# Utility of cardiovascular magnetic resonance in pregnancy

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## ABSTRACT

**Pregnant women with known or suspected cardiovascular disease (CVD) often require cardiovascular imaging during pregnancy. Decisions about imaging in pregnancy are premised on understanding the physiology of pregnancy, understanding basic concepts of different imaging modalities, the clinical manifestations of existent CVD in pregnancy and features of new CVD. Cardiovascular magnetic resonance (CMR) imaging is safe in pregnancy and is not associated with any adverse foetal effects, provided there are no general contra-indications to magnetic resonance (MR) imaging. CMR also does not involve any ionising radiation. In pregnancy, CMR is useful to confirm diagnosis of CVD, assess disease severity, to stratify risk and prognosticate, to plan appropriate management, and to assess response to therapy. Use of any imaging test in pregnancy needs to have safety considerations balanced against the importance of accurate diagnosis and thorough assessment of the pathological condition. This review summarises the evolving role of CMR in evaluation of known or suspected new CVD in pregnancy.** SAHeart 2022;19:194-200

## INTRODUCTION

Cardiovascular disease (CVD) in pregnancy encompasses a broad spectrum of pathologies, which may be exacerbations of pre-existing conditions in the pregnant woman or new disease that has developed during the pregnancy (Table I for abbreviations). CVD in pregnancy is a significant cause of or morbidity and mortality and has been cited to be present in 1% - 4% of all pregnancies.[1,2] When hypertensive disease is included, the estimation is even higher, given that hypertensive disorders of pregnancy have been approximated to occur in up to 8% of pregnancies.[3]

Pregnant women with known CVD or a newly diagnosed cardiac condition in pregnancy often require cardiovascular imaging during the pregnancy to confirm the diagnosis, to assess disease severity and stratify risk, to prognosticate, to plan for appropriate management and to assess response to therapy.[4] A variety of cardiovascular imaging modalities are available for such and include X-ray – which encompasses chest radiography, cardiovascular computed tomography, computed tomographic

**TABLE I: Abbreviations.**

| | |
|---|---|
| CMR | Cardiovascular magnetic resonance |
| CVD | Cardiovascular disease |
| ECV | Extracellular volume |
| FDA | United States Food and Drug Administration |
| GBCA | Gadolinium-based contrast agents |
| LGE | Late gadolinium enhancement |
| MR | Magnetic resonance |
| PPCM | Peripartum cardiomyopathy |
| RF | Radiofrequency |
| SCMR | Society for Cardiovascular Magnetic Resonance |

pulmonary angiography, coronary computed tomographic angiography, fluoroscopy and invasive angiography – as well as echocardiography, cardiovascular magnetic resonance (CMR) and nuclear scintigraphic techniques.

The spectrum of CVD in pregnancy is wide, and is related to congenital and acquired cardiac lesions, and may be driven by the complex hormonal changes and physiology of pregnancy (Table II). Pre-existing conditions that can predispose pregnant women to CVD include hypertension, diabetes mellitus, cardiomyopathy, valvular heart disease, and congenital heart disease. CVD that may develop in pregnancy include preeclampsia, hypertensive disorders of pregnancy, spontaneous coronary artery dissection, myocardial infarction, dilated cardiomyopathy (DCM) and peripartum cardiomyopathy (PPCM).

Several unique properties of CMR contribute to its widespread utility in the assessment of the cardiovascular system. The high spatial and temporal resolution coupled with excellent tissue contrast enables comprehensive assessment of multiple parameters pertaining to cardiovascular morphology and function, without exposure to ionising radiation.[5] The ability of CMR to obtain images in any tomographic plane, regardless of body habitus, confers significant advantage in patients with limited sonographic acoustic windows. Characterisation of myocardial tissue is a unique feature of CMR, traditionally achieved through late gadolinium-enhancement (LGE) imaging and based on the relative difference in volume of distribution of intravenously administered contrast and subsequent alteration of longitudinal relaxation (T1) times between normal and abnormal myocardium.[6] Parametric mapping techniques allow direct measurement of myocardial relaxation times on a pixel-wise basis, parameters which have been extensively validated offering similar diagnostic performance and superior sensitivity for inflammation, infiltration, acute injury and fibrosis as compared with LGE imaging in detecting myocardial pathology.[7] Indications for CMR in pregnancy are listed in Table III.

