Cardiac magnetic resonance findings and prognosis in type 1 myotonic dystrophy

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**Background** Cardiac involvement is a major determinant of prognosis in type 1 myotonic dystrophy (DM1), but limited information is available about myocardial remodeling and tissue changes. The aim of the study was to investigate cardiac magnetic resonance (CMR) findings and their prognostic significance in DM1.

**Methods** We retrospectively identified all DM1 patients referred from a neurology unit to our CMR laboratory from 2009 to 2020.

**Results** Thirty-four patients were included (aged 45 ± 12, 62% male individuals) and compared with 68 age-matched and gender-matched healthy volunteers (43 male individuals, age 48 ± 15 years). At CMR, biventricular and biatrial volumes were significantly smaller (all P<0.05), as was left ventricular mass (P<0.001); left ventricular ejection fraction (LVEF) and right ventricular ejection fraction (RVEF) were significantly lower (all P<0.01). Five (15%) patients had a LVEF less than 50% and four (12%) a RVEF less than 50%. Nine patients (26%) showed mid-wall late gadolinium enhancement (LGE; 5% ± 2% of LVM), and 14 (41%) fatty infiltration. Native T1 in the interventricular septum (1041 ± 53 ms) was higher than for healthy controls (1017 ± 28 ms) and approached the upper reference limit (1089 ms); the extracellular volume was slightly increased (33% ± 2%, reference <30%). Over 3.7 years (2.0–5.0), 6 (18%) patients died of extracardiac causes, 5 (15%) underwent device implantation; 5 of 21 (24%) developed repetitive ventricular ectopic beats (VEBs) on Holter monitoring. LGE mass was associated with the occurrence of repetitive VEBs (P = 0.002). Lower LV stroke volume (P = 0.017), lower RVEF (P = 0.016), a higher LVMi/LVEDVI ratio (P = 0.016), fatty infiltration (P = 0.04), and LGE extent (P<0.001) were associated with death.

**Conclusion** DM1 patients display structural and functional cardiac abnormalities, with variable degrees of cardiac muscle hypotrophy, fibrosis, and fatty infiltration. Such changes, as evaluated by CMR, seem to be associated with the development of ventricular arrhythmias and a worse outcome.

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Introduction

Type 1 myotonic dystrophy (DM1) or Steinert disease is the most common genetic form of muscular dystrophy, with an estimated prevalence of 5–20:100 000.1 Transmission is autosomal dominant and the genetic defect consists of an abnormal expansion of CTG triplet repeats within the DMPK gene. Normal people carry 5–34 CTG repeats; 35–49 repeats identify a premutation allele, and more than 50 repeats result in full-penetrance phenotype.1 The typical form has juvenile–adult onset and features distal muscle weakness, grip myotonia, ptosis, and weakness of oropharyngeal muscles. Respiratory function may be affected.1

Cardiac involvement is very common in DM1. Abnormalities at the ECG or at ECG Holter monitoring are observed in about 80% of patients.2–4 Bradycardias and ventricular tachyarrhythmias may account for the relatively high incidence of sudden cardiac death (SCD; ~0.56% per year).5,6 PR and QRS elongation and atrial tachyarrhythmias have been associated with SCD.5–9 Left ventricular hypertrophy and dilation, mitral valve prolapse, and regional wall motion abnormalities are among the most common echocardiographic findings, each affecting about 10–20% of patients.10 Left ventricular systolic dysfunction (LVSD) has a similar prevalence (7–14%),6,10,11 and diastolic dysfunction is common even in early disease stages.12–18 At histology, myocardial disease in DM1 is characterized by fibrosis, fatty replacement and lymphocytic infiltrates, along with an increased variability in fiber size, with coexisting atrophic and hypertrophic myocytes.19–22 Such changes promote
re-entry phenomena\textsuperscript{23–25} and likely also conduction disturbances.

