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Contribution of Cardiac MRI in the Diagnosis of Acute Myocarditis

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Abstract

Objective: To describe the MRI abnormalities observed in acute myocarditis. **Materials and Methods:** Retrospective cross-sectional study with a descriptive aim, carried out at the North Franche-Comte Hospital, over a period of 12 months, from January 2021 to December 2021. It covered all patients who received an MRI of heart disease and were diagnosed with myocarditis. The diagnosis of myocarditis was retained in all patients on the basis of two arguments: a T2 PSIR hyper signal and a late enhancement at 15 min in T1 PSIR with gadolinium. **Results:** Myocarditis was diagnosed in 20 patients out of a total of 214 who performed cardiac MRI, *i.e.* 10.30% of cases. The average age was 33.7 ± 14.3 with extremes of 17 and 69 years. We observed a male predominance with 11 men (55%) for 9 women (45%) or a sex ratio of 1.2. Clinical suspicion of myocarditis and acute coronary syndrome were the main indications for MRI. The lesion sites were subepicardial (95%) and/or intramural (30%), respecting the subendocardium, interesting for the majority, segments 12 (anterolateral) in 50% and/or 11 (inferolateral) in 43% of cases. Global hypokinesia was observed in 30% of patients associated with a decrease in LVEF. There was no cardiac volume abnormality or valvular abnormality. **Conclusion:** Cardiac MRI is nowadays the most efficient non-invasive imaging in the diagnosis of acute myocarditis. The diagnosis of myocarditis was made on 2 pathognomonic signs, namely a T2 STIR hyper signal and late enhancement at 15 min in T1 PSIR after injection of gadolinium. The morphology and lesion locations were in agreement with those described in previous studies. Global hypokinesia and pericardial effusion were observed in some patients. On the other hand, there was neither valvular anomaly, nor cardiac volume anomaly.

1. Introduction

Acute myocarditis is an inflammatory pathology of the myocardium, frequently of viral origin. When symptomatic, it is often difficult to diagnose, and the gold standard remains myocardial biopsy [1]. Myocarditis is a serious pathology, involved in the appearance of chronic dilated heart disease, but also in 8.6% to 12% of sudden deaths in young adults [2]. Faced with chest pain, electrocardiogram abnormalities and elevated blood levels of cardiac enzymes, myocarditis can be suspected in a young subject without cardiovascular risk factors, or at any age when coronary angiography is normal. However, first-line examinations do not provide the diagnosis of myocarditis with certainty, and do not make it possible to eliminate other etiologies, and in particular, an infraction with healthy coronary arteries [3]. There is, therefore, a need for a non-invasive diagnostic tool to confirm a diagnosis in these patients for whom the exit diagnosis is often a probability diagnosis. MRI is, therefore, the non-invasive diagnostic examination of reference, based on the semiological criteria of Lake-Louise, based on the identification of edema and capillary hyperemia, necrosis or myocardial fibrosis [4]. Initially, established in 2009, they were revised in 2018 based on developments in cardiac MRI acquisition techniques, in particular T1 and T2 mapping sequences and estimation of the Extracellular Volume (ECV) fraction of the myocardium [5]. Some authors have also shown that MRI with the injection of gadolinium, in this clinical situation, makes it possible to make the differential diagnosis between ischemic and non-ischemic pathologies [6]. By applying this semiology, we sought to confirm in our study the contribution of cardiac MRI in the face of a clinical picture suggestive of myocarditis, for which the first-line examinations cannot formally conclude.