The Society for Cardiovascular Magnetic Resonance (SCMR) has recently published 2 position statements with recommendations for clinical utilisation of CMR in women with CVD, including those who are pregnant.[8,9] The documents were prepared by the SCMR Consensus Group on CMR imaging for female patients with cardiovascular disease with the goals of (i) guiding the informed selection of cardiovascular imaging methods, (ii) informing clinical decision-making, (iii) educating stakeholders on the advantages of CMR in specific clinical scenarios, and (iv) empowering patients with clinical evidence

**TABLE II: Spectrum of common cardiovascular disease in pregnancy.**

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| Hypertension |
| Preeclampsia |
| Valvular heart disease |
| Coronary heart disease |
| Cardiomyopathy |
| Heart failure |
| Congenital heart disease |
| Arrhythmia |
| Aortopathy |
| Pulmonary embolism |

**TABLE III: Rationale for use and indications for cardiovascular magnetic resonance in pregnancy** (adapted from Ntusi NAB, et al. Cardiovasc J Afr 2016;27(2):95-103.)**.**

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| Evaluation of biventricular structure, geometry, size, and function. |
| Evaluation of native and prosthetic valve disease. |
| Evaluation of pregnancy-induced hypertension and hypertensive heart failure of pregnancy. |
| Evaluation of congenital heart disease. |
| Evaluation of myocarditis. |
| Evaluation of specific cardiomyopathies:<br>Dilated cardiomyopathy;<br>Peripartum cardiomyopathy;<br>Hypertrophic cardiomyopathy;<br>Arrhythmogenic right ventricular cardiomyopathy;<br>Iron-overload cardiomyopathy;<br>Restrictive cardiomyopathy;<br>Myocardial infiltration (e.g., sarcoidosis);<br>Cardiomyopathy related to systemic rheumatic diseases (e.g., rheumatoid arthritis, systemic lupus erythematosus, systemic sclerosis);<br>Other less-common diseases (e.g., Chagas disease, nutritional cardiomyopathies, Churg-Strauss syndrome). |
| Evaluation of pericardial disease:<br>Pericarditis;<br>Pericardial effusions;<br>Pericardial tumours;<br>Pericardial effusive-constrictive syndrome;<br>Pericardial constriction. |
| Evaluation of great vessels and pulmonary veins. |
| Evaluation of cardiac masses (differentiation of tumour from thrombus). |
| Evaluation of infective endocarditis. |
| Evaluation of ischaemic heart disease:<br>Diagnosis of myocardial infarction and its sequelae;<br>Assessment of myocardial viability;<br>Assessment for inducible ischaemia;<br>Coronary imaging;<br>Assessment of suspected coronary artery fistula;<br>Assessment of suspected anomalous coronary origins. |
| Differentiation of ischaemic left ventricular dysfunction vs. non-ischaemic cardiomyopathy. |
| Evaluation of mechanical dyssynchrony. |
| Evaluation of unexplained heart failure or stroke. |

to participate in their clinical care. The Pan-African Society of Cardiology has also published a position paper on reproductive healthcare for women with rheumatic heart disease, including in pregnancy.[10]

In this review, we summarise the evolving role of CMR in evaluation of known or suspected new CVD in pregnancy.

