Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Furthermore, comparing the means of the 2 studies, a significant decline in LGE was observed in the second CMR study (CMR I 7.4% ± 4.8% vs CMR II 3.4% ± 4.2%; $P = 0.018$), with overall similar location and pattern of the remaining LGE. No significant difference in the volume of the left ventricle was observed.

The current study evaluated a follow-up CMR scan among patients with myocarditis after a COVID-19 vaccine. It found an improvement in LVEF and a decline in LGE, with no significant change in left ventricular volumes compared with baseline CMR scan. These findings are overall in-line with a study by Aquaro et al,[2] who evaluated 187 patients with "classical" viral myocarditis and found that LGE disappeared completely in 18 (10%) patients, the number of LGE segments decreased in 87 (46%), was unchanged in 58 (31%), and increased in 26 (14%). We found that the extent of LGE has decreased in all patients and disappeared completely in 1 patient. Aquaro et al[2] also showed that the LGE of the follow-up CMR imaging and the trend of the LGE between baseline and follow-up CMR studies was a strong prognostic marker in viral myocarditis. Thus, our findings could imply a favorable course of post-COVID-19 vaccine myocarditis, although this remains to be further proven in a larger cohort. However, a study by Mahrholdt et al[5] in which the CMR scan was repeated 6 months after myocarditis reported a complete disappearance of LGE in 19 (27%) of 71 patients. These findings support the hypothesis that LGE in the acute setting of myocarditis does not entirely represent irreversible myocardial damage and probably results, at least partially, from the presence of edema and the inflammatory milieu increasing the volume of distribution of gadolinium and slowing its wash-out.[2]

We also observed a significant improvement in the left ventricular function at the follow-up CMR scan. This finding is of significance because left ventricular function at baseline and at 6 months' follow-up has been shown to be a strong predictor in patients with viral myocarditis.[3] Limitations include a relatively small sample and the fact that the CMR scans were not performed in all patients and with a nonidentical (often relatively delayed) interval or different scanners resulting in potential bias.

In conclusion, follow-up CMR imaging showed a significant decline in the extent of LGE and an improvement in LVEF among patients with post-COVID-19 vaccine myocarditis, possibly supporting a relatively favorable clinical course and outcomes in these patients.

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Follow-Up Cardiovascular Magnetic Resonance Findings in Patients With COVID-19 Vaccination-Associated Acute Myocarditis

Several case series have described acute myocarditis developing shortly after receiving messenger ribonucleic acid (mRNA) COVID-19 vaccines.[1] Cardiac magnetic resonance (CMR) characteristics in these patients resemble those found in patients with myocarditis from other causes. However, no prior reports or studies describe the evolution of myocardial edema and late gadolinium enhancement (LGE) on serial CMR evaluation—data that may help define the natural course of the disease.

In this case series, we describe the clinical course and repeat CMR findings after 3-6 months in 9 young male patients diagnosed with acute myocarditis after receiving an mRNA-based COVID-19 vaccine. All

