres; GE Healthcare, Little Chalfont, United Kingdom). None of the patients in the study experienced any adverse effects related to UEA administration including sustained arrhythmic events, deterioration of respiratory status including endotracheal intubation, cardiac arrest or death[53].

Contrast echocardiography in patients undergoing extra-corporeal membrane oxygenation (ECMO)

Though the use of UEAs during TTE have been evaluated in COVID-19 patients who were spontaneously breathing or on mechanical ventilation[53], their use during TTE in the setting of ECMO for COVID-19 ARDS can be potentially problematic. UAE can trigger an air bubble alarm, which is integrated in ECMO circuits as a safety measure. This can result in stoppage of the ECMO circuit forward flow or engaging a ''Zero-flow mode" which can result in rapid deterioration of hypoxic patients who are dependent on ECMO flow.(58) Bleakley et al used a protocol that involves the deactivation of air-bubble alarms before administration of contrast to avoid such potential complication.[54].

Transesophageal echo (TEE) in COVID-19: a new outlook

TEE offers multiple advantages including better imaging windows by virtue of the TEE probe being close to the cardiac chambers and great vessels compared with conventional TTE probes. In addition, TEE is not hampered by other factors such as high PEEP positive ventilation, prone position, body habitus, and emphysematous lungs that constitute a limiting factor for obtaining good images by TTE [55,56]. Studies demonstrated that superior vena caval (SVC) collapsibility index is superior to IVC distensibility index in predicting fluid responsiveness[57,58]. As TEE is generally required to measure SVC collapsibility, it is inherently able to predict volume status much better than TTE among critically ill patients. Given the fact that ECHO is the modality of choice in investigating cardiogenic shock[59], TEE could help in providing real time information regarding LV function, trends of quantitative indices under acute therapy and whether or not cardiac dysfunction is acute and reversible (as in septic cardiomyopathy) [60]. With the challenges of volume resuscitation among COVID-19 patient with ARDS, TEE may prove to be an important tool in fluid management.

TEE is also essential in identification of acute cor pulmonale (ACP) as it provides the necessary short axis view of the heart required to identify ACP[56]. With regards to assessing RV systolic function, the RV fractional area change (FAC) measured by TEE is still considered the best parameter for measurement [61]. However, the measurement of an accurate RV FAC requires the entire endocardium to be clearly visible, which is sometimes difficult in patients who develop ACP and are on mechanical ventilation. In this subset of patients, measurement of the tricuspid longitudinal annular displacement (TMAD), a bi-dimensional strain parameter that tracks the tricuspid annular tissue motion toward the RV apex, thereby allowing an objective quantitative assessment of RV systolic function may be helpful[62]. TMAD is also angle independent and is unaffected by endocardial definition, which further adds to its ability to identify and quantify RV systolic dysfunction in patients in whom a traditional FAC measurement would be difficult. In a study by Beyls et al, a TMAD at the RV free wall (TMADlat) cutoff value of 18.5 mm was found to be statistically significant in identifying RV systolic dysfunction as compared with RV GLS. The sensitivity and specificity of TMADlat in identifying RV systolic dysfunction were 80% and 70%, respectively and the intraobserver reproducibility of TMADlat was excellent (intraclass correlation coefficient = 0.98 [0.93 to 0.99]), thereby, adding support for the use of this measurement in COVID-19 patients to identify RV systolic dysfunction[63].

Recent international guidelines recommend the use of ECMO therapy in patients with severe ARDS due to COVID-19 who have failed mechanical ventilation[64,65]. Pre-procedure TEE plays a fundamental role in ECMO initiation as it can identify unexpected and reversible findings while ruling out severe valvular abnormalities that may affect the success of venovenous(VV) or venoarterial(VA) ECMO therapy. In addition, the presence of severe LV dysfunction identified by TEE before placement of ECMO prompts consideration of VA ECMO instead of VV ECMO[66,67]. Embryologic remnants of right heart structures or other congenital abnormalities may affect the safe and appropriate placement of venous cannulas during ECMO initiation. A persistent left SVC leading to a dilated coronary sinus may be accidentally cannulated, leading to compromised oxygenation on ECMO. Similarly, a prominent Chiari network may impede cannula positioning and may increase the risk of subsequent thrombosis. TEE guidance can help confirm the course of a guidewire during insertion and help in excluding coiling of the guidewire in the right atrium, crossing of the guidewire across the interatrial septum or its entrance in the coronary sinus. It can also ensure that the return cannula is positioned clear of the interatrial septum and the tricuspid valve, thereby reducing the risk for recannulation [67–71]. TEE can also help identify the cause for worsening hypoxemia during ECMO which includes scenarios where the cannula tips are too close to each other causing recirculation, hypovolemia causing inadequate ECMO flow and thrombus formation in the cannula which may be impeding adequate flow[66].