2. Materials and Methods

We conducted a retrospective descriptive study. It took place in the Radiology Department of the North Franche-Comte Hospital (France). It covered a period of 12 months, from January 2021 to December 2021. The study population consisted of all patients seen for cardiac MRI. Were included in the study, patients in whom the diagnosis of myocarditis was retained in the presence of at least 2 of the 3 Lake Louise criteria, namely myocardial hyperemia, highlighted by an early global enhancement of the myocardium on T1-weighted sequences with the injection of gadolinium, regional or global myocardial edema, demonstrated by a hyper signal in T2-weighted STIR sequence and myocardial necrosis or fibrosis, most often multifocal, of subepicardial location (as opposed to scars under endo-heart attacks of ischemic origin), highlighted by late enhancement on T1-weighted se-

quences with the injection of gadolinium. Patients with a doubtful diagnosis with the presence of a single Lake Louise criterion associated or not with pericardial effusion and those with a strong clinical and biological suspicion but without signs on the MRI were not retained. The examinations were carried out with a Phillips brand 1.5 T MRI machine commissioned in 2017. The absence of major absolute contraindications, including the presence of a stent or a metal valve, was verified at prior. The patients were installed in the supine position with the knees supported in half flexion by a foam wedge; a phased array coil (dedicated cardiac coil) was used. The myocardium study protocol included: cine-MRI in short axis, long axis and 4 chambers with determination of LVEF, T2-weighted morphological sequence, 3D viability sequence at 6 min in short axis, long axis and four chambers and PSIR short axis to study late enhancement 15 min after injection of gadolinium.

The analysis was done by a senior radiologist, in two stages. First, a morphological analysis of the signal anomalies (shape and topography) according to the segmentation of the heart into 17 segments. Then, a functional analysis was done for the quantification of the systolic ejection fraction. We also looked for the presence of other signs such as valvular involvement. The parameters studied were recorded in the patient's file. These parameters were the sex and age of the patients, the indications and the protocol of the MRI examination, then the morphological lesions (late enhancement under endocardial, intramural, under endocardial or transmural) and functional anomalies observed (akinesia, hypokinesia or dyskinesia). Data entry and analysis were performed using Stata version 14 software. We performed a simple descriptive analysis of the different variables.

3. Results

Over a period of 12 months, 20 patients met our inclusion criteria out of a total of 214, *i.e.* 10.30% of patients who underwent cardiac MRI during the study period. We found a male predominance with 11 men (55%) for 9 women (45%) or a sex ratio of 1.2. The mean age of the patients was 33.7 ± 14.3 with extremes of 17 and 69 years. The majority age group (55%) was between 15 and 30 years old (Table 1).

The reasons for consultation were dominated by clinical suspicion of myocarditis and acute coronary syndrome respectively in 39% and 34% followed by chest pain in 27%.

A morphological abnormality such as slight dilation of the left ventricle was observed in two patients, *i.e.* 10%.

Regarding functional abnormalities, global hypokinesia of the left ventricle was observed in six patients, *i.e.* 30% associated with a drop in Left Ventricular Ejection Fraction (LVEF). There was no cardiac volume abnormality or valvular abnormality detected.

For the diagnosis of myocarditis, all the patients presented a T2 STIR hyper signal and a late enhancement on the T1 PSIR sequences with injection of gado-

linium (Figure 1 and Figure 2).

The lesions were multisegmental and the majority were located in segments 12 (anterolateral) in 50% and/or 11 (inferolateral) in 43%.

There was a predominance of subepicardial lesions in 90% followed by intramural lesions in 30%. The morphology of the lesions was mainly linear 90% and/or nodular 25%. Pericardial effusion was observed in four 20% patients. There was no transmural involvement or isolated subendocardial involvement (Table 2).

Table 1. Distribution of patients according to age.

Age	Frequency	Percentage
15 - 30	11	55
30 - 45	4	20
45 - 60	4	20
≥60	1	5
Total	20	100