Cardiac magnetic resonance (CMR) case series have shown a reduction of mean cardiac mass and volumes in patients with DM1.\textsuperscript{4,15–18} A normal mass/volume ratio has been reported,\textsuperscript{17} but most studies did not evaluate ventricular geometry. Mid-wall late gadolinium enhancement (LGE) has been reported, most often in the septal/inferolateral segments,\textsuperscript{16,18,26–31} and an enlarged extracellular volume has been demonstrated through mapping techniques.\textsuperscript{16,17,28,30,32} The link between CMR findings and electrical disturbances in DM1 is controversial\textsuperscript{16–18,27–34} and their prognostic significance is unclear.

In this study, we investigated cardiac involvement in DM1 focusing on ventricular mass and volumes and tissue changes at CMR, and their association with clinical outcome.

**Methods**

**Patient population**

We reviewed electronic health records (EHRs) of the Fondazione Toscana Gabriele Monasterio (Pisa, Italy) to retrieve all patients with a genetic diagnosis of DM1, referred for cardiological assessment between 2009 and 2020, and with sufficiently detailed clinical information at the Neurology Unit of the Azienda Ospedaliera Universitaria Pisana (Pisa, Italy). Patients with a history of myocardial infarction, coronary revascularization or cardiac surgery were excluded, because we were interested in studying the nonischemic cardiomyopathy specifically associated with DM1.

Seventy-three patients (43 male individuals, age 48 ±15 years) with DM1 were identified. One patient was excluded because of the lack of follow-up data, and two because of a prior myocardial infarction. The other 36 patients had not undergone a CMR scan because of a PM/ICD (n = 14) or refusal to undergo the examination (n = 22). The final study population included 34 patients with DM1. Moreover, a control population of 68 healthy volunteers (43 male individuals, age 48 ±15 years; age-matched and gender-matched 2 : 1 with DM1 patients) who had undergone a noncontrast CMR scan at the Fondazione Toscana Gabriele Monasterio was retrospectively retrieved, as a reference control group.

All clinical, laboratory, electrocardiographic, and echocardiographic data at the time of CMR were recorded. Neuromuscular disability was assessed by the Muscular Impairment Rating Scale (MIRS), a five-point scale evaluating extent and severity of muscular impairment (from score 0 – asymptomatic to score 5 – severe proximal weakness).\textsuperscript{35} The study complied with the Declaration of Helsinki; all patients provided written informed consent.

**Cardiac magnetic resonance**

Patients underwent CMR with a 1.5 T scanner (Signa CVi, GE Healthcare, Milwaukee, USA). Biventricular systolic function was assessed by breath-hold steady-state free precession (SSFP) cine imaging in the short-axis (SA) stack (8 mm thickness, no gap). Sequence parameters were: field-of-view: 360–400 mm, repetition/echo time: 3.2/1.6 ms, flip angle: 45–60°, matrix: 224 × 224, phases: 30. Black blood imaging was acquired in the same short-axis stack (8 mm thickness, no gap), using a proton-density (PD) fast-spin-echo (FSE) sequence; field-of-view: 360–400 mm, repetition time: two RR interval (1200–2000 ms, according to patients’ heart rate); echo time: 20–40 ms; matrix: 224 × 224. Late gadolinium enhancement imaging was performed between 10 and 20 min after contrast agent administration (Gadoteric acid, DOTAREM, 0.2 mmol/kg) using a segmented T1-weighted gradient-echo (GRE) inversion-recovery pulse sequence. In SA orientation, the left ventricle (LV) was encompassed by contiguous 8 mm thick slices (with no inter-slice gap). Inversion time (TI) was individually adapted to suppress the signal of normal remote myocardium (220–320 ms). LGE was also confirmed or excluded in vertical and horizontal long-axis views. Sequence parameters were: field-of-view: 360–400 mm, slice thickness: 8 mm, repetition/echo time: 4.0/1.3 ms, flip angle: 15–20°, matrix: 224 × 192. Native (precontrast) T1 mapping was acquired in three SA slices (basal, medium, and apical) using a modified Look-Locker (MOLL) sequence (3.3, 5 scheme; flip angle: 35°; matrix: 172 × 172 pixels; partial Fourier = 0.75) in a subset of 13 (38%) patients; postcontrast T1 mapping was acquired 15–20 min after gadolinium injection in nine (27%) patients.

