Review Article

MRI assessment of cardiac tumours: part 2, spectrum of appearances of histologically malignant lesions and tumour mimics

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Abstract: Cardiac magnetic resonance imaging (MRI) is the reference standard technique for assessment and characterization of a suspected cardiac tumour. It provides an unrestricted field of view, high temporal resolution and non-invasive tissue characterization based on multi-parametric assessment of the chemical micro-environment. Sarcomas account for around 95% of all primary malignant cardiac tumours with lymphoma, and primary pericardial mesothelioma making up most of the remainder of cases. By contrast cardiac metastases are much more common. In this article we review the MRI features of the spectrum of histologically malignant cardiac and pericardial tumours as well as some potential tumour mimics.

Keywords: Magnetic resonance imaging (MRI); cardiac tumours; angiosarcoma

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Introduction

Cardiac magnetic resonance imaging (MRI) is considered the reference standard technique for characterization of a suspected cardiac mass. It provides an unrestricted field of view, high temporal resolution (30-50 ms) and non-invasive tissue characterization based on multi-parametric assessment of the chemical micro-environment (1). As such MRI is extremely helpful for diagnosis, assessment of the functional impact of a lesion, treatment planning and post treatment follow-up (2,3). We present a two-part review of the role of cardiac MRI in the assessment of cardiac tumours. Part 1 focuses on specific cardiac MRI techniques, protocol design and the appearance of histologically benign tumours. This article, part 2 covers histologically malignant tumours including cardiac metastases and also reviews the MRI appearance of some potential tumour mimics.

Sarcomas account for the vast majority of histologically malignant primary tumours of the heart (4-6). By comparison, metastatic involvement of the heart is 100-500 times more frequent than primary tumours (7). Cardiac tumours are frequently asymptomatic and often discovered incidentally during evaluation of an unrelated problem or physical finding. Symptoms and signs depend on the size and location of the tumour, haemodynamic effects (chamber obstruction or embolization) and interference with cardiac conduction (heart blocks or cardiac arrhythmias).

Malignant primary cardiac tumours

Sarcomas account for around 95% of all primary malignant cardiac tumours with lymphoma, and primary pericardial mesothelioma making up most of the remainder of cases. Although there are a few sporadic reports of long term survival the prognosis of primary cardiac tumours is dire with a median survival from several large series in the order of 6-12 months (5,6). Currently there is no TNM staging classification system for malignant cardiac tumours and treatment pathways and algorithms are not well defined.

Table 1 MRI features suggesting the presence of a malignant cardiac tumour (7,8)
Origin from the right heart chambers
Involvement of >1 heart chamber
Broad based attachment
Size >5 cm
Ill-defined margins
Haemorrhagic pericardial effusion
Heterogeneous signal on T1 and T2 weighted images
First pass perfusion enhancement
Heterogeneous late gadolinium enhancement

Complete surgical resection is rarely possible as most cases are at an advanced stage with extensive local infiltration by the time of first clinical presentation and diagnosis however some patients may gain symptomatic benefit with a de-bulking surgical procedure in combination with adjuvant chemotherapy (5,6).

General imaging findings which favour a malignant over a benign cardiac tumour are presented in *Table 1*.

Sarcomas

Sarcomas are the second most common primary cardiac tumours after myxoma (9). They represent a diverse group of mesenchymal tumours with broad histological subtypes of angiosarcoma, sarcoma of myo- or fibroblastic differentiation and rhabdomyosarcoma.

Angiosarcoma

Angiosarcoma is the most common primary malignant cardiac tumour. It is a very aggressive infiltrative lesion with an origin from mesenchymal angioblasts (10). Histologically it is composed of irregularly shaped vascular channels lined by anaplastic epithelial cells with large areas of intra-tumoural haemorrhage and necrosis (11). There is a strong male predominance and a peak incidence in the fourth decade. Approximately 75% of angiosarcomas arise within the right atrium, typically filling this chamber with infiltration into adjacent structures such as the tricuspid valve, right coronary artery, right ventricle and pericardium. A large haemorrhagic pericardial effusion is frequently present (12). At time of clinical presentation the tumour is usually at an advanced unresectable stage with distant metastases present in up to 89% of cases; most often to mediastinal lymph nodes, lung, liver and bone (13). Clinical symptoms usually relate to cardiac tamponade or right heart failure secondary to intracavitary obstruction. Prognosis is extremely poor with very few patients surviving more than 12-month even with surgical debulking and aggressive chemotherapy (13).

MRI demonstrates a large infiltrative mass with heterogeneous signal intensity. T1-weighted images show tumour tissue as predominantly isointense to myocardium with areas of high T1 signal change reflecting intratumoural haemorrhage and areas of signal void reflecting blood flow within vascular channels (14). A large mixed signal pericardial effusion reflecting blood products is invariably present. Angiosarcoma appears predominantly high signal on T2-weighted images (*Figure 1*). First pass and LGE is avid and may predominate along prominent vascular channels to give a characteristic "sunray" pattern (15).

Sarcomas with myofibroblastic differentiation

These are a diverse group of tumours many of which contain heterologous elements such as fat and bone. They are subclassified as undifferentiated sarcoma, leiomyosarcoma, fibrosarcoma, liposarcoma and osteosarcoma. Most present in adulthood with a peak incidence between the 3rd and 5th decades (16). Location is most often from the left atrium, typically along its posterior wall with direct infiltration into one or more pulmonary vein ostia (17,18). These tumours tend to be locally aggressive although distant metastases can occur (19). Complete surgical clearance is rarely possible.