## HOW CARDIOVASCULAR MAGNETIC RESONANCE WORKS

CMR is a remarkably powerful imaging modality, free of ionising radiation, with high spatial and temporal resolution, performed via excitation of hydrogen protons within a powerful magnetic field.[4-7] The strong magnetic field aligns the nuclear magnetisation spin of the hydrogen protons, which are then excited by radiofrequency (RF) pulses. After the RF pulses are switched off, the protons give off energy as they precess back to their equilibrium magnetisation; this dissipated energy is detected by the MR receiver coils. Fourier transformation is used to convert frequencies into images.[4] The signal from the myocardium is determined by a number of factors including proton density (PD) , longitudinal relaxation time (T1) and transverse relaxation time (T2).[5] PD, T1 and T2 vary substantially for different tissues, and may vary substantially within the same tissue from health to disease; these differences are used to generate contrast in MR images.[7] To prevent artifacts from cardiac motion, CMR images are generated with fast sequences gated to the R wave of the electrocardiogram. Respiratory motion may be eliminated by acquiring CMR images in end-expiratory breath-hold.

MR has been used to evaluate cardiovascular, obstetric, placental and foetal abnormalities in pregnant patients for more than 30 years and is recognised as a beneficial diagnostic tool utilised routinely to assess CVD in pregnant patients.[4] While there has been a paucity of systematic studies directed towards determining the relative safety of using MR procedures in pregnant patients, there has been no evidence of harm from the use of CMR and other forms of MR imaging in pregnancy.[11]

In a single CMR study, one can glean insights into cardiovascular anatomy, function, viability, haemodynamics, and tissue characteristics amongst many others (Figure 1). Cine imaging is a method used in CMR to produce a set of moving images, which is useful in the assessment of biventricular function (ref) and to quantify myocardial deformation (i.e., strain and strain rates) throughout the cardiac cycle. Cine acquisitions can also distinguish between restrictive and constrictive physiology, and are useful for the study of aortopathies, which may be complemented by contrast or non-contrast angiographic studies. 3-D magnetic resonance angiography can be constructed and – in the case of aortic dissection – MR technology can be used to evaluate the true and false lumens within the aorta and its branches. For vascular imaging in pregnancy, time-of-flight sequences can be used to selectively visualise arterial or venous signals without the administration of contrast.