All CMR studies were analyzed offline on the Advantage Workstation (GE Healthcare) with dedicated software (MASS 6.1, Medis, Leiden, Netherlands) by one experienced CMR reader blinded to clinical data (GDA, AB, CG, GT); all CMR analysis were revised by a second CMR reader and, in case of discordance, final agreement was found with a third reader. LV and right ventricular (RV) volumes, mass, and global function were calculated on SA cine images and indexed on body surface area. Biventricular fatty infiltration was assessed as banding artifacts in the cine SSFP sequences, confirmed by the presence of hyperintense intramyocardial areas in PD-weighted FSE imaging. LGE presence and extent were determined on SA images as areas with signal intensity at least 6 standard deviations above remote, nonenhanced myocardium.\textsuperscript{34,36} Native and postcontrast T1-mapping were analyzed by drawing a region of interest in the septum (segments 2,3,8,9,14). Native T1-mapping was available for a subset of 13 (38%) patients, while both native and postcontrast T1 were available for 9 (27%) of them. In these nine patients, myocardial extracellular volume (ECV) was calculated as (ΔR1myocardium/ΔR1blood)×(1-hematocrit), where ΔR1 = (1/T1postcontrast – 1/T1precontrast).\textsuperscript{37} Total LV matrix and cell volumes were calculated from the product of LV...
Follow-up
Follow-up data were retrieved in August 2022 from EHRs, patients, cardiologists, or general practitioners. All available ECG, Holter recordings and device interrogations performed after CMR examination were searched for evidence of atrioventricular blocks (AVB), intraventricular conduction disturbances (IVCD), atrial fibrillation or flutter (AF/Fl), and repetitive (Lown class 4) ventricular ectopic beats (VEBs). Furthermore, all echocardiographic and CMR reports were checked for the presence of LVSD. Overall, AVB, IVCD, AF/Fl, evidence of Lown class 4 VEBs at Holter monitoring and LVSD were considered as separate surrogate end points. When available, CMR examinations after the first one were analyzed.

Statistical analysis
The R software (version 4.0.2, 2020) was used. Normality was assessed through the Shapiro–Wilk test. Categorical variables are reported as count (percentage). Normal continuous variables are presented as mean ± SD, while nonnormal continuous variables were presented as median (interquartile interval). Paired-sample and unpaired-sample Wilcoxon or t-tests were used as appropriate to compare continuous variables; chi-square tests were used for proportions. Logistic regression analysis was performed to find clinical predictors of fatty infiltration or LGE at CMR. Univariate Cox regression models were fitted to the data; survival curves were compared through the likelihood ratio test. Schoenfeld residuals were tested for each model; when data significantly deviated from proportional hazards, time-dependent weights were applied. Accordingly, an average hazard ratio (AHR) was calculated as the ratio between the LVM index (LVMI) and the LV end-diastolic volume index (LVEDVI). The mass/thickness index was calculated as the ratio between the LVM and the maximal end-diastolic thickness (the thickest of the two standard measurements at the anteroseptal and inferolateral basal wall).

Results

Baseline population characteristics
Thirty-four patients were enrolled, predominantly male individuals (62%), with a median age of 45 (36–52) years. Neurologic and genetic features of the recruited patients are presented in Tables S3 and S4, http://links.lww.com/JCM/A531. At neurological examination, 8 (24%) patients had minimal neurological signs, 15 (44%) distal muscle weakness (44%), 9 (26%) mild-to-moderate proximal muscle weakness, and 2 (6%) proximal muscular involvement.

