Heterogeneity in the Diagnostic Management of MINOCA:

A UK clinician Survey

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Running title: MINOCA clinical practice survey.

ABSTRACT

Background: Myocardial injury with non-obstructive coronary arteries (MINOCA) accounts for around one in ten hospitalisations with acute myocardial infarction. Despite guideline recommendations, diagnostic and management approaches vary. We aimed to characterise current UK practice for the investigation and treatment of patients with MINOCA.

Methods: We conducted a cross-sectional online survey of UK clinicians involved in MINOCA care between March and December 2025. To provide clinical context, two clinical vignettes with probable nonischaemic (Case A) and ischaemic (Case B) aetiologies were used to assess investigation preferences, with agreement documented using a Likert scale from 0 to 5 and reported as the proportion agreeing or strongly agreeing (score 4 or 5). General management questions and free-text responses underwent thematic analysis by two independent reviewers.

Results: Of 146 respondents, 140 provided demographic data. Most were cardiology consultants (76/140, 54.3%) from tertiary centres (74/140, 52.9%). Echocardiography received high endorsement across both vignettes (Case A: 93/99 [93.9%] vs Case B: 86/88 [97.7%] agreeing or strongly agreeing). Cardiac magnetic resonance (CMR) imaging preferences differed between vignettes: 83/101 (82.2%) agreed or strongly agreed with CMR for the younger patient with viral prodrome versus 38/86 (44.2%) for the older patient with atheroma (P<0.001). Hyperaemic (adenosine) coronary microvascular function testing was endorsed by 14/100 (14.0%) and 18/88 (20.5%), respectively, and no respondent endorsed acetylcholine provocation testing in either vignette. Thematic analysis identified four themes: context-dependence of decisions, uncertainty regarding diagnostic utility, psychological burden on patients, and concerns about MINOCA terminology.

Conclusions: UK clinicians demonstrate considerable variation in the investigation of patients with MINOCA, with clinical presentation strongly influencing recommendations for CMR imaging. Although the vignettes differed in several clinical features, the extent of variation in investigation preferences highlights the absence of a standardised diagnostic approach. These findings support the need for evidence-based care pathways incorporating refined case definitions and more precise terminology.

Keywords: MINOCA; myocardial infarction; cardiac magnetic resonance; coronary physiology; clinical practice

What is already known on this topic – summarise the state of scientific knowledge on this subject before you did your study and why this study needed to be done

Despite guideline recommendations in MINOCA, diagnostic and management approaches vary.

What this study adds – summarise what we now know as a result of this study that we did not know before

UK clinicians demonstrate considerable variation in preferences for investigation of patients with MINOCA, with clinical presentation strongly influencing CMR utilisation. The extent of variation in investigation preferences, and the low endorsement of invasive coronary function testing, highlight the absence of a standardised diagnostic approach.

How this study might affect research, practice or policy – summarise the implications of this study in context of all available evidence

These findings support the need for evidence-based care pathways incorporating refined case definitions and more precise terminology.

INTRODUCTION

Myocardial injury with non-obstructive coronary arteries (MINOCA) is defined as a presentation with symptoms or signs of suspected acute coronary syndrome, evidence of acute myocardial injury, and non-obstructive coronary arteries (stenosis <50% in a major epicardial vessel) on coronary angiography.[1] It accounts for 5 to 10% of presentations with possible myocardial infarction and disproportionately affects women.[2,3,4] Underlying aetiologies are heterogeneous and in those with confirmed myocardial infarction include atherosclerotic plaque disruption with spontaneous reperfusion, epicardial coronary artery spasm, coronary microvascular dysfunction, coronary thromboembolism, and spontaneous coronary artery dissection.[3,5] Conditions that mimic acute myocardial infarction are common in those with MINOCA, and include takotsubo syndrome and myocarditis.[1,3]

The 2023 European Society of Cardiology (ESC) guidelines for the management of acute coronary syndromes recommend systematic diagnostic evaluation in patients presenting with MINOCA, including cardiac magnetic resonance (CMR) imaging when the diagnosis remains unclear after invasive coronary angiography.[1] Optical coherence tomography or intravascular ultrasound is recommended where epicardial plaque rupture or erosion is suspected, and intracoronary provocative testing with acetylcholine should be considered when an epicardial or microvascular vasomotor disorder is suspected.[1,3,5] Despite these recommendations, real-world adoption and practice variation has not been well characterised. Importantly, when evaluating a patient with MINOCA after coronary angiography, clinicians must decide which further investigations to undertake, and the extent to which these decisions are influenced by the clinical presentation rather than a standardised diagnostic pathway is unknown.