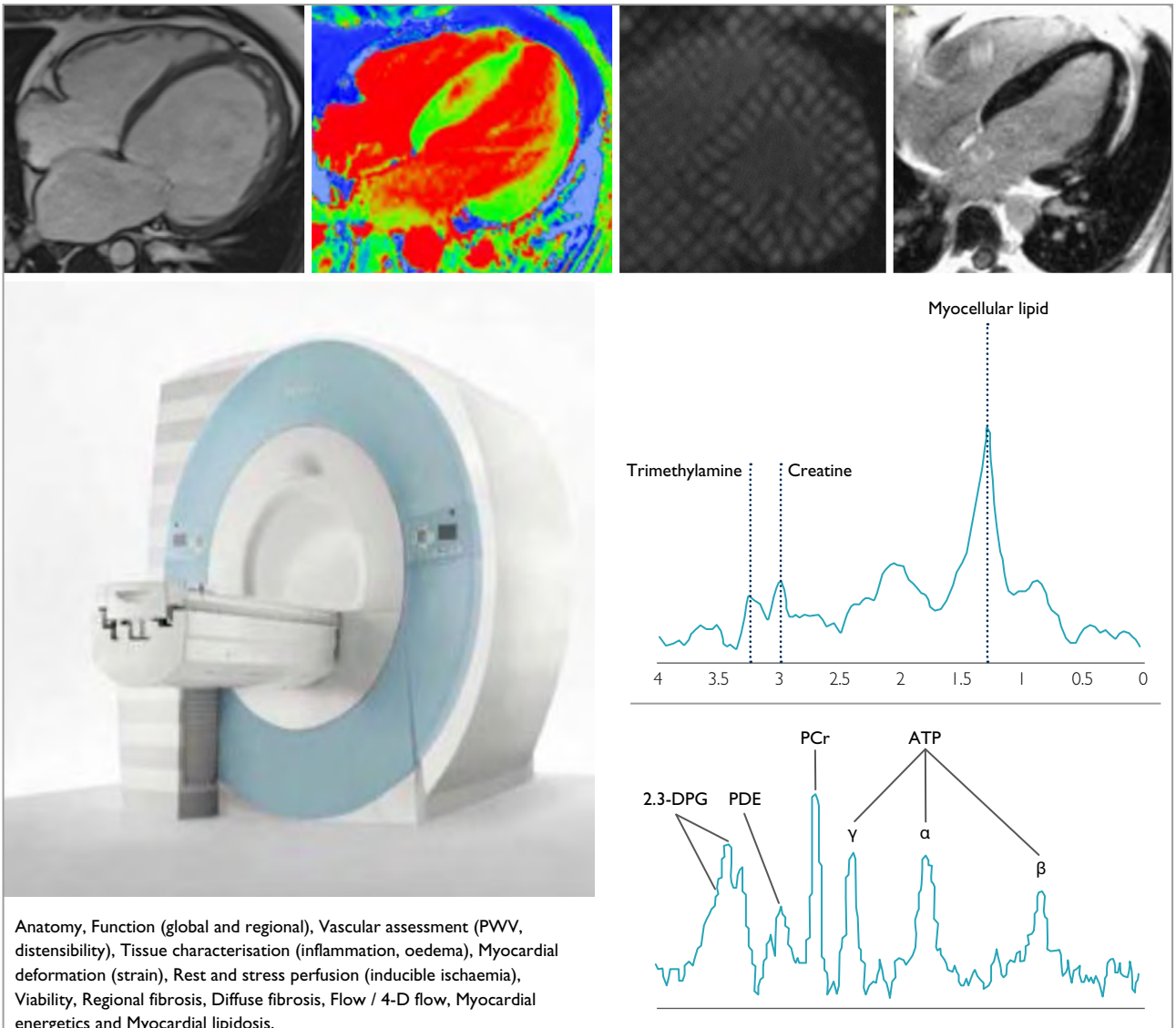
Use of LGE imaging following contrast administration is particularly helpful for myocardial disease; and must be considered in pregnancy when indicated. T1 mapping, before and after contrast administration, using modified Look-Locker inversion recovery-based or saturation recovery single-shot acquisition-based sequences is well-established for tissue characterisation. For ease of interpretation, these values are displayed as a colour map superimposed on anatomic images, allowing global and segmental quantification of T1 values using targeted regions-of-interest. Postcontrast T1 maps allow for the estimation of myocardial extracellular volume (ECV), a marker of myocardial tissue remodelling which has been shown to be a robust measure of the degree of myocardial fibrosis.[12]

## SAFETY OF CARDIOVASCULAR MAGNETIC RESONANCE AND GADOLINIUM IN PREGNANCY

In CMR during pregnancy, safety concerns include possible bioeffects of the static magnetic field of the MR system, risks associated with exposure to the gradient magnetic fields, the potential adverse effects of RF energy, possible adverse effects related to heating and to the combination of these 3 electromagnetic fields, possible acoustic injury from the vibration and noise in the scanner, and possible toxicity from gadolinium-based contrast agents (GBCAs) used in patients with renal dysfunction.[4,13] MR environment-related risks have been difficult to assess for pregnant patients due to the number of possible permutations of the various factors that are present in this setting (e.g., differences in field strengths, pulse sequences, exposure times, stage of pregnancy). Importantly, numerous experimental and clinical investigations of the effects of MR in pregnancy showed no evidence of injury or harm to the foetus or the mother.[14,15] Few human studies performed in pregnant human subjects exposed to MR or the MR environment have not reported adverse outcomes for the pregnant women or their babies.[16,17] Concerns about the possibility of acoustic noise associated with MR impacting on the foetus have not stood up to epidemiological scrutiny.[18] A retrospective study in 754 neonates who had 1.5 T MRI in utero showed no effect on hearing function or birth weight compared to control

neonates.[19] In a large retrospective study in Canada that analysed 1 737 pregnancies scanned with MR, an exposure to MR was not associated with a higher risk of stillbirth or neonatal death, congenital abnormalities, neoplasm or hearing loss when compared to 1.4 million pregnancies without MR.[20]

