ESC European Society of Cardiology

European Heart Journal - Cardiovascular Imaging (2021) **22**, 852–854
doi:10.1093/ehjci/jeab097

INVITED EDITORIAL

Going after COVID-19 myocarditis

Patrick Doeblin[1,2,*] and Sebastian Kelle [1,2,3]

[1]Department of Internal Medicine—Cardiology, German Heart Center Berlin, Berlin, Germany; [2]DZHK (German Centre for Cardiovascular Research), partner site Berlin, Berlin, Germany; and [3] Medical Department, Division of Cardiology, Charité – Universitätsmedizin Berlin, Berlin, Germany

Online publish-ahead-of-print 2 June 2021

This editorial refers to 'Early cardiac involvement in patients with acute COVID-19 infection identified by multiparametric cardiovascular magnetic resonance imaging', by Chen *et al.* pp. 844–851.

> In battle, in a war, a soldier sees only a tiny fragment of what is available to be seen. The soldier is not a photographic machine. He is not a camera. He registers, so to speak, only those few items that he is predisposed to register and not a single thing more. Do you understand this? So I am saying to you that after a battle each soldier will have different stories to tell, vastly different stories, and that when a war is ended it is as if there have been a million wars, or as many wars as there were soldiers.
>
> —Tim O'Brien, Going After Cacciato

The pandemic has ravaged through our lives in so many ways that we readily believe it scars our hearts as well. Patients complain of cardiac symptoms long after recovery, seemingly unrelated to COVID-19 severity.[1] Observational cardiac magnetic resonance (CMR) studies have found a plethora of abnormalities with remarkable variation between groups.[2–9] The only consistent findings seem to be a paucity of classical myocarditis and no clear relation between abnormalities and symptoms. Pathologic studies showed increased numbers of macrophages in the myocardium of many patients, a high prevalence of thrombotic complications but few cases of lymphocytic myocarditis.[10–13]

Chen *et al.*[14] add another brick to the house of COVID-19. While previous CMR studies have focused on recovered COVID-19 patients, this is the first CMR study in acute COVID-19 patients. The authors deserve our great respect for putting themselves at risk by scanning patients that are still infectious. From a collective of 120 hospitalized COVID-19 cases, the authors selected 25 patients based on symptoms and clinical findings, thus maximizing pre-test probability of cardiac involvement. The authors further stratified patients by Troponin elevation and compared both groups to age- and sex-matched healthy controls.

Their main findings were:

- overall slight impairment of left ventricular systolic function by volumetry and strain analysis (right ventricular function was not assessed),
- high prevalence of myocardial oedema on T2-weighted imaging (56%) and T2 mapping,
- low prevalence of irreversible focal necrosis (one patient with late gadolinium enhancement), and
- patients with elevated Troponin scored worse in all categories.

Out of 120 patients who were sick enough to warrant hospitalization, the authors identified only one case of 'classical' myocarditis with focal necrosis. While findings of functional impairment and myocardial oedema warrant follow-up, studies at later intervals post-COVID-19 showed little functional impairment of the left ventricle even in troponin-positive patients.[2–9]

Open questions remain regarding the specificity of the findings. Transient cardiac dysfunction is apparent in a substantial number of patients with severe infections irrespective of the causative organism.[15] Vasodilation and redistribution of fluid into the extracellular space are basic features of our systemic inflammatory response, which might explain elevations in the mapping parameters native T1, T2, and extracellular volume (ECV).[16] Most of us have encountered the perils of high-sensitivity troponin in our residency and we are familiar with the concept of 'type 2 myocardial infarction', namely a rise in troponin due to causes other than acute coronary artery occlusion. Are we heading in the same direction with high-sensitive CMR, diagnosing 'type 2 myocarditis'?

The CMR diagnosis of myocarditis relies strongly on the Lake–Louise–Criteria (LLC), which require evidence of both oedema and myocardial damage. While the LLC show good sensitivity and specificity for the detection of acute myocarditis in patients with reasonable clinical suspicion, their diagnostic accuracy for chronical conditions

The opinions expressed in this article are not necessarily those of the Editors of *EHJCI*, the European Heart Rhythm Association or the European Society of Cardiology.