(a)   (b)   (c)
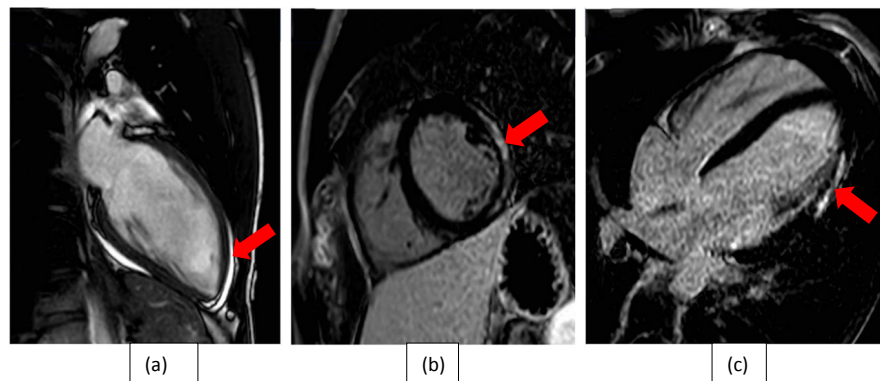
Figure 1. Cardiac MRI: (a) (long axis 2 chambers): pericardial effusion (red arrow); (b) and (c) late PSIR enhancement sequence 15 min after Gadolinium injection (2-cavity and 4-cavity minor axis incidence): late enhancement with subepicardial distribution (red arrows) in the median and apical, lateral and inferolateral wall.

Figure 2. Cardiac MRI (short axis 2 chambers T2 STIR), edema in T2 hyper signal (red arrow) of the infero-lateral wall of the left ventricle.

Table 2. Distribution of patients according to the site of the lesion.

Site	Frequency	Percentage
Subepicardial	19	95
Intramural	6	30
Subendocardial	0	0
Transmural	0	0

4. Discussion

Our study aimed to describe the MRI aspects of acute myocarditis.

4.1. Limitations of the Study

First of all, our workforce was, in fact during our study period we only listed 20 cases of myocarditis. Cardiac MRI is a long and restrictive examination; it requires in particular apneas and prolonged decubitus, as well as good cooperation from the patient. It is sometimes impossible to perform in arrhythmic or claustrophobic patients. There may therefore be a recruitment bias.

No myocardial biopsy was performed, which currently remains the gold standard for the diagnosis of myocarditis [1]. It is invasive and often unprofitable [3], and is currently not indicated as first-line treatment in the absence of signs of severity [7] [8]. Our diagnoses were therefore established according to the MRI semiology already described [4] [9]. The concordance of our results with these studies contributes to the validation of this semiology and the diagnostic capacities of MRI, as a non-invasive method.

4.2. Epidemioclinical Characteristics

Our patients were young, with an average age of 33.7 ± 14.3 and extremes of 17 and 69 years. Our result is close to that noted by Dubois (39.3 years) [10]. In our study, the patients were predominantly male (55%). This male predominance was observed in almost all of the available studies. Touré and Augier [11] [12] had observed it between 100% and 69%. In our series, the indication for MRI was dominated by clinical suspicion of myocarditis and acute coronary syndrome respectively in 39% and 34% followed by chest pain in 27%. In a study by Oloudé *et al.*, coronary syndrome was the main indication for MRI 76% followed by suspicion of myocarditis 24% [13].

4.3. Examination Protocols

The myocardium study protocol included for all patients: cine-MRI sequence in the short axis, long axis and 4 cavities with determination of the LVEF, T2-weighted morphological sequence, 3D viability sequence at 6 min in the short axis, long axis and four chambers and short-axis PSIR to study late enhancement 10 min after gadolinium injection.

T1 and T2 maps of the myocardium, with quantification of the Extracellular

Volume (ECV), have recently been proposed for the tissue characterization of the myocardium. In patients with myocarditis, these techniques overcome certain limits of the Lake Louise criteria [14]. Mapping techniques provide quantitative data on tissue magnetic properties, including myocardial T1 and T2 relaxation times, and are therefore less sensitive to the limitations of the often subjective or visual assessment of signal intensity. They were not carried out in our in our service given the unavailability on our device. The T2-weighted morphological sequences made it possible to visualize in the patients edematous segments which appear in hyper signal within the myocardium. The dynamic sequences provided functional arguments concerning the systolic function of the LV (ejection fraction), the segmental kinetics, the measurements of diameters, thicknesses and volumes of the cardiac chambers. The sequences after injection confirmed the existence of a normal perfusion during the first pass. Late enhancement sequences were able to highlight contrast-enhancing segments in patients. Delayed enhancement after injection of contrast product would therefore constitute a sensitive and effective method for detecting the presence, distribution and extent of myocardial fibrosis or necrosis, and therefore myocarditis [15]. Several studies had correlated the presence of late enhancement and myocarditis proven by myocardial biopsy; with a specificity of 91.4% but a variable sensitivity of 73.8% on average. It would be possible that the sensitivity of this technique is dependent on the duration of the symptoms, with a higher sensitivity in the acute phase [16].