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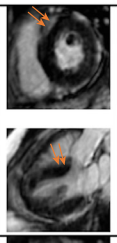
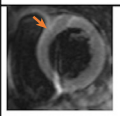
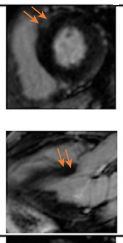
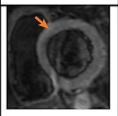
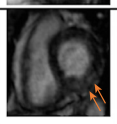
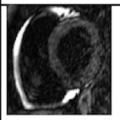
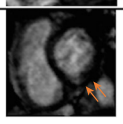
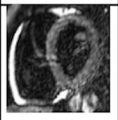
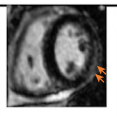
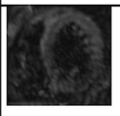
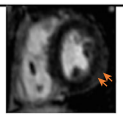
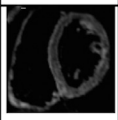
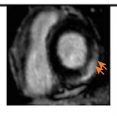
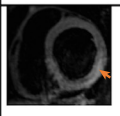
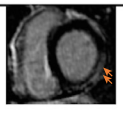
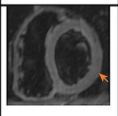
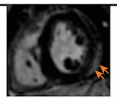
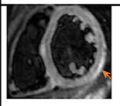
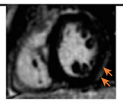
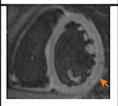
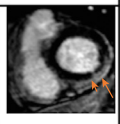
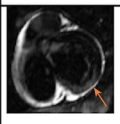
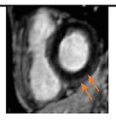
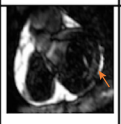
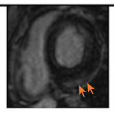
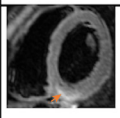
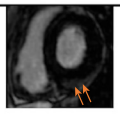
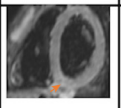
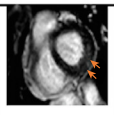
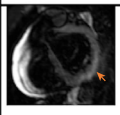
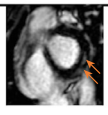
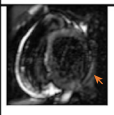
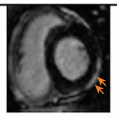
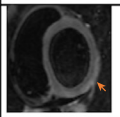
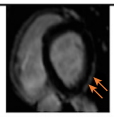
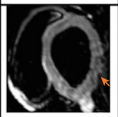
FIGURE 1 **CMR Characteristics on Admission and on Follow-Up Among 9 Young-Adult Male Patients With Acute Myocarditis Following mRNA-Based COVID-19 Vaccination**

	Admission			Follow-Up			
	CMR Parameters	LGE Images	T_2- Weighted Images	CMR Parameters	LGE Images	T_2- Weighted Images	Findings
Case 1	LVEF: 60% GLS: -15.6% GCS: -16.4% RVS: -21.3% T1: 1089 ms T2: 55 ms			LVEF: 65% GLS: -17.8% GCS: -15.6% RVS: -23.4% T1: 1040 ms T2: 45 ms			LGE: Resolving Edema: Resolving
Case 2	LVEF: 62% GLS: -17% GCS: -18% RVS: -18.2% T1: 981 ms T2: 42 ms			LVEF: 60% GLS: -13.5% GCS: -17.6% RVS: -26.1% T1: 981 ms T2: 42 ms			LGE: Resolved Edema: No change
Case 3	LVEF: 63% GLS: -12.6% GCS: -15.0% RVS: -15.7% T1: 1041 ms T2: 50 ms			LVEF: 63% GLS: -12.6% GCS: -14.8% RVS: -16.0% T1: 963 ms T2: 43 ms			LGE: Resolving Edema: Resolved
Case 4	LVEF: 65% GLS: -17.2% GCS: -16.2% RVS: -23.9% T1: 988 ms T2: NO			LVEF: 64% GLS: -17.9% GCS: -14.4% RVS: -22.9% T1: NO T2: NO			LGE: Resolving Edema: Resolved
Case 5	LVEF: 55% GLS: -15.5% GCS: -14.3% RVS: -18.6% T1: 979 ms T2: 45 ms			LVEF: 58% GLS: -14.6% GCS: -14.4% RVS: -23.4% T1: 971 ms T2: 43 ms			LGE: Resolving Edema: Resolved
Case 6	LVEF: 55% GLS: -15.5% GCS: -12.2% RVS: -19.6% T1: 1053 ms T2: 47 ms			LVEF: 54% GLS: -15.1% GCS: -12.4% RVS: -21.3% T1: 1058 ms T2: 46 ms			LGE: Resolving Edema: Resolved
Case 7	LVEF: 60% GLS: -16.5% GCS: -15.5% RVS: -14.9% T1: 932 ms T2: 44 ms			LVEF: 58% GLS: -14.3% GCS: -14.9% RVS: -15.3% T1: 954 ms T2: 44 ms			LGE: Resolving Edema: Resolved
Case 8	LVEF: 57% GLS: -14.5% GCS: -16.2% RVS: -14.7% T1: 961 ms T2: 42 ms			LVEF: 58% GLS: -13.5% GCS: -15.7% RVS: -14.4% T1: 943 ms T2: 41 ms			LGE: Resolving Edema: Resolved
Case 9	LVEF: 61% GLS: -16.5% GCS: -15.3% RVS: -22.2% T1: 984 ms T2: 46 ms			LVEF: 58% GLS: -16.8% GCS: -16.8% RVS: -27.7% T1: 969 ms T2: 42 ms			LGE: Resolving Edema: Resolved