* Corresponding author. Tel: +49 (30) 4593 2400. E-mail: doeblin@dhzb.de

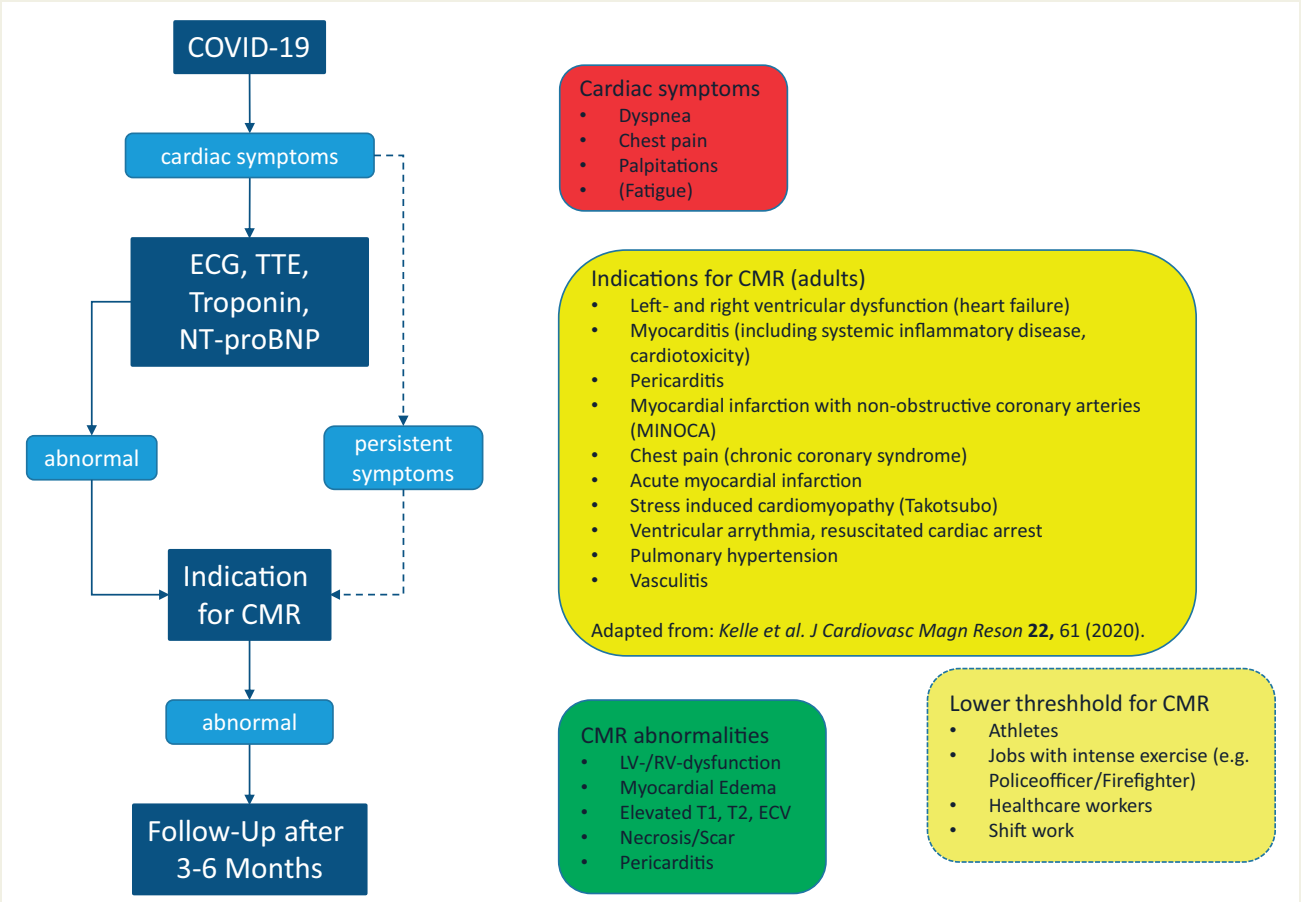

Figure 1 Recommendation for a symptoms-oriented approach towards CMR in patients with suspected cardiac involvement post COVID-19. CMR, cardiac magnetic resonance; COVID-19, coronavirus infectious disease 2019; ECG, electrocardiogram; LV, left ventricle; NT-proBNP, N-terminal pro-brain natriuretic peptide; RV, right ventricle; T1, T1 relaxation time; T2, T2 relaxation time; TTE, transthoracic echocardiography.

has not been established. Furthermore, the LCC were recently updated to include the mapping-parameters native T1, T2, and ECV.[17] T1 and T2 relaxation times of protons are the main determinants of native tissue contrast in magnetic resonance imaging, while the ECV determines uptake of extracellular contrast agents. Modern mapping methods allow direct quantification of these underlying tissue properties, comparable to the Hounsfield-Units in computer tomography. All three parameters are elevated in myocardial oedema and necrosis, whereas T1 and ECV are also elevated in fibrosis.[17]

While the original LLC required evidence of necrosis or scar on late enhancement imaging, the updated criteria accept elevated native T1 or ECV as a surrogate, effectively expanding the CMR diagnosis of myocarditis to myocardial oedema without myocardial damage. The resulting increase in sensitivity is welcome for well-selected patients with a high pre-test probability of myocarditis and greatly facilitates follow-up. However, this comes at a cost of decreased specificity. Applying the updated LLC to patients with low pre-test probability, especially in the presence of possibly confounding conditions, inevitably increases the number of false positives. It will produce a barrage of unspecific elevations in parameters that check the boxes for myocarditis but might just resemble systemic inflammation. We have yet to understand the prognostic relevance of these findings and their relation to the patients' symptoms and long-term follow-up data are needed. Furthermore, we need comparisons with patients with other pulmonary and systemic infections to differentiate COVID-19-specific pathology from physiological inflammatory response.

Currently, there is no evidence for routine clinical use of CMR during or after COVID-19 in the absence of symptoms or signs suggestive of a cardiac pathology. In our clinic, we choose a pragmatic, symptom-oriented approach, depicted in *Figure 1*.[18] For certain high-risk occupations, a lower threshold for imaging might be appropriate depending on symptoms and the clinical course. Ultimately, the decision lies on us as clinical cardiologists to use diagnostic procedures wisely as a guide to treatment. As always, diagnostic procedures have harms that we need to weigh against their benefits.

Because COVID-19 is an international disease, we recommend that researchers and clinicians share their anonymized data in international registries to allow for independent assessment of their findings and epidemiological analyses that might shed light on the missing

links. As an example for CMR, the Society for Cardiovascular Magnetic Resonance (SCMR) offers a registry with extensive data reporting options (https://scmr.org/page/COVID-19Registry). With mutual collegial assistance, maybe one day our individual fragments will combine to form a comprehensive picture of what COVID-19 does or does not do to our hearts and lead to a better understanding of not just COVID-19-related inflammatory cardiac diseases.

Conflict of interest: P.D. owns stock of Siemens and Bayer. S.K. is the past-Chair of the Advocacy Committee of the Society for Cardiovascular Magnetic Resonance (SCMR) and current member of the SCMR COVID-19 Registry Task Force and is supported by Philips Health Care.

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