At the time of CMR, 13 (38%) patients had a history of AVB, 30 (88%) an intraventricular conduction disturbance, and 4 (12%) an atrial fibrillation or flutter. No patient had severe valvular heart disease at echocardiography. The main baseline characteristics of our cohort are reported in Table 1.

Cardiac magnetic resonance findings
At CMR, five patients (15%) displayed LVSD (LVEF <50%) and four (12%) a depressed RV function (RVEF <50%). Baseline CMR findings are reported in Table 2. Compared with age-matched and gender-matched controls, DM1 patients presented significantly lower biventricular diastolic volumes (P = 0.028 and P = 0.002 for the left and right ventricles, respectively).

Table 1 Baseline characteristics of the cohort at the time of cardiac magnetic resonance, including clinical and electrocardiographic (rest ECG and Holter) findings, and pharmacologic provisions throughout follow-up

| Variables                          | Patients (n = 34) |
|-----------------------------------|------------------|
| Clinical findings                 |                  |
| Age at CMR (years)                | 45 ± 12          |
| Gender (m/f)                      | 21/13            |
| BMI (kg/m²)                       | 26 ± 4           |
| Smoking                           |                  |
| Hypertension                      | 2 (6%)           |
| High cholesterol                  | 12 (35%)         |
| Diabetes                          | 0 (0%)           |
| Systolic arterial pressure (mmHg) | 114 ± 13         |
| Diastolic arterial pressure (mmHg)| 69 ± 8           |
| Mean arterial pressure (mmHg)     | 84 ± 9           |
| Baseline electrocardiographic findings |              |
| Atrioventricular block            | 13 (38%)         |
| 1st degree AVB                    | 12 (35%)         |
| 2nd degree Mobitz I               | 1 (3%)           |
| Intraventricular conduction disturbance |       |
| LAFB                              | 3 (9%)           |
| LBBB                              | 5 (15%)          |
| incRBBB                           | 1 (3%)           |
| RBBB                              | 5 (15%)          |
| nsIVCD                            | 16 (47%)         |
| Atrial fibrillation/flutter        | 4 (12%)          |
| Atrial fibrillation²              | 4 (12%)          |
| Atrial flutter³                   | 1 (3%)           |
| Pharmacologic therapy             |                  |
| Thyroxin                          | 5 (15%)          |
| Calcium channel blockers (CCB)    | 1 (3%)           |
| β-blockers                        | 4 (12%)          |
| ACE-inhibitors/ARB                | 7 (21%)          |
| Mineralocorticoid receptor antagonist (MCRA) | 3 (9%) |
| Loop diuretics                    | 1 (3%)           |
| Mexitelene                        | 4 (12%)          |

ACE, angiotensin-converting enzyme; AF/Fl, atrial fibrillation/flutter; ARB, angiotensin II receptor blockers; AVB, atrioventricular block; CCB, calcium channel blockers; ECG, electrocardiogram; incRBBB, incomplete right bundle branch block; IVCD, intraventricular conduction disturbance; LAFB, left anterior fascicular block; LBBB, left bundle branch block; MCRA, mineralocorticoid receptor antagonist; nsIVCD, nonspecific intraventricular conduction disturbance; RBBB, right bundle branch block; V, verapamil (phenylalkylamine) family. *One patient by the date of CMR had had evidence of both atrial fibrillation and flutter.
Table 2 Baseline cardiac magnetic resonance findings