We conducted a national survey to evaluate UK clinicians' diagnostic and management strategies for MINOCA, to compare reported practice against guideline recommendations, and to explore whether clinical presentation influences investigation selection.

METHODS

Between March and August 2025, an online survey was circulated through UK cardiology professional networks including the British Cardiovascular Society the Scottish Cardiac Society, subspecialty research collaboratives and regional training programmes. The survey was open to any UK clinician involved in the care of patients with MINOCA and was distributed by e-mail and social media through these networks. Because the memberships of these networks overlap and distribution was open, the number of clinicians reached cannot be determined precisely and a conventional response rate cannot be calculated. The full survey instrument is provided as Supplementary File 1. The survey was developed by the NIHR-BHF Cardiovascular Partnership MINOCA and Myocardial Injury Workstream and contained two anonymised clinical vignettes presenting only the limited information available immediately following coronary angiography. Vignettes were sourced from patients with MINOCA who had provided written informed consent to participate in a clinical trial (NCT03686696) undertaken at the Golden Jubilee National Hospital, Clydebank and University Hospital Hairmyres, East Kilbride, between 2022 and 2026.

Case A described a 49-year-old patient ('viral prodrome' phenotype) presenting with chest pain preceded by a viral illness, an elevation in cardiac troponin I concentration (124 to 155 ng/L), and unobstructed arteries on invasive coronary angiography. Case B described a 73-year-old patient ('atheroma' phenotype) with cardiovascular risk factors (obesity, smoking history), anterolateral ST-segment depression with T-wave inversion, diffuse non-obstructive atheroma on invasive

coronary angiography, and a peak cardiac troponin I concentration of 43,850 ng/L. Respondents were not informed of the aetiology in either case; both presentations could plausibly be a consequence of plaque disruption, epicardial spasm, microvascular dysfunction, takotsubo syndrome, or myocarditis. Vignettes were therefore designed to assess whether clinical presentation influences the selection of patients for further investigation in the setting of diagnostic uncertainty. In both cases the subsequent CMR imaging study revealed subendocardial to transmural late gadolinium enhancement consistent with an ischaemic aetiology, but this was not disclosed to respondents.

Clinicians rated their likelihood of performing nine investigations using a 0 to 5 Likert scale (0 = strongly disagree / very unlikely, 5 = strongly agree / very likely). Throughout, endorsement is reported as the proportion of respondents scoring 4 or 5 (agree or strongly agree), with mean ± SD scores also presented for the vignette comparisons. Guidewire-based hyperaemic (adenosine) assessment of coronary microvascular function was asked about in both the vignettes and the general questions; these refer to the same investigation and are described using the same terminology throughout. Subsequent sections addressed general diagnostic strategies, indication and timing for CMR imaging, pharmacotherapy, and follow-up. Free-text comments were invited and responses inputted into REDCap.

All responses with available data were included (intention-to-analyse approach). Completion at each stage is represented by denominator. Continuous data are presented as mean ± SD, with proportions of respondents scoring 4 or 5 reported as n/N (%). Differences between vignettes were evaluated using Welch's t-tests with *P*-values reported to three decimal places or as <0.001. Sub-group comparisons of mean scores by centre type, respondent grade and cardiology subspecialty used Mann-Whitney U tests (two groups) or Kruskal-Wallis tests (three groups). Free-text

responses underwent inductive thematic analysis by two independent reviewers, with discrepancies resolved through discussion.

RESULTS

Respondent characteristics

Of 146 survey entries, 140 provided demographic information. Cardiology consultants comprised 76/140 (54.3%), followed by cardiology registrars 23/140 (16.4%), cardiology specialist nurses 13/140 (9.3%), and other allied health professionals 13/140 (9.3%). Most respondents worked in tertiary centres 74/140 (52.9%) or regional teaching hospitals 42/140 (30.0%) and managed patients with MINOCA on a monthly 58/134 (43.3%) or weekly 45/134 (33.6%) basis. Among cardiologists declaring a subspecialty interest, interventional cardiologists represented 54/94 (57.4%) and non-invasive imaging specialists 15/94 (16.0%).