GBCAs can cross the placenta and are excreted by the foetal kidneys into the amniotic fluid and return to the foetal circulation by swallowing. Although the amounts of gadolinium chelate in foetal tissues and amniotic fluid were much smaller than the maternal injected dose, there is potential concern about prolonged recirculation of the contrast medium in foetal tissue leading to adverse effects.[21,22] Accordingly, GBCAs should ideally be used if contrast-enhanced CMR is considered critical and the potential benefits justify the potential risk to the foetus.[22] When there is a very strong indication for contrast-enhanced CMR, the smallest possible dose of a macrocyclic GBCA may be given to the pregnant women.[22] In summary, CMR up to 3T appears to be safe in all stages of pregnancy.[23] Higher field strengths have not been evaluated in the setting of pregnancy.[4] CMR, where available, together with echocardiography, remains preferable to any studies using ionising radiation for cardiovascular imaging in pregnancy, in particular during the first trimester. Despite the lack of evidence of harm from MR in pregnancy, the current guidelines of the FDA require labelling of MR devices to indicate that the safety of MRI in relation to the foetus "has not been established". Generally, in pregnant women with suspected myocarditis or




Anatomy, Function (global and regional), Vascular assessment (PWV, distensibility), Tissue characterisation (inflammation, oedema), Myocardial deformation (strain), Rest and stress perfusion (inducible ischaemia), Viability, Regional fibrosis, Diffuse fibrosis, Flow / 4-D flow, Myocardial energetics and Myocardial lipidosis.

**FIGURE 1: Cardiovascular magnetic resonance utility in pregnancy** (adapted from Ntusi NAB. Cardiovasc J Afr 2018;29(3):135-138).

cardiomyopathy, CMR can evaluate ventricular function as well as the presence of tissue infiltration or scar, where LGE CMR is helpful.[22]

Previously, some centres have recommended avoidance of breast-feeding for 24 hours after administering GBCA in lactating women. However, less than 0.04% of the total maternal dose of intravenous GBCA passes into the breast milk over 24 hours, with only a small fraction of this amount absorbed from the gastrointestinal tract.[24] Therefore, according to the current guidelines,[21,22] breast feeding may be continued when macrocyclic GBCA are given to the mother.

## CLINICAL APPLICATIONS OF CARDIOVASCULAR MAGNETIC RESONANCE IN PREGNANCY

In the largest cohort to-date describing CMR in pregnancy, which included consecutive pregnant patients from 4 centres in the UK and South Africa, 83 women underwent diagnostic CMR without complications.[25] In this study, the commonest indications for CMR in pregnancy were vascular or congenital disease (in 48%), followed by cardiomyopathy / myocarditis (in 43%). Nineteen percent of pregnant women received GBCAs, and CMR changed management in 35% overall, and in 50% of patients who received contrast. We concluded that CMR frequently changes management in pregnancy, thus adding valuable guidance for patient care, and recommended that CMR should be offered to pregnant women when indicated, including the administration of contrast as per current guidelines. In this publication, we also offered recommendations for performing CMR in pregnancy (Table IV).

A retrospective record review of 17 peripartum CMR studies without contrast in 16 women for which the main indications were congenital heart disease (47%), Marfan syndrome or strong family history of Marfan syndrome (29%), cardiomyopathy (6%), cardiac mass (6%), persistent dyspnoea with a normal echocardiogram (6%), and hypertension with suspected aortic root dilation (6%) (26). In addition, CMR confirmed the echocardiogram diagnosis in 47% and improved/altered the diagnosis in 29% of the cases reviewed. Availability of CMR findings changed the delivery management in 12%. CMR was especially helpful in assessing the size of the aortic root in women at risk for dilation.