| Variables                             | Patients (n = 34) | Healthy controls (n = 68) | P-value |
|---------------------------------------|------------------|---------------------------|---------|
| HR (bpm)                              | 66 ± 12          | 63 ± 11                   | 0.277   |
| LVEDVi (ml/m²)                        | 73 ± 22          | 81 ± 17                   | 0.028*  |
| LVESVi (ml/m²)                        | 29 (19–38)       | 29 (23–34)                | 0.744   |
| LVEF (%)                              | 60 ± 10          | 65 ± 7                    | 0.009** |
| RVEDVi (ml/m²)                        | 70 ± 18          | 82 ± 17                   | 0.002** |
| RVESVi (ml/m²)                        | 29 ± 9           | 30 ± 9                    | 0.902   |
| RVF (%)                               | 58 ± 7           | 63 ± 7                    | <0.001***|
| S1–S3, http://links.lww.com/JCM/A531  |                  |                           |         |
| CI (l/min/m²)                         | 2.6 (2.3–3.1)    | 3.2 (2.7–3.6)             | <0.001***|
| LAAi (cm²/m²)                         | 11 ± 3           | 12 ± 2                    | 0.043*  |
| RAAl (cm²/m²)                         | 10 ± 2           | 11 ± 2                    | 0.043*  |
| WMSI                                  | 1 (1–1.04)       | 1 (1–1)                   | <0.001***|
| WMA                                   | 26%              | 0%                        | <0.001***|
| ASW (mm)                              | 9 ± 2            | 10 ± 2                    | 0.189   |
| ILW (mm)                              | 8 (7–8)          | 8 (7–10)                  | 0.011*  |
| LVMi (g/m²)                           | 53 (46–59)       | 61 (55–68)                | <0.001***|
| LV mass/thickness index               | 11 ± 2           | 13 ± 3                    | 0.004** |
| RV/LV                                | 0.89 ± 0.16      | 1.01 ± 0.11               | 0.515   |
| M/V (%)                               | 0.72 (0.61–0.86) | 0.79 (0.64–0.93)          | 0.215   |
| Fatty infiltration (patients %)       |                  |                           |         |
| LV: 9 (26%)                           |                  |                           |         |
| RV: 13 (38%)                          |                  |                           |         |
| Total: 14 (41%)                       |                  |                           |         |
| LGE (patients %)                      | 9 (26%)          | Not assessed              |         |
| LGE mass (g)                          | 4 (3–5)          |                           |         |
| LGE mass (%)                          | 5 ± 2            |                           |         |
| Native T1 (ma)                        | 1041 ± 53        | 1017 ± 28                 | 0.003** |
| ECV (%)                               | 33 ± 2           | Not assessed              |         |
| Total LV matrix volume (ml/m²)a       | 16 ± 3           |                           |         |
| Total LV cell volume (ml/m²)b         | 33 ± 6           |                           |         |

ASW, anteroseptal wall thickness; CI, cardiac index; CO, cardiac output; HR, heart rate; ILW, infarcted wall thickness; LAAi, left atrial area; LAAi, left atrial area index; LGE, late gadolinium enhancement; LV, left ventricle; LVEDVi, left ventricular end-diastolic volume; LVESVi, left ventricular end-systolic volume; LVEF, left ventricular ejection fraction; LVMi, left ventricular end-diastolic mass; LVMSi, left ventricular mass index; M/V, mass/volume ratio; RV/LV, right ventricular end-diastolic mass/right ventricular end-diastolic volume; RVF, right ventricular ejection fraction; RVESV, right ventricular end-systolic volume; WMSI, wall motion score index.

LVEDVi and RVEDVi, respectively) and ejection fraction (P = 0.009 and P < 0.001 for LVEF and RVEF, respectively), lower biatrial volumes (both P = 0.043), a smaller LV mass (P < 0.001), and a lower LV mass/wall thickness ratio (P = 0.004); on the other hand, the RV/LV volumetric ratio (P = 0.513) and M/V ratio (P = 0.215) were similar to control patients.

Nine patients (26%) presented with mid-wall LGE (mean extent 5 ± 2% of LVM). The distribution of LGE is shown in Fig. 1: the inferoseptal and inferolateral segments were more frequently involved. Fourteen patients (41%) had some areas of fatty infiltration (n = 9 involving the LV, n = 13 the RV). Among clinical parameters, there was only a weak association between dyslipidemia and the presence of fatty infiltration (P = 0.04), whereas there were no significant clinical predictors of LGE. Some exemplary cases with LGE and/or myocardial fatty infiltration are shown in Figures S1–S3, http://links.lww.com/JCM/A531.