Case vignette comparisons: evidence of presentation-driven decision making

Investigation preferences differed markedly between vignettes (Figure 1, Table 1). Echocardiography was consistently endorsed across both presentations (Case A mean 4.7 ± 0.9; Case B mean 4.8 ± 0.7; $P = 0.282$). However, CMR received significantly higher endorsement for Case A (mean 4.2 ± 1.2, with 83/101 [82.2%] respondents scoring 4-5) than for Case B (mean 2.9 ± 1.7, 38/86 [44.2%] scoring 4-5; $P < 0.001$), suggesting that clinicians preferentially selected CMR for the younger patient with possible viral prodrome.

Conversely, repeat invasive coronary angiography or further interventional assessment of the index angiogram was more strongly endorsed for Case B (mean 4.9 ± 0.3, 88/88 [100%] scoring 4-5) than for Case A (mean 3.5 ± 1.7, 65/100 [65.0%] scoring 4-5; $P < 0.001$). Intravascular imaging endorsement was limited, although was more frequently endorsed in the patient with

atheroma (Case A 10/96 [10.4%] scoring 4-5 versus Case B 42/87 [48.3%]; $P < 0.001$). Computed tomography (CT) coronary angiography was rarely selected and was favoured more for Case A (34/99 [34.3%]) than for Case B (3/87 [3.4%]; $P < 0.001$).

Intracoronary acetylcholine provocation testing received no endorsement in either vignette (Case A 0/97 [0.0%]; Case B 0/84 [0.0%] scoring 4-5), with mean Likert scores of 0.7 ± 1.0 in both cases.

General diagnostic strategy and CMR utilisation

In response to general (non-vignette) questions on CMR strategy, 63/75 (84.0%) of respondents agreed or strongly agreed that CMR should be performed when the diagnosis remains unclear after invasive coronary angiography. Fewer agreed or strongly agreed that CMR should be used in all MINOCA patients regardless of troponin level (46/75 [61.3%]). Respondents largely rejected restricting CMR to those with troponin >1,000 ng/L (13/74 [17.6%] scoring 4-5), regional wall motion abnormality (7/74 [9.5%]), or multiple hospitalisations (3/75 [4.0%]).

Regarding timing, 46/73 (63.0%) of respondents supported CMR within 14 days of presentation, while 51/74 (68.9%) endorsed triaging by clinical need. Only 31/75 (41.3%) supported inpatient CMR scanning, and only 4/73 (5.5%) considered delays of up to 3 months to be acceptable.

Invasive coronary function testing

Guidewire-based hyperaemic (adenosine) assessment of coronary microvascular function during the index angiogram received limited support in both vignettes (Case A 14/100 [14.0%] versus Case B 18/88 [20.5%] scoring 4-5). In response to general questions on the same investigation, routine use was supported by 13/71 (18.3%) and selective use by 30/71 (42.3%) scoring 4-5. Routine intracoronary acetylcholine provocation testing was endorsed by only a minority (3/72

[4.2%] scoring 4-5), although selective use was more acceptable (19/72 [26.4%]). Importantly, only 29/72 (40.3%) of respondents reported access to acetylcholine provocation testing in their centre, compared with 60/72 (83.3%) reporting access to adenosine-based hyperaemic assessment.

Pharmacotherapy and follow-up

For patients with MINOCA on a background of atherosclerotic coronary disease, dual antiplatelet therapy with aspirin and clopidogrel was the most strongly endorsed pharmacological strategy (39/70 [55.7%] scoring 4-5), followed by statin therapy (26/69 [37.7%]) and angiotensin-converting enzyme inhibitors or angiotensin receptor blockers (24/68 [35.3%]). Where coronary angiography revealed entirely smooth coronary arteries without atherosclerosis, 51/70 (72.9%) of respondents indicated that this would influence their antiplatelet decision-making. The preferred timing of first follow-up was within 3 months of discharge (54/68 [79.4%] scoring 4-5).

Thematic and respondent sub-group analysis

Thirteen respondents provided substantive qualitative feedback with four themes emerging.