Despite the numerous advantages TEE has over TTE, its performance is difficult as there is a decreased availability of health care providers who have adequate training and expertise in performing the procedure. There is also an increased risk of aerosol exposure to healthcare providers during a TEE when compared with a conventional TTE. Although, obtaining expertise in TEE requires a lot of hands-on training, competence in performing TEE for assessing central hemodynamics can be achieved in a short span of time after approximately 35 examinations. This number is based on the international consensus statement on training standards for advanced critical care ECHO citing evidence from a prospective, multicentric trial that validated the number of TEEs required to be performed to gain competence in monitoring central hemodynamics[72,73]. Adoption of adequate personal protective measures as per current guidelines should lead to a decreased risk of acquiring transmissible diseases while performing TEE[15].

Lung Ultrasound Findings in COVID-19

The most common lung ultrasound (LUS) findings in screened studies and their relative prevalence were irregular pleural lines (27.9 to 89% in patients), pleural thickening (6.5 to 86%), separate "distinct or scattered" B-lines (16.6 to 88%), confluent "coalescent" B-lines with or without "white lung" (12 to 78.6%), pulmonary consolidations (31.1 to 77%), sub-pleural consolidations (8.06 to 73%) and pleural effusions (3.8% to 56%)[74–82] **[Table 2]** . Variability in prevalence of LUS findings is likely related to heterogeneity in the severity of the disease, as well as the timing of LUS in the course of the disease. For example, Mafort et al studied symptomatic healthcare professionals who had a positive RT-PCR test for COVID-19. They detected coalescent B-lines and subpleural consolidations in 36% and 8.06% of patients, respectively. Bilateral involvement was seen in only 50.1% of patients. Of note, they studied patients during their first assessment and those hospitalized or undergoing intensive care were not included[76].

With regards to the distribution of LUS, bilateral distribution was noted in 50.1 to 100% of cases. A greater tendency to involve the posterior and lateral regions with less involvement of the anterior region was demonstrated by Smargiassi A et al [83]. Using a specific scoring system ranging from 0 to 3 (worst score, 3), they were able to demonstrate a higher prevalence of score 3 in posterior and lateral regions, and a higher prevalence of score 0 in the anterior regions in a population of non-critically ill patients. A more prominent involvement of the posterior and lower regions was also noted by Castelao J et al in 95.5% and 73.8% of studied patients, respectively[84]. Similar predilection for posterior and lower region involvement was described by Lu W et al, who also noted a subpleural and peripheral pulmonary zones distribution of LUS findings[78]. Interestingly, a more prominent involvement of the anterior areas of the lungs was noted in patients with severe disease relative to those with mild disease (36% vs 21% of patients, p .021)[85], and clinical deterioration was associated with loss of aeriation in anterior lung segments[86].

Diagnostic performance of LUS

LUS demonstrated remarkable sensitivity and negative predictive value (NPV) among reviewed studies, with sensitivity ranging from 68% to 93.3% and a NPV ranging from 52%to 94.1% [78,80,82,87], suggesting the utility of LUS as a screening test to rule out COVID-19 lung infection. Data regarding specificity, positive predictive value (PPV) and diagnostic accuracy has been conflicting, with some studies demonstrating values as low as 21.3%, 19.2% and 33.3% for specificity, PPV and diagnostic accuracy, respectively[87], while others demonstrating higher values up to 92.9%, 84.6% and 93.3% for specificity, PPV and diagnostic accuracy, respectively[78]. Lu W et al. demonstrated higher sensitivity and NPV of LUS in patients with moderate disease (77.8% and 88.9%, respectively) with both values reaching 100% in patients with severe disease. Overall, LUS showed a higher efficacy in assessing patients with no and severe lung lesions, with diagnostic accuracy for patients with no, mild, moderate, and severe lung lesions of 93.3 %, 76.7 %, 76.7 %, and 93.3 %, respectively[78]. Bar S et al. suggested four ultrasound signs that were independently associated with a positive COVID-19 RT-PCR; Upper sites B lines [?] 3 [OR 1.52 (1.31-1.79]), lower sites thickened pleura [OR 1.73 (1.49-1.98)], lower sites consolidation [OR 2.39 (2.07-2.69)], and posterolateral sites thickened pleura [OR 1.97 (1.72-2.22)][88], suggesting a role for LUS in triaging patients with suspected COVID-19 lung infection.

