SUPPLEMENTAL MATERIAL

Supplementary Methods

Inclusion and exclusion criteria

DCM patients were included if they had a clinical diagnosis and a dilated LV cavity (end-diastolic diameter >55mm) with impaired function (ejection fraction <50%) on imaging. IHD patients were eligible for inclusion if they had a previous myocardial infarction with significant coronary artery disease at angiography and an impaired LV (EF <50%). Both DCM and IHD patients were excluded if they had a contraindication to MR scanning, were in atrial fibrillation or had more than mild valvular heart disease. 4 patients (3 IHD and 1 DCM) had mild MR, 1 DCM patient had mild AR on echocardiogram. Healthy controls were excluded if they had contraindications to MRI scanning.

Cardiac magnetic resonance protocol and analysis

Cine imaging and analysis

Cine images were acquired using steady state free precession imaging.[1] Scan parameters were typically: voxel size 2.0x2.0x8.0mm, FOV 380x380mm, TR/TE 39.6/1.12ms, flip angle 50°, matrix 192x192, GRAPPA=3, 24 reference lines, segments=15, concatenations=1. Pilot images were initially acquired and used to plan and acquire horizontal long axis, vertical long axis, left ventricular outflow long axis and short axis stack images.

LV short axis epicardial and endocardial borders were manually contoured at end diastole and end systole for determining end diastolic volume (EDV), end systolic volume (ESV) and stroke volume (SV). Ejection fraction (EF) was calculated by EF= SV/EDV.

Myocardial mass was calculated by subtracting the endocardial volume from the epicardial volume, based on prior knowledge of myocardial specific gravity (1.05 g/cm^3).

Tagging image acquisition

A gradient echo-based tagging pulse sequence was performed in the long-axis and in the mid short-axis slice, with a segmented k-space, multi-shot sequence (repetition time 4.47ms, echo time 7.4ms, and flip angle 25˚). Spatial modulation of magnetisation (SPAMM)[2] produced images with a grid-based pattern of horizontally and vertically modulated 'stripes' 7mm apart, acquired during a single breath-hold, using a prospectively gated sequence. The temporal resolution was 40.2ms in all data sets, and 15-25 frames per cardiac cycle were recorded, depending on heart rate.

^{31}P-MR spectroscopy

25 DCM patients and 10 controls underwent ^{31}P MR spectroscopy at 7T (Magnetom, Siemens, Germany) using a 16 channel coil (Rapid Biomedical, Würzberg, Germany). Spectroscopy was performed on the same day as the 3T 4D flow data acquisition. Spectroscopy data were acquired with the patient supine and were not gated to avoid potential bias due to mistriggering. Spectra were acquired as previously described by our group in healthy volunteers and patients [3, 4]. In summary localization was performed and subject-specific B_1 maps were computed. Spectra were recorded by using a chemical-shift imaging pulse sequence (three-dimensional phase-encoded "ultrashort echo time" chemical shift imaging) with matrix, 16 × 16 × 8; voxel size, 15 × 15 × 25 mm^3; acquisition weighting with 10 averages (k = 0); and repetition time, 1 second. Excitation was at 400 V, giving a flip angle of ~30° in the interventricular septum. Excitation was centered at more than +266 Hz relative to PCr. A 25-mm-thick saturation band suppressed the signal from the anterior chest wall.

Analysis was performed using in house software within Matlab vR2012a (Mathworks, Natick, Massachusetts).[3] Spectra from a voxel overlying the midventricular septum were fitted using a custom Matlab (Mathworks, Natick, Mass) implementation of the advanced method for accurate, robust, and efficient spectroscopic (AMARES) fitting, with prior knowledge specifying 11 Lorentzian peaks (α, β, γ-ATP, PCr, phosphodiester, and 2 × 2, 3-diphosphoglycerate), fixed amplitude ratios, and literature values for the scalar couplings for the multiplets. We then corrected for blood contamination and partial saturation using T1 values from the literature. The final PCr/ATP was taken as PCr/γ-ATP by discounting α-ATP, because it overlaps nicotinamide adenine dinucleotide phosphate (NADPH) and β-ATP because it was not fully excited at 7 T.

Supplementary Tables

Supplementary Table 1. Medical therapy in DCM and IHD patients

	DCM (n=34)	**IHD (n=30)**
ACE-I/ARB	30 (88)	26 (87)
Beta-Blocker	24 (71)	27 (90)
Aldosterone antagonist	18 (53)	12 (40)
Diuretic	16 (47)	13 (43)
Aspirin	6 (18)	26 (87)
Statin	4 (12)	26 (87)
Warfarin	7 (21)	10 (33)

Values are number with percentages in brackets. ACE-I indicates angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; DCM, dilated cardiomyopathy; IHD, ischaemic heart disease.

Supplemental Table 2. Results from Multiple Linear Regression Model with dependent variables 6 minute walk test, independent variables age, height, LVEF, BNP, direct flow average kinetic energy and peak systolic circumferential strain.

	Unstandardised coefficients		**Standardised Coefficients**	**t**	**Significance**
	B	**Std. Error**	**Beta**		
Constant	582.738	58.803		9.910	<0.0001
Age	-2.181	0.899	-0.315	2.428	0.019
Direct flow average KE	7608.150	3518.021	0.280	2.163	0.035

KE indicated kinetic energy; Std. Error, standard error.

Overall R^2 of the model=0.466, P=0.002.

Video Legends

Video 1. Left ventricular flow component visualisation for healthy control. Direct flow, green; retained inflow, yellow; delayed ejection flow, blue and residual volume, red.

Video 2. Left ventricular flow component visualisation for dilated cardiomyopathy patient (LVEF 16%). Direct flow, green; retained inflow, yellow; delayed ejection flow, blue and residual volume, red.

Video 3. Left ventricular flow component visualisation for ischaemic cardiomyopathy patient (antero-apical myocardial infarct). Direct flow, green; retained inflow, yellow; delayed ejection flow, blue and residual volume, red.

Supplemental References

1. Flett AS, Hasleton J, Cook C, Hausenloy D, Quarta G, Ariti C, Muthurangu V and Moon JC. Evaluation of techniques for the quantification of myocardial scar of differing etiology using cardiac magnetic resonance. *JACC Cardiovascular imaging*. 2011;4:150-6.

2. Stuber M, Spiegel MA, Fischer SE, Scheidegger MB, Danias PG, Pedersen EM and Boesiger P. Single breath-hold slice-following CSPAMM myocardial tagging. *MAGMA*. 1999;9:85-91.

3. Rodgers CT, Clarke WT, Snyder C, Vaughan JT, Neubauer S and Robson MD. Human cardiac 31P magnetic resonance spectroscopy at 7 Tesla. *Magnetic resonance in medicine*. 2014;72:304-15.

4. Stoll VM, Clarke WT, Levelt E, Liu A, Myerson SG, Robson MD, Neubauer S and Rodgers CT. Dilated Cardiomyopathy: Phosphorus 31 MR Spectroscopy at 7 T. *Radiology*. 2016;281:409-417.