While transthoracic echocardiography (TTE) is the most widely used imaging modality for the assessment of cardiovascular function during pregnancy, the role of CMR is not clearly established. The Cardiac Hemodynamic Imaging and Remodeling in Pregnancy (CHIRP) study was designed to compare TTE and CMR in the non-invasive assessment of maternal cardiac remodeling during the peripartum period, and included 34 women imaged during the third trimester.[27] TTE and CMR demonstrated an increase in left ventricular (LV) end-diastolic volume from 95mL - 115mL and 98mL - 125mL, respectively. By TTE and CMR, there was also an increase in LV mass during pregnancy from 111g - 163g and 121g - 179g, respectively. Although there was good correlation between both imaging modalities for LV mass, stroke volume, and cardiac output, the values were consistently underestimated by TTE. This study was also used to develop reference values for cardiac indices during normal pregnancy and the post-partum state.

Small observational studies have evaluated the role of CMR in the assessment of aortic disease[28,29] and congenital heart disease in pregnancy.[30,31] Likewise, small studies have reported on the role of CMR in PPCM and DCM[32-36] (Figure 2) and in myocarditis and infiltrating cardiomyopathy[37] during pregnancy and the puerperium. These studies have reported on a common finding of a poor prognosis in these myocardial disorders when focal myocardial fibrosis indicated by LGE is present.

**TABLE IV: Recommendations for performing cardiovascular magnetic resonance in pregnancy** (adapted from Herrey AS, et al. Eur Heart J Cardiovasc Imaging 2019;20:291-297).

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| Establish clinical need. |
| Ensure informed consent is obtained, detailing the use of gadolinium contrast and any other medications to be given during the scan. Please check they are safe to be given in pregnancy. |
| Confirm and record gestational age (this should be beyond 12/40) and any problems with pregnancy so far. |
| Record baseline heart rate and blood pressure. |
| Scan at lowest field strength possible, usually 1.5 T. |
| Position in head first, supine position. If >20 weeks gestation use wedge or pillow under right buttock to tilt pelvis off the vena cava, thus avoiding cava compression syndrome. |
| Please make sure patient is comfortable! |
| Place vector electrocardiogram gating near left ear to allow for cardiac displacement in advanced pregnancy. |
| SAR considerations: Ensure scan is performed on normal SAR – first level must not be switched on or switched over to during the scan. |
| If gadolinium contrast is necessary to answer clinical question, give minimum amount required, using low-risk agent. |
| Keep image acquisition to a minimum. Keep breath-holds short and ensure protocol is established prior to starting the scan. |
| Check heart rate and blood pressure prior to the patient leaving the department. |
| If there are concerns liaise with her obstetric team. |

## FOETAL IMAGING

MRI has been used for foetal imaging with no evidence of negative impact on the foetus.

The lack of ionising radiation with MRI is a clear advantage compared with other modalities. Theoretic concerns with respect to the foetus include the possibility of teratogenesis and acoustic damage, but most studies have shown a good safety profile.

As with all studies, analysis of the potential benefit of the information derived and the possible risks, although small, should be performed and presented to patients when obtaining informed consent.