Comparison to other imaging modalities

A chest computed tomography (CT) scan is considered as the gold standard for the diagnosis of COVID-19 pneumonia, having a sensitivity greater than RT-PCR [89]. Zieleskiewicz L et al demonstrated a significant association between LUS score and chest CT severity. A LUS score $>$ 23 predicted severe SARS-CoV-2 pneumonia (specificity $>$ 90% and a PPV of 70%) and a score $<$ 13 excluded severe SARS-CoV-2 pneumonia (sensitivity$>$ 90% and an NPV of 92%) diagnosed by chest CT scan[90]. Similarly, Ottaviani et al observed 21 non-ICU patients, noting the extent of affected lung using LUS score for B lines ,(wherein each lung is divided into 6 segments delineated by anterior, posterior axillary lines, parasternal and paravertebral lines), as well as the presence of ultrasound consolidations had an excellent correlation with the percentage of lung involvement on chest high resolution (HR)CT ($r=0.935$, $p<0.001$ and $r=0.452$, $p=0.04$, respectively) [91]. A significant positive correlation of LUS score with CT visual score ($r = 0.65$, $p < 0.001$) was also described in a study by Nouvenne A et al[75]. These data suggest a promising role for LUS as an alternative to CT scan for screening patients with suspicion of COVID-19, as well as assessing the severity of the disease. Shumilov et al compared LUS findings to chest X ray (CXR) in 18 symptomatic COVID-19 patients and found LUS was useful in detecting interstitial syndrome compared with CXR (94% "B-lines" vs. 61% "hazy increased opacity"; $p<0.02$) as well as detecting lung consolidations effectively (77% for LUS vs. 38.8% for CXR; $p<0.02$)[77]. Similar findings were described by Pare JR et al, wherein LUS was more sensitive than CXR (88.9% vs 51.9%, respectively) for the association of pulmonary findings of COVID-19 ($p = 0.013$).

Prognostic implications and utility of LUS scoring

Y Lichter et al found the presence of pleural effusion, pleural thickening and a high total LUS score at baseline examination were significantly associated with increased mortality. The unadjusted hazard ratio of death for patients with LUS score >18 was 2.65 [1.14–6.3], p = 0.02, suggesting a 2.6-fold increase in mortality in those patients[86]. Extent of lung involvement on LUS was predictive of the need for intensive care unit admission as noted by Bonadia N et al, patients admitted to ICU had a median 93% of areas involved versus 20% of areas involved in patients who did not require ICU admission[92]. In a study by Zhao L et al., a LUS score cutoff point of 32 was found to predict refractory disease (defined as respiratory failure with a PaO2/FiO2 of [?]100 mm Hg or patients who were treated with ECMO) with a specificity of 89.3% and a sensitivity of 57.1%[93] Description of LUS scores in individual studies is provided in supplementary Table 2 . Castelao J et al used a self-designed scoring system to evaluate severity of lung involvement. The total lung score showed a strong correlation (r = -0.765) with the oxygen pressure–to–fraction of inspired oxygen ratio, and the anterior region lung score was significant (OR, 2.159; 95% confidence interval, 1.309–3.561) for the risk of requiring noninvasive respiratory support (NIRS)[84]. LUS score correlated with IL-6 concentrations (r = 0.52, p = 0.001) and arterial pCO2 (r = 0.30, p = 0.033) and was inversely correlated with oxygenation (r = - 0.34, p = 0.001) in mechanically ventilated patients with COVID-19[94].