First, respondents stressed that investigation and management are strongly context-dependent. Clinicians emphasised that the decision to perform additional tests hinged on the results of preceding investigations; some described sequentially layering investigations only if initial assessments were negative, and others noted that management depended on whether the presentation was judged to be a definite versus a potential plaque-related event.

Second, there was uncertainty about the incremental diagnostic yield and cost-effectiveness of the various investigations. Several respondents questioned whether comprehensive testing adds meaningful diagnostic or prognostic value relative to its resource requirements. Third, one respondent highlighted the significant psychological and emotional burden borne by patients

labelled with 'MINOCA' and urged clinicians to provide better explanations and structured support; this underlines the need to consider patient experience when designing diagnostic pathways. Finally, views diverged on terminology itself. Although MINOCA is intended as a working diagnosis, a substantial minority were sceptical about whether this label improves care or understanding. Quantitatively, 44 of 69 respondents (63.8%) agreed that 'MINOCA' should remain only a working diagnosis until the diagnosis is clarified, and 30 of 69 (43.5%) rejected the descriptor 'MINOCA mimic' as useful. These themes underscore the need to balance investigation against yield and patient burden, and the importance of clear communication when applying or revising diagnostic terminology over the course of the patient journey.

Sub-group analyses by centre type, respondent grade and cardiology subspecialty are summarised in Figure 2 and Supplementary Table 1. Recommendations for CMR did not differ by centre type, respondent grade or cardiology subspecialty for either vignette. Respondents from tertiary or supra-regional centres gave higher scores than those from non-tertiary centres for coronary microvascular function testing in Case A (mean 1.58 vs 0.88; P=0.047) and for intravascular imaging in Case B (3.31 vs 2.31; P=0.013). Interventional cardiologists gave higher scores than imaging and other cardiology respondents for invasive coronary angiography in Case A (4.02, 2.79 and 2.75; P=0.009) and for intravascular imaging in both vignettes (Case A 1.76, 0.69 and 1.87; P=0.043; Case B 3.49, 1.93 and 2.73; P=0.003). No differences were observed by respondent grade.

DISCUSSION

This national survey reveals heterogeneity in the approach to management of patients with MINOCA across the UK, and suggests that the clinical presentation influences recommendations for further investigation. The divergent responses to two vignettes where diagnostic uncertainty

remained following coronary angiography align with previous reports of variable real-world MINOCA care across health systems.[3,4,6]

The finding that only 63/75 (84.0%) of respondents agreed that CMR should be performed when the diagnosis remains unclear after angiography is perhaps unexpected given the Class I, Level B recommendation in the 2023 ESC guidelines.[1] The marked between-vignette difference in CMR preference (82.2% versus 44.2%) may reflect clinician perspective that CMR is less informative in older patients with atherosclerotic phenotypes.[4,7]

Prospective studies indicate that early comprehensive CMR provides a diagnosis in approximately three-quarters of patients with a working diagnosis of MINOCA: 77% when performed at a median of 3 days after admission with parametric mapping in the SMINC-2 study, compared with 47% with later and less comprehensive imaging in SMINC-1,[11] and 74% in an unselected registry population imaged at a median of 37 days,[16] with diagnostic yield falling as the interval from presentation increases.[7,9,11] Multimodality assessment combining CMR with intracoronary optical coherence tomography identified myocardial infarction in 59% and MINOCA mimic in 20% of participants, including 270 women and 66 men.[5] Although prevalence was greater in female participants, there was no difference in proportion for the underlying aetiology by sex.[5] These data demonstrate the diagnostic importance of adjunctive multimodality imaging to confirm the underlying aetiology,[8,10] and suggest that education, improved access to adjuvant imaging and evidence-based care pathways are needed to improve diagnosis.

The minimal endorsement of intracoronary acetylcholine provocation testing (no respondent agreeing with its use in either vignette; 40.3% of respondents reporting local access) contrasts with practice in other countries where acetylcholine testing is performed routinely as part of the diagnostic workup of MINOCA and angina with non-obstructive coronary arteries.[12,13] Recent

evidence supports both the diagnostic and prognostic value of advanced diagnostics strategies incorporating invasive coronary function testing and acetylcholine provocation.[13,14,15] A recent international clinician and patient consensus statement has called for ANOCA/INOCA services that 'consider the whole patient' and provide multidisciplinary, patient-centred care with an individualised approach and personalised care plan to reflect the variation in underlying aetiology and symptoms experienced.[12] Similarly, there was relatively low endorsement for intracoronary imaging, which is considered a helpful adjunct to provide insight into the underlying mechanism of MINOCA and has a class II level B guideline recommendation where there is diagnostic uncertainty.