The adoption of ultrafast MRI sequences has led to an extreme improvement of foetal MRI by diminishing artifacts caused by excessive foetal motion and reducing the necessity to use sedation during this examination. Turbo spin echo is a standard sequence for foetal MRI examination using single time repetition (TR single shot) also known as single-shot fast spin echo (SSFSE). This sequence is based on a single slice acquisition in a very short time repetition (TR) (<3ms) so the artefacts can be efficiently reduced. Two types of T1-weighted sequences are used: gradient echo (GRE), with short TR and echo time (TE), and fast spin echo (FSE-T1). FSE-T1 grants improved spatial resolution but requires about 20 s of breath-holding, while GRE requires 14–15 s of breath-holding but provides reduced spatial resolution. In contrast to T2-weighted SSFSE, slices in the gradient-echo sequence are acquired simultaneously meaning that even a slight foetal movement reflects in all slices as a motion artifact. T1-weighted sequences provide less information compared to T2-weighted SSFSE sequences.[38,39]

## CONCLUSIONS

Pregnant women with known or suspected CVD often require cardiovascular imaging during pregnancy. CMR is safe in pregnancy and is not associated with any adverse foetal effects, provided there are no general contra-indications to MRI. CMR also does not involve any ionising radiation. In pregnancy, CMR is useful to confirm diagnosis of CVD, assess disease severity, to stratify risk and prognosticate, to plan appropriate management, and to assess response to therapy.

## FUNDING

This article is not funded. Ntobeko Ntusi gratefully acknowledges funding from the National Research Foundation, South African Medical Research Council, Medical Research Council United Kingdom, and the Lily and Ernst Hausmann Trust.

**Conflict of interest: none declared.**

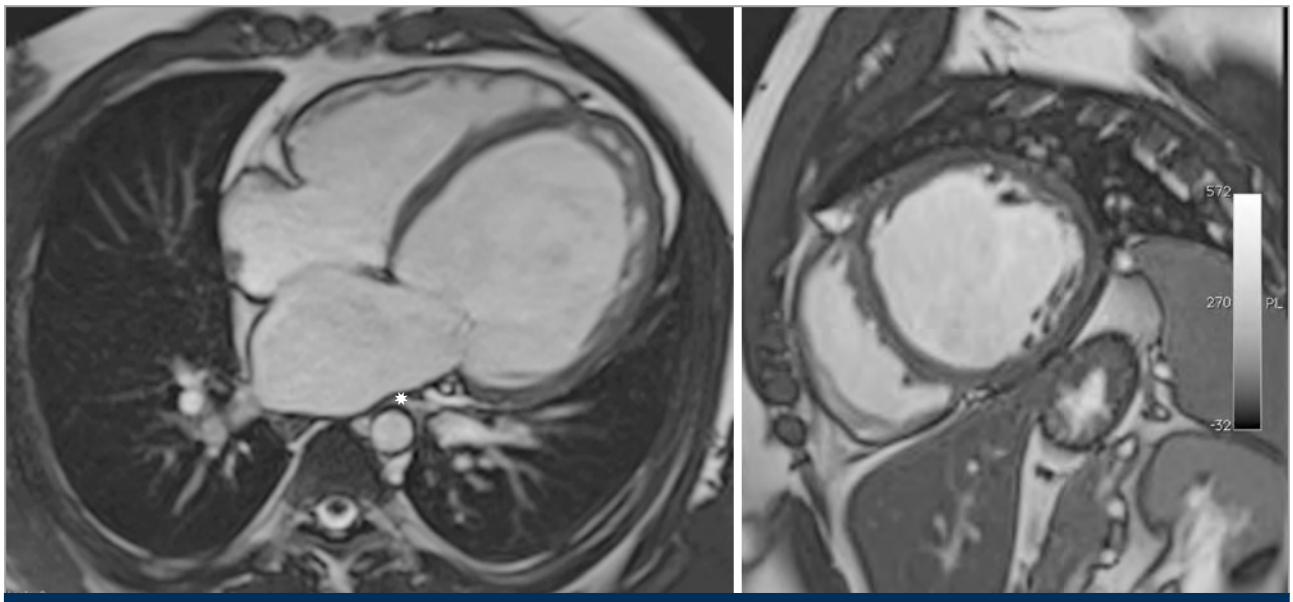


**FIGURE 2: Cardiovascular magnetic resonance in peripartum cardiomyopathy. Four-chamber and short-axis view of patient with PPCM.**

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