Potential implications for management

Usefulness of point-of-care ultrasound in the primary care setting has been evaluated in previous studies[95,96], and Calvo-Cebrián A et al aimed to evaluate its utility in influencing decisions about patients with clinical suspicion of COVID-19. A self-designed LUS severity scale and the individual finding of coalescent B-lines was found to be significantly associated with the main outcome of appropriate hospital referral (P = .008; OR, 4.5; 95% CI, 1.42–14.27) and a higher rate of hospital admission (P = .02; OR, 4.76; 95% CI, 1.18–19.15)[81]. Another utility of LUS was demonstrated by Dargent A et al., who monitored the evolution of COVID-19 pneumonia in 10 patients admitted to the ICU, and observed a lower LUS score in all patients on the day of extubation compared with admission, suggesting an accurate reflection of disease progression[97]. Gaspardone et al. observed LUS findings in the post-acute phase of COVID-19, noting residual lung alterations on the LUS and a higher LUS score at the time of discharge in patients who had more severe disease during the acute phase compared with patients with milder disease[85].

Utility in pregnant women

LUS is a potential alternative to CT scan in pregnant women, given the lack of radiation and option for short interval repeat testing associated with the procedure. Given obstetricians/gynecologists use ultrasound in their routine examinations, the systematic utilization of this practice to expand to LUS evaluation has previously been proposed[98]. Usefulness of LUS in assessing lung involvement in pregnant women with suspected or confirmed COVID-19 infection has been explored in several studies[99–101]. The addition of LUS scoring to symptoms and exposure history in pregnant women had significant impact on the prediction of a positive RT-PCR result, increasing the positive predictive value of the model from 77.1% (95% CI, 67.0–84.8%) to 93.7% (95% CI, 83.7–97.8%)[100]. In a series of 8 pregnant women with a positive COVID-19 RT-PCR, who underwent point-of-care LUS examinations after routine obstetric ultrasound, Yassa M et al. was able to detect serious lung involvement in 7 patients, significantly influencing their management and providing an alternative imaging modality in 2 patients not willing to undergo a CT chest[101].

MRI Findings in COVID-19

5 studies fulfilled our inclusion criteria [102–106]. 2 studies had control groups comparators [102,106]. Patients underwent MRI because of biochemical evidence of myocardial injury as evidenced by elevated high sensitivity troponin [102,104] or because of cardiac symptoms [104,105] while other studies performed screening MRI to identify high risk athletes in competitive sports [103,106]. Of note, in 1 study, none of the patients had elevated cardiac troponins [103].

Ejection fraction and volumetric assessment

LV and RV ejection fraction (EF) were noted in 4 studies [102,104–106]. In a study of 100 patients, and 50 controls, patients who recovered from COVID-19 had lower LVEF, RVEF, and higher left ventricular mass [102]. This was duplicated in another study of 10 patients where 2 had depressed LVEF with apical ballooning suggesting a takotsubo pattern and 3 patients having mildly reduced EF[104]. In another study of athletes recovering from COVID-19 compared with controls, RVEF was significantly reduced in the COVID-19 group [106].

Myocardial edema/late Gadolinium enhancement (LGE) and myocarditis pattern

Myocardial edema based on T2 sequences was reported in 3 out of 5 studies [103–105]. Lake Louise criteria were satisfied in 4 out of 26 [103] and 8 out 10 patients[104]. Similarly, LGE was reported in 5 studies[102–106]. Location and extent of LGE varied between individual studies. Non -ischemic scar was observed in 20 out of 100 patients [102],in another study 8 patients had scar at RV insertion (2 patients), 3 patchy involvement and 3 linear involvement [103]. 3 out of 10 patients [104] and 14 out of 26 patients [105] had subepicardial LGE, 1 study reported that most LGE was observed at inferior, and inferolateral basal and mid segments [105] and this was confirmed in another study where 2 patients had infero-septal LGE [106].

T1/T2 mapping and extracellular volume (ECV)

4 studies reported T1 values [102,104–106]. Native T1 was increased compared with controls in 2 studies [102,105]. One study showed normal T1 values as compared with controls [106] and one study had no comparators [104]. Similarly, native T2 values were elevated compared with controls [102,105,106]. ECV was reported in 3 studies [104–106] and was significantly elevated compared with controls [106] or patients with negative MRI [105]. Reported values for ECV were ranging between 28 to 36% [104,105]. 1 study reported that ECV was increased in mid-septum [106].

Conclusion

This review article highlights the most common findings and clinical implications found in COVID-19 patients evaluated with echocardiography, LUS and CMR. Future studies are needed to further guide treatment of this challenging disease.

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Figure Legend

Figure 1: PRISMA flow chart for study inclusion

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