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The relationship between the contralateral collateral supply and myocardial viability on cardiovascular magnetic resonance: Can the angiogram predict functional recovery?

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ABSTRACT

Background: A collateral circulation which supplies a myocardial territory, subtended by a chronic total occlusion (CTO), may be observed at invasive coronary angiography. The prognostic and protective role of such collateralisation is well demonstrated suggesting that a good collateral circulation may be a predictor of myocardial viability, but current evidence is discrepant. The aim of this study is to assess the relationship between collateralisation from the contralateral epicardial vessels and myocardial viability by cardiovascular magnetic resonance (CMR).

Method: Consecutive patients with CTO having had both CMR and invasive coronary angiography were retrospectively identified. The collateral circulation was graded with the Cohen and Rentrop classification. CMR images were graded per segment for wall motion (1: normal/hyperkinetic, 2: hypokinetic, 3: akinetic, or 4: dyskinetic) and wall motion score index (WMSI) was calculated. The segmental transmurality of late gadolinium enhancement was scored as 1 (0%), 2 (1–25%), 3 (26–50%), 4 (51–75%) and 5 (76–100%).

Results: A good collateral circulation was more likely to supply viable myocardium ($p = 0.01$). There was no relationship between collateral circulation supply and wall motion score index (WMSI), however, increasing transmurality of LGE was significantly associated with higher mean WMSI representing increasing dysfunctional myocardium ($p < 0.001$).

Conclusion: The presence of collateral coronary circulation at angiography predicts the presence of viability on cardiovascular MRI, with a gradation of greater viability associated with improving Rentrop grade. A collateral circulation at angiography should, therefore, prompt more formal assessment of viability and consideration of revascularisation in order for the patient to obtain the associated functional and prognostic improvement.

1. Introduction

A coronary artery is deemed to be chronically occluded (CTO) if angiography demonstrates a total occlusion felt to be of >3 month duration [1]. The incidence of CTOs at angiography has been reported as being 20–30% [2]. Dysfunctional myocardium which has the potential for contractile recovery after revascularisation is deemed 'viable' tissue. A collateral circulation which supplies a myocardial territory, subtended by a chronic total occlusion (CTO), may be observed at invasive coronary angiography. The prognostic and protective role of such collateralisation in those with coronary artery disease has been described [3,4] and the presence of a degree of viability in territories supplied by a collateral circulation has also been demonstrated [5–8]. These observations provide the hypothesis that the presence of a good collateral circulation may be a predictor of myocardial viability, but current evidence is discrepant [9]. Theoretical benefits to improving blood supply to areas of viable myocardium include left ventricular (LV) functional recovery and improved prognosis. Correspondingly, several studies have shown that revascularisation of CTO provides survival benefit, including the multi-centre TOAST-GISE study [10], although the current evidence is

Abbreviations: BSA, body surface area; CABG, coronary artery bypass graft; CMR, cardiovascular magnetic resonance; CTO, chronic total occlusion; HLA, horizontal long axis; LGE, late gadolinium enhancement; LV, left ventricle; LVOT, left ventricular outflow tract; MACE, major adverse cardiovascular event; PCI, percutaneous coronary intervention; PET, positron emission tomography; SSFP, steady state free precession; WMSI, wall motion score index; VLA, vertical long axis.

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conflicting [11–13]. Furthermore, percutaneous treatment of CTO is not without risk and often technically challenging. Thus, whilst TOAST-GISE demonstrated a survival benefit there was a failure rate of approximately 25% in percutaneous revascularisation intervention (PCI) rates of CTO and a major adverse cardiovascular event (MACE) rate of 5% [10]. Therefore, clinically differentiating between viable and non-viable myocardium is fundamentally important as invasive revascularisation procedures such as PCI and coronary artery bypass grafting (CABG) could be avoided if there is deemed to be no clinical benefit. Currently appropriate patient selection based upon the prediction of functional recovery remains uncertain.

Ischaemic myocardial injury is characterised by the presence of scars distributed from the subendocardium outwards, reflecting the transmural gradient in vulnerability of the myocardium. Assessment of cardiac viability with late gadolinium enhancement (LGE) cardiovascular magnetic resonance (CMR) imaging is a robust, reproducible and widely established technique, whereby the extent of transmurality of an infarct correlates with pathological specimens [14]. There is a strong association between transmural extent of hyper-enhancement and the likelihood of functional recovery after revascularisation [15–17]. LGE-CMR has been demonstrated to correlate strongly with fluorodeoxyglucose (^{18}F-FDG) positron emission tomography (PET) [18,19], which is widely regarded as the gold standard for the assessment of in vivo viability.

The aim of this study was to assess the relationship between collateralisation from the contralateral epicardial vessels, with the Cohen and Rentrop classification [20], and viability of the supplied myocardium, defined by LGE-CMR [14]. We hypothesise that those myocardial territories with good collateralisation supply viable myocardial tissue. This hypothesis, if proved to be correct, has significant clinical implications for the determination of the need for revascularisation of occluded arteries in order to target therapy accurately.

2. Materials & methods

2.1. Study population

Consecutive patients (n = 71) investigated with CTO having had both CMR and invasive coronary angiography within a 6 week window were retrospectively identified from local databases in two cardiac centres (Royal Devon & Exeter NHS Foundation Trust and University Hospital Southampton NHS Foundation Trust).