The thematic analysis was limited by the small number of respondents and the findings may not be generalisable. The emphasis on clinical context, while appropriate, highlights the challenge of applying standardised approaches to a patient group that are heterogeneous. The psychological burden theme identifies an often-overlooked dimension that warrants explicit attention in care pathway design, including clear lay explanation of MINOCA as a working diagnosis and structured referral to cardiac rehabilitation where appropriate.[4]

Several limitations should be acknowledged. Although we adopted a standardised dissemination strategy through established UK cardiology societies and trainee networks, respondents were self-selecting and likely to have a particular interest in MINOCA, which may have biased responses toward more guideline-concordant practice than the wider clinical community. Because the survey was distributed through overlapping professional networks, the total number of clinicians reached is unknown and a response rate cannot be calculated. We did not collect detailed geographic, sex, or seniority subgroup data sufficient to map regional variation across the UK. The vignettes were necessarily simplified summaries of two index cases and we did not test whether disclosure of the

final CMR diagnosis would have changed reported management. The two vignettes also differed in several respects, including age, cardiovascular risk factors, electrocardiographic findings, troponin concentration and angiographic appearance, so the observed differences in investigation preference cannot be attributed to any single patient characteristic and should not be interpreted as evidence of bias; rather, they illustrate how strongly the overall presentation shapes investigation in the absence of a standardised pathway. Despite these caveats, this survey is, to our knowledge, the first national characterisation of MINOCA practice and underscores the need for a co-ordinated, evidence-based approach that minimises clinician variability and ensures equitable access to advanced diagnostics for affected patients.

CONCLUSIONS

UK clinicians demonstrate variation in the investigation of patients with MINOCA, with the clinical presentation influencing whether to perform further investigations despite diagnostic uncertainty. We observed a lack of endorsement of invasive coronary vasomotor function testing and limited uptake of intravascular imaging across the UK in the provided scenarios. These findings support the development of standardised MINOCA care pathways, enhanced and equitable diagnostic access, and educational initiatives to address the observed variation in clinical practice. The main findings are summarised in Figure 3.

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Competing interests

Colin Berry is employed by the University of Glasgow which holds consultancy and research agreements for his work with Abbott Vascular, AskBio, AstraZeneca, Boehringer Ingelheim, CorFlow, Edwards Lifesciences, Merck, Servier, Novartis, Roche, Siemens Healthcare, Vahaticor and Zoll Medical. NLM has received honoraria or consultancy from Abbott Diagnostics, Roche Diagnostics, and Siemens Healthineers within the last 36 months. ARC has received honoraria or consultancy from Abbott Diagnostics and Johnson & Johnson within the last 36 months. Other authors: none declared.

Contributorship

RAS and ARC conceived and designed the survey, analysed the data and drafted the manuscript. All authors (CB, SB, ED, DD, SF, DJ, VK, NLM, SAM, JAR) contributed to the design of the survey instrument, interpretation of the findings and critical revision of the manuscript; authors to confirm individual contributions. All authors approved the final version. RAS and AC are the guarantors.

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Ethical approval

The survey collected anonymous professional opinion from clinicians and did not involve patients or identifiable data. The clinical vignettes were derived from participants in the Stratified medicine of eplerenone in Acute Myocardial Infarction or Injury and no Obstructive Coronary Arteries

(StratMedMINOCA) clinical trial (NCT05198791) who provided written informed consent, and which gained ethics approval was in January 2022 (20/WS/0075).

Data sharing statement

De-identified survey data and the analysis code are available from the corresponding author on reasonable request.

Patient and public involvement

Patient partners SB and JR are co-authors and contributed to the design, interpretation of the findings and revision of the manuscript.