4.4. Morphological Lesions

All the patients in our study had presented a linear and/or nodular hyper signal, independent of the vascular territories, not reaching the subendocardium, on the T2 STIR sequence and an enhancement at 15 min after injection of Gadolinium on the T1 PSIR sequence. Our results were in agreement with those of Paule and Feldman [1] [12] who had reported that the majority of patients presented hyper signals suggestive of acute myocarditis in 91% in T2 STIR and 97% on late enhancement in T1 PSIR at 15 min. after gadolinium injection. The most important study concerning the analysis of myocarditis by MRI is that of Mahrholdt *et al.* [9], who evaluated 128 patients (87 of whom presented with myocarditis) by 1.5 T MRI (cine MRI, late enhancement analysis), MRI-guided endomyocardial biopsies, histological and virological analyses. In this study, late enhancement was present in 95% of patients with active myocarditis, 40% of patients with healing myocarditis, and none of the patients with no histopathological criteria for myocarditis (except for a patient with cardiac amyloidosis).

4.5. Topography of Lesions

In our study, lesions predominated in segments 11 and 12 in 43% and 50%. Our results were slightly superior to those of Augier [17] who had shown a predominance of lesions with contrast price at the level of segments 11 and 12 in 37%

for each of the sites. Other authors had also observed that generally, the preferential involvement would be the anterolateral wall, with or without thickening of the latter [18]. Mahroldt and Liu [8] [9] had also shown that the affected areas were in the early stage of the disease, the lateral wall (segment 11). At the level of the myocardium, the lesions were preferentially located subepicardial 90% and/or intramural 30%, never subendocardial. Our result was identical to that of Paule *et al.* who reported one or more foci of late subepicardial and/or intramyocardial enhancement in 90% of patients [12]. These results are in line with the data in the literature by constituting a reliable argument in favor of the diagnosis of acute myocarditis and helping to rule out an Acute Coronary Syndrome (ACS) [9]. In infarcts, the attack of the subendocardium is systematic and of more "brilliant" aspect because containing less viable myocytes between the areas of necroses [9].

4.6. Associated Lesions

In our study, pericardial effusion was associated in 4 out of 20 patients, *i.e.* 20%. This result is consistent with that of Laissy who reported pericardial effusion in 20% of patients [18]. Regarding functional abnormalities, we found global hypokinesia associated with a decrease in LVEF in 30% of patients. Roditi *et al.* [7], on 12 MRIs of patients presenting with myocarditis, noting kinetic disorders at the level of the zones marked by late enhancement in ten patients, and normal kinetics at the level of the marked zones in two patients. Not all authors agree on the correspondence between areas with kinetic disturbance and areas of late enhancement: most publications report late enhancements located outside dyskinetic areas [4] [18] [19].

5. Conclusion

The results of our study are in agreement with those of previous studies. The diagnosis of myocarditis was made in all patients on 2 pathognomonic signs, namely a T2 STIR hyper signal and late enhancement at 15 min in T1 PSIR after injection of gadolinium. As described in the literature, our patients were young with a male predominance, consulting mostly for acute coronary syndrome and/or for clinical suspicion of myocarditis. Lesion locations were voluntarily subepicardial and/or intramural, never subendocardial. Global hypokinesia and pericardial effusion were noted in some patients. On the other hand, there was neither valvular anomaly, nor anomaly of the cardiac volumes.

Authors' Contribution

All authors contributed to the acquisition of data, analysis and interpretation of the data and writing of the article.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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