2.2. Cardiovascular MR examination

Patients were examined using a clinical 1.5 T whole body MRI (Magneto, Siemens Healthcare, Munich, Germany). Standard low resolution localiser scans were performed to define the cardiac long and short axes. Steady state free precession (SSFP) cine images were acquired in the horizontal long axis (HLA), vertical long axis (VLA), and left ventricular outflow tract (LVOT) views. Further SSFP cine images were acquired in 10–12 contiguous, end-expiratory, multiphase, short axis slices parallel to the mitral valve annulus covering the whole of the left ventricle (slice thickness 8 mm, interslice gap 1 mm). A total of 0.2 mmol/kg of gadobutrol (Gadovist®, Bayer Schering Pharma, Berlin, Germany) contrast agent was administered at 4 ml/s via a peripheral venous cannula, followed by 30 mls of 0.9% normal saline flush at 4 ml/s. After 10–15 min postinjection of gadolinium based contrast a breath-hold 2-dimensional segmented inversion recovery sequence, inversion time (TI) 240–300, was acquired in the same orientation as the cine images. Phased sequence inversion recovery (PSIR) images were acquired subject to the operator's discretion.

Image analysis was performed on a Siemens' workstation. Left ventricular diastolic and systolic volumes were calculated and indexed to body surface area (BSA) allowing the calculation of left ventricular systolic function. Each segment of the myocardium was assessed visually and scored by the American College of Cardiology Foundation/American Heart Association (ACC/AHA) 17 segment model [21] for wall motion with each segment scored as 1 (normal/hyperkinetic), 2 (hypokinetic), 3 (akinetic), or 4 (dyskinetic). A wall motion score index (WMSI) was calculated by dividing the sum of all scores by the number of segments in the coronary territory (with a WMSI of 1 representing normal function).

All short axis images from the base to the apex of the left ventricle were analysed and the transmural extent of infarction/scar of each myocardial segment was assessed by LGE. Interpretation of LGE was performed visually with the enhanced area defined as a percentage of the myocardial thickness with each segment scored as 1 (0%), 2 (1–25%), 3 (26–50%), 4 (51–75%) and 5 (76–100%). For data analysis a median score of 3 or less was deemed viable consistent with that of published evidence [15].

Analysis was performed by a cardiologist blinded to the clinical details and invasive coronary angiography result. Myocardial segments were subsequently correlated with the supplying coronary vessels observing standard models [21] with coronary dominance considered.

2.3. Invasive angiography

Coronary angiography was performed using the standard Judkins technique [22]. The collateral circulation was graded with the Cohen and Rentrop classification [20] with scores of 0 (no collateral flow), 1 (collateral circulation fills only the side branches), 2 (partial filling of the main epicardial coronary vessel) and 3 (complete filling of the epicardial coronary vessel) applied. For data analysis the collateral circulation was grouped into having either poor or no flow (grades 0–1), moderate flow (grade 2) or good flow (grade 3) to the occluded vessel.

Analysis was performed by a cardiologist blinded to the clinical details and CMR result. Image analysis was performed by a single cardiologist with >3 year experience in both CMR and coronary angiography.

2.4. Statistical analysis

All data analyses were performed using SPSS 19.0 for Windows (SPSS, Chicago, Illinois, USA). Data are presented as mean ± S.D. or median as appropriate. The transmural extent of the LGE was expressed as a median of the segments in that coronary territory. Ordinal data were compared using χ^2, two-tailed test. A probability value of ≤0.05 is considered statistically significant.

3. Results

71 patients were identified as having undergone both invasive coronary angiography (with one occluded coronary artery) and CMR. 63 were male (89%) and 8 were female (11%) with a median age of 65 years (range 36 to 88). There was no significant difference between the mean ages of the male and female groups. Detailed patient characteristics and risk factors are presented in Table 1. Background clinical cardiovascular risk factors were available in 61 patients with no case records available in the remaining 10.

Angiographically, of 71 patients, 3 (4%) had no collateral circulation (Rentrop grade 0), 10 (14%) had poor collateral circulation (Rentrop grade 1), 22 (31%) had moderate collateral circulation (Rentrop grade 2) and 36 (51%) had good collateral circulation (Rentrop grade 3) (Table 1).

Table 1
Patient characteristics.

Parameters	Results (n = 71)
Gender, male, n (%)	63 (89%)
Age, year	65
Range, year	36–88
Angiographic data (n = 71)	
Rentrop classification 0, n (%)	3 (4%)
Rentrop classification 1, n (%)	10 (14%)
Rentrop classification 2, n (%)	22 (31%)
Rentrop classification 3, n (%)	36 (51%)
Clinical factors (n = 61)	
Hypertension, n (%)[a]	24 (39%)
Diabetes mellitus, n (%)[a]	11 (18%)
Hyperlipidaemia, n (%)[a]	30 (49%)
Cigarette smoking[a]	
Current smoker, n (%)[a]	21 (34%)
Ex-smoker, n (%)[a]	18 (30%)
CMR parameters (n = 71)	
End diastolic volume (ml)	200 ± 69
Indexed end systolic volume (ml/m^2)	103 ± 34
End diastolic volume (ml)	111 ± 66
Indexed end systolic volume (ml/m^2)	57 ± 33
Stroke volume (ml)	89 ± 20
LV ejection fraction	48 ± 15

Data are mean ± S.D. where appropriate.
[a] 10 patients' background characteristic data unavailable.