Continued on the next page

patients developed acute myocarditis within 72 hours of receiving the second dose of COVID-19 vaccination, and they underwent initial CMR within 7 days of their hospital stay. Acute myocarditis was diagnosed based on clinical presentation (typical chest pain symptoms, electrocardiogram, and elevated cardiac biomarkers) and the presence of modified Lake Louise criteria on T_1- and/or T_2-weighted CMR images.[2] All CMR studies were performed on 1.5-T scanners using a standard myocarditis protocol based on guidelines from the Society for Cardiovascular Magnetic Resonance. All CMR studies were analyzed off-line using CVi42 (Circle Cardiovascular Imaging) by a level III reader. Follow-up evaluation for recurrent chest pain, hospital readmission, heart failure, and arrhythmias were obtained from outpatient cardiology clinic notes after index hospitalization discharge. The study was approved by the Institutional Review Board of the Lifespan Health System.

The mean age of the cohort was 22 years. None of the patients had a history of COVID-19 infection prior to the diagnosis of acute myocarditis. Two patients received Moderna COVID-19 vaccination and 7 patients received Pfizer COVID-19 vaccination. Over a median follow-up of 146 days, none of the patients experienced recurrent myocarditis, heart failure, or arrhythmias and none were readmitted to the hospital for any cause.

Follow-up CMR findings after a median of 94 days following initial diagnosis of acute myocarditis in these patients are shown in **Figure 1**. During the index hospitalization for acute myocarditis, subclinical myocardial dysfunction (defined by left ventricular global longitudinal strain [GLS] and/or global circumferential strain [GCS] $<-17\%$) was present in 8 of 9 patients. On follow-up, left ventricular GLS remained mildly abnormal in 7 of 8 patients and left ventricular GCS remained mildly abnormal in 8 of 9 patients. Similarly, right ventricular GLS was abnormal ($<-23.9\%$) in all 9 patients at baseline, and although there was a numerical improvement in right ventricular GLS in all patients on the follow-up, only 2 of 9 patients had GLS value of $>-23.9\%$ on the follow-up. There was complete resolution of myocardial edema in 8 of 9 patients on T_2-weighted images. LGE was present initially in all cases. On follow-up, there was resolution of LGE in 1 of 9 patients and resolving but persistent LGE in 8 of 9 patients.

CMR can help determine longer-term prognosis in patients with acute myocarditis.[3] The ITAMY (Italian Study in Myocarditis) registry showed that the presence of any LGE without myocardial edema compared to the absence of LGE on 6-month follow-up was associated with an increased risk of adverse cardiac events including sudden cardiac death, implantable cardioverter-defibrillator shocks, and heart failure hospitalization.[4] In this case series, we found that most of our patients have resolving LGE without the presence of myocardial edema on follow-up. It is likely that the persistence of LGE in the absence of myocardial edema represents myocardial fibrosis. Given that no clinical events were observed in our short-term follow-up, these tissue-related imaging findings likely portend a more favorable prognosis in the short term, but a long-term follow-up is needed to determine whether such persistence of LGE is associated with future cardiac events.

Reduced left ventricular GLS and GCS in patients with acute myocarditis have been reported to be associated with worse cardiovascular outcomes.[5] In our case series, we found persistent mild abnormalities in GLS and GCS in many patients. Such findings may portend less favorable prognosis of these patients on long-term follow-up.