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FIGURE LEGENDS

Figure 1: Radar plot comparing investigation preferences between clinical vignettes representing mean Likert scores (0-5 scale) for nine investigations across both vignettes. Despite both vignettes representing diagnostic uncertainty with unknown underlying aetiology, marked differences in CMR selection ($P<0.001$), invasive angiography ($P<0.001$), and intravascular imaging ($P<0.001$) suggest presentation-driven decision-making. *P<0.001 between vignettes (Welch t-test). ACh, acetylcholine; CMD, coronary microvascular dysfunction; CT, computed tomography; CV, cardiovascular; LV, left ventricular; MRI, magnetic resonance imaging.

Figure 2: Investigation preferences by respondent sub-group. Mean Likert scores (0-5 scale, bars show mean ± SEM) for invasive coronary angiography, intravascular imaging, adenosine coronary microvascular function testing, acetylcholine provocation testing and cardiac MRI in Case A (upper panels) and Case B (lower panels), stratified by centre type (tertiary or supra-regional versus non-tertiary), respondent grade (consultant versus non-consultant) and cardiology subspecialty (interventional, imaging, other). P-values from Mann-Whitney U (two groups) or Kruskal-Wallis (three groups) tests; group sizes are given in Supplementary Table 1. ACh, acetylcholine; CMD, coronary microvascular dysfunction; MRI, magnetic resonance imaging.

Figure 3 (Central Illustration): Key themes and practice patterns identified from the UK MINOCA clinical practice survey. The illustration summarises four themes from qualitative analysis with integrated quantitative findings: context-dependence of management (68.9% supporting clinical need-based CMR timing), uncertainty regarding diagnostic utility (84.0% agreeing that CMR should be performed when the diagnosis is unclear after angiography), psychological burden on patients (48.5% supporting cardiac rehabilitation for MINOCA mimics), and terminology concerns (63.8% viewing MINOCA only as a working diagnosis). Major practice

gaps include acetylcholine provocation testing (no respondent agreeing with its use in either vignette; 40.3% with local access) and presentation-driven CMR utilisation (82.2% vs 44.2% agreeing or strongly agreeing between vignettes). Proportions are respondents scoring 4 or 5 on the 0 to 5 Likert scale. ACh, acetylcholine; CMR, cardiac magnetic resonance.

Table 1. Investigation preferences by clinical vignette

Case A: 49-year-old, viral prodrome, non-obstructed coronaries, troponin 124-155 ng/L

Case B: 73-year-old, CV risk factors, diffuse atheroma, ST-depression/T-inversion, troponin 43,850 ng/L

Investigation	**Case A** **Mean±SD (n)**	**Case B** **Mean±SD (n)**	**Score 4-5: n/N (%)**	***P*-value**
Invasive coronary angiography	3.5±1.7 (100)	4.9±0.3 (88)	65/100 vs 88/88 (65.0% vs 100%)	<0.001
LV angiography	1.6±1.7 (98)	1.5±1.7 (85)	17/98 vs 14/85 (17.3% vs 16.5%)	0.599
CT coronary angiogram	2.4±1.8 (99)	0.7±1.1 (87)	34/99 vs 3/87 (34.3% vs 3.4%)	<0.001
Intravascular imaging	1.5±1.4 (96)	2.9±1.7 (87)	10/96 vs 42/87 (10.4% vs 48.3%)	<0.001
Adenosine (hyperaemic) coronary microvascular function testing	1.3±1.6 (100)	1.6±1.8 (88)	14/100 vs 18/88 (14.0% vs 20.5%)	0.172
Invasive ACh provocation testing	0.7±1.0 (97)	0.7±1.0 (84)	0/97 vs 0/84 (0.0% vs 0.0%)	0.801

Echocardiography	4.7±0.9 (99)	4.8±0.7 (88)	93/99 vs 86/88 (93.9% vs 97.7%)	0.282
Cardiac MRI	4.2±1.2 (101)	2.9±1.7 (86)	83/101 vs 38/86 (82.2% vs 44.2%)	<0.001
CT pulmonary angiogram	1.1±1.1 (98)	0.4±0.8 (84)	4/98 vs 0/84 (4.1% vs 0.0%)	<0.001

ACh, acetylcholine; CT, computed tomography; CV, cardiovascular; LV, left ventricular; MRI, magnetic resonance imaging. Likert scale: 0=strongly disagree/very unlikely, 5=strongly agree/very likely. Score 4-5 denotes respondents who agreed or strongly agreed. *P*-values from Welch's *t*-tests comparing mean scores between vignettes.