In 13 (38%) patients with T1 mapping sequences, native T1 in the interventricular (1041 ± 53 ms) was higher than healthy controls (1017 ± 28 ms) and approached the upper reference limit (1089 ms) for our CMR laboratory.41 The extracellular volume could be measured in nine patients (27%), and was slightly increased (33 ± 2%, reference values <30%),41

Eleven (32%) patients underwent at least another CMR scan after 1.6 (1.2–2.3) years from the baseline scan. Table S5, http://links.lww.com/JCM/A531 compares the first and the last examinations. Overall, LVEF increased, though none of the three patients with LVSD and serial CMR evaluations achieved a normal LVEF during follow-up. Eight out of 11 patients (73%) had an increase in LVEF. Of these eight patients, four were not on therapy, one was on loop diuretics, one on β-blockers, one on ACE inhibitors and one on both β-blockers and ACE-inhibitors. Three of them were on thyroid hormone replacement therapy. The anteroseptal wall thickness also increased, whereas the inferolateral wall thickness did not vary significantly over time. The number of patients with LGE or fatty infiltrations did not change. However, patients with LGE showed a nearly significant expansion of LGE mass, both in absolute terms and relative to cardiac mass.

**Follow-up**

After a median follow-up of 3.7 years (2.0–5.0) after baseline CMR, six (18%) patients died – four of...
infectious and respiratory complications, two for unknown reasons. Five (15%) underwent device implantation – four (12%) permanent pacemakers and one (3%) cardioverter/defibrillator (ICD). Three pacemakers were indicated for progression of conduction disturbances, one for bradyarrhythmias including sinoatrial pauses up to 3.5 s; the ICD was implanted because of trifascicular block and family history of sudden cardiac death. No device was used for cardiac resynchronization therapy. Data on the other end points are shown in Table S6, http://links.lww.com/JCM/A531. Only one patient developed LVSD during follow-up, while most patients had already developed an IVCD before CMR, so we did not consider these two end points for further analyses.

The association between CMR findings and our end points is presented in Table S2, http://links.lww.com/JCM/A531. No significant predictor was found for the occurrence of AVB and atrial fibrillation/flutter. A smaller RV volume, a thicker anteroseptal wall and a lower mass/thickness ratio were associated with device (PM/ICD) implantation. LGE extent was significantly correlated with the appearance of Lown class 4 VEBs. A lower LV stroke volume, a lower RVEF, a higher M/V ratio, fatty infiltration, and LGE extent were all univariate predictors of all-cause mortality.

Discussion
We investigated cardiac remodeling and tissue changes occurring in DM1 patients. Compared with healthy controls, we found lower cardiac volumes and mass, together with a lower mass/thickness ratio and LV or RV systolic dysfunction in a minority of patients. Tissue characterization showed LGE in 26% and fatty infiltration in 41% of patients. Over 3.7 (2.0–5.0) years, 6 (18%) patients died of extracardiac causes, 5 (15%) underwent device implantation, and 5 of 21 (24%) developed repetitive VEBs on Holter monitoring. LGE extent was associated with the occurrence of repetitive VEBs; a lower LV stroke volume, a lower RVEF, a higher M/V ratio, fatty infiltration, and LGE extent were predictors of death.
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CMR studies on DM1 have been highly heterogeneous as to the prevalence and patterns of cardiac involvement. To some extent, this is also because of the rarity of the disease and the limited availability of the technique – as compared with echocardiography. Previous reports seem to confirm echocardiographic findings of left ventricular dilation, hypertrophy, biventricular systolic dysfunction, and wall motion abnormalities. In addition, CMR could detect a trend towards reduced ventricular volumes and mass. Our study provides additional evidence of a reduction of cardiac cavities and mass in DM1 patients.