FIGURE 1 Continued

Hyperintense signal suggestive of myocardial edema on T_2-weighted fat suppression **(single arrow)** and late gadolinium enhancement on T_1-weighted images **(double arrow)**. All cardiac magnetic resonance (CMR) studies were performed on 1.5-T Siemens magnetic resonance imaging scanner. Global longitudinal strain (GLS) of the left ventricle was evaluated using feature tracking (CVi42) from apical long-axis views containing 4-, 3-, and 2-chamber cine views. Global circumferential strain (GCS) of the left ventricle was obtained using feature tracking on short-axis cine views. Similarly, GLS of the right ventricle was used with feature-tracking method in apical 4-chamber view. The peak strain values for GLS (negative value) and GCS (negative value) were determined from the strain curves. The reference value of left ventricular GLS and GCS was -17%, whereas the reference value of right ventricular GLS was -23.9%. T_1- and T_2-weighted mapping: myocardial native T_1 maps were obtained on 1.5-T using a breath-hold, motion-correction, electrocardiogram-triggered, modified Look-Locker inversion recovery sequence with images acquired at end diastole before and approximately 20 minutes after contrast injection in the mid-ventricular short-axis plane. T_2 mapping was performed on 1.5-T using a single-shot T_2 prepared steady-state free precision in the mid-ventricular short-axis plane at end diastole during breath-hold with motion correction. LGE = late gadolinium enhancement; LVEF = left ventricular ejection fraction; mRNA = messenger ribonucleic acid; NO = not obtained; RVS = right ventricular strain.

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Limitations of this study include our relatively small patient cohort lacking any female patients. As such, our results may not be generalizable to a larger more diverse population. We did not have any Holter monitoring and exercise treadmill stress testing data on follow-up. However, the strength of this study includes robust CMR imaging techniques including T_1 and T_2 mapping, global ventricular strain reporting, and close follow-up of the patients.

This small case series suggests patients with acute myocarditis following mRNA-based COVID-19 vaccination have CMR evidence of myocardial recovery at 3-6 months but can have persistent mild abnormalities. These findings should be confirmed in a larger study cohort.

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Development and Validation of a Diagnostic Echocardiographic Mass Score in the Approach to Cardiac Masses

Cardiac masses (CMs) are a diagnostic dilemma in clinical practice and require multiple imaging techniques to assess malignancy, which is essential to guide the proper treatment.[1-3] Echocardiography can provide precious information and represents the first-line imaging approach to CMs, as more advanced methods may not be available at all centers. This study was planned to investigate the echocardiographic features of CMs that may suggest malignancy and build a score, the diagnostic echocardiographic mass (DEM) score, that can increase diagnostic yield.

All consecutive patients undergoing complete echocardiographic evaluations from 2004 to 2020 were enrolled. On the basis of definitive diagnosis, achieved by histologic examination or, in the case of cardiac thrombi, with radiological evidence of thrombus resolution after appropriate anticoagulant treatment, CMs were distinguished as benign or malignant and classified according to the World Health Organization's 2015 classification of tumors of the heart and pericardium.[4] Echocardiograms were obtained using high-quality ultrasound machines (Philips iE33 or EPIQ) following the recommendations of the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Images were analyzed offline by 2 expert echocardiography cardiologists with more than 10 years' experience in cardiac imaging, blinded to clinical information and CM histology. Several echocardiographic characteristics were assessed to select those able to potentially identify malignant masses. Variables maintaining statistical significance in independently predicting malignancy after logistic regression analysis were used to build a multiparametric predictive score, which was developed in a derivation sample and tested in a validation cohort. All patients were managed according to the Declaration of Helsinki and provided informed consent for the anonymous publication of scientific data. The study protocol was approved by the local ethics committee (registration number 102/2017/0/Oss).

Our final study population included 249 patients, 181 (72%) with benign CMs and 68 (28%) with malignancies, and no significant differences in terms of clinical and demographic characteristics were observed between the derivation (178 subjects [70%])