Such a trend seems to have been overlooked by echocardiography. This is probably because of the higher accuracy of CMR. Echocardiography is known to overestimate mass but the frequently poor acoustic window accompanying muscular dystrophies may account for this apparent inconsistency. It has also been supposed that CMR studies may exclude more severely compromised patients, thereby ignoring some cases of ventricular dilation. In the latter case, CMR studies might depict an early stage of the disease, before more severe systolic dysfunction occurs.

Various phenomena may be held responsible for the small cardiac size and mass in DM1. Above all, a reduced stroke volume has been noted and must be taken into account: this is likely to be the result of the decreased metabolic demands of dystrophic muscles. Indeed, an inverse correlation has been observed between LV end-diastolic and systolic volumes and cardiac muscle hypertrophy at pathology, which might prove relevant to the correct evaluation of systolic dysfunction in diabetes mellitus.

Left ventricular dysfunction was quite prevalent (≈15%) in our cohort, and a lower LV stroke volume was associated with increased mortality. This is consistent with existing literature. Nonetheless, we observed a significant increase in left ventricular ejection fraction (LVEF) over time, which was evident in 8 out of 11 patients with serial CMR examinations, though none of the 3 patients with LVSD and serial CMR evaluations normalized their LV function at follow-up. Therapy does not seem to justify such changes, as half of the patients who apparently improved their function were not on therapy. The increased accuracy of CMR in determining volumes might partly explain the increase in LVEF, which might be influenced by the reduction in LV end-diastolic volumes. Another potentially confounding factor is the link between DM1 and mitral valve prolapse. Further studies are needed to confirm our findings, which might prove relevant to the correct evaluation of systolic function in diabetes mellitus.

Our data confirm that LGE is rather common (≈26%) in DM1 and that it is mainly found in the mid-wall layer of septal and inferolateral segments. We lacked statistical power to demonstrate an increase of LGE mass over time, but such a trend could be observed. Despite the existence of considerable clues to a link between myocardial tissue alterations at CMR and conduction disturbances and arrhythmias, no definitive evidence has been obtained so far. We could add another piece to the puzzle by observing that LGE extent was associated with the occurrence of repetitive VEBs at follow-up. Moreover, LGE extent showed a significant association with all-cause mortality, even though a clear relationship with cardiac and arrhythmic death could not be assessed because of the limited number of events.

We report that intramyocardial fat is common in both ventricles of myotonic dystrophy type 1 patients and that it may be encountered in as many as 40% of patients. Adipose tissue is a distinctive feature of a number of diseases, where it is likely to play some pathogenetic role. The extent and patterns of infiltration, which we observed seemed to go beyond what we would normally expect in an otherwise healthy patient. Fatty infiltration of the RV in DM1 has been associated with the induction of ventricular arrhythmias, though they were mainly nonsustained. Our study further suggests that there might be a link between fatty infiltration and outcome, as adipose tissue was associated with increased mortality, even though a clear relationship with ventricular arrhythmias could not be demonstrated.

Much of the relevance of our work lies in the inclusion of serial CMR evaluations and the assessment of the prognostic value of CMR in DM1. Indeed, except for one analysis on PR and QRS prolongation over time, more generally purposed longitudinal studies and serial CMR
evaluations in these patients are currently lacking or have provided insufficient follow-up data. 24

Evidence exists of right cardiac involvement in DM1 both from mechanical and electrical standpoints. 18 Some link with Brugada syndrome, which appears to arise from the RV outflow tract, has also been suggested. 49 In our link with Brugada syndrome, which appears to arise from

There are no conflicts of interest.

Conflicts of interest

Conclusion

Patients with DM1 display several structural and functional cardiac abnormalities, with variable degrees of cardiac muscle hypotrophy, fibrosis, and fatty infiltration. Such changes, as evaluated by CMR, may anticipate the occurrence of electrocardiographic and/or clinical end points, and might help the clinician to guide the management of these cases.

Conflicts of interest

There are no conflicts of interest.

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