MRI features are non-specific and most often those of an infiltrating left atrial lesion with intermediate T1- and high T2-signal intensity with varying amounts of first pass and LGE. The main imaging differential is a broad based (sessile) myxoma with key distinguishing features for sarcoma being extension into the pulmonary veins and breach of the left atrial wall (*Figure 2*) (20-25).

Rhabdomyosarcoma

Rhabdomyosarcoma is the commonest primary paediatric cardiac tumour and infrequently occurs in adults. These tumours arise from the myocardium with no chamber predilection. They commonly show areas of necrosis have multiple sites of origin and have a strong tendency for infiltrating into the pericardial space and the valves (18).

Described MRI features are those of a peripherally solid lesion (isointense to myocardium on T1-weighted images)

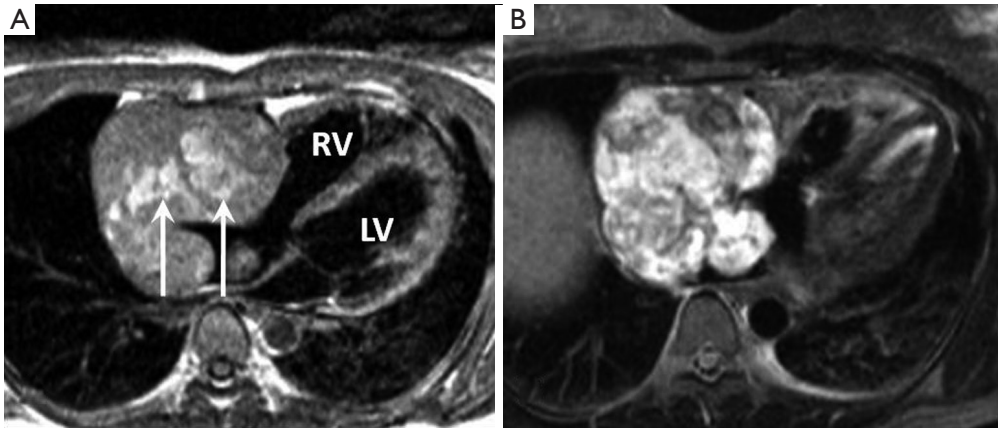

Figure 1 Angiosarcoma. (A) Axial T1-weighted black blood image showing a large infiltrative heterogeneous signal mass. Central areas of high T1 signal suggest the presence of intra lesional haemorrhage (arrows). (B) Axial T2-weighted black blood image showing the tumour to contain areas of very high T2-signal change in keeping with oedema and some areas of low signal intensity suggestive of necrosis. RV, right ventricle; LV, left ventricle.

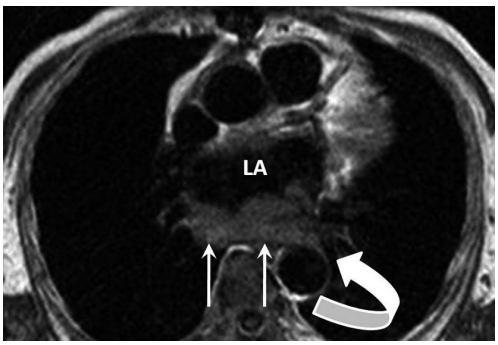

Figure 2 Leiomyosarcoma. Axial T1-weighted black blood image showing an infiltrative lesion along the posterior wall of the left atrium (arrows). The lesion is extending into the left inferior pulmonary vein ostium (curved arrow) which is a feature helping distinguish it from a broad based left atrial myxoma. LA, left atrium.

with central necrotic elements (high T2-signal regions). The solid components show LGE and cavitating pulmonary metastases may be present (*Figure 3*) (18,26).

Primary cardiac lymphoma

Primary cardiac lymphoma is much less frequent than secondary involvement and is defined as disease confined to the heart or pericardium (11,27). The vast majority are of large B-cell origin and occur in immunocompromised patients (22). They usually arise from the right heart chambers, particularly the right ventricle with an associated pericardial effusion (28). These tumours are usually aggressive but may respond well to monoclonal anti-CD20 antibody (rituximab). MRI features are variable with two main patterns described. The first is of multiple solid appearing myocardial based masses which are isointense on T1 and mildly hyperintense on T2-weighted images, most often occurring within the right ventricle (29). The second is that of diffuse pericardial soft tissue infiltration with a haemorrhagic effusion (*Figure 4*). Lymphoma tissue often displays heterogeneous LGE (29,30). Absence of necrosis and less frequent valvular involvement in conjunction with a history of immunocompromise suggest the possibility of lymphoma over other primary cardiac tumours.

Primary pericardial malignancy

Pericardial mesothelioma arises from mesothelial cells of the parietal pericardium. It virtually always occurs in patients with a history of asbestos exposure, many of whom with have asbestos related pleural disease (pleural thickening, effusion, plaques). There is progressive encasement of the heart causing breathlessness and chest pain, often with clinical signs of pericardial constriction and/or tamponade (31,32). It is unusual for mesothelioma to directly invade the adjacent myocardium (33,34). Prognosis is usually very poor but surgical resection for localized cases can be curative (35,36). MRI shows multiple coalescing pericardial masses isointense to myocardium on T1 and heterogeneous on T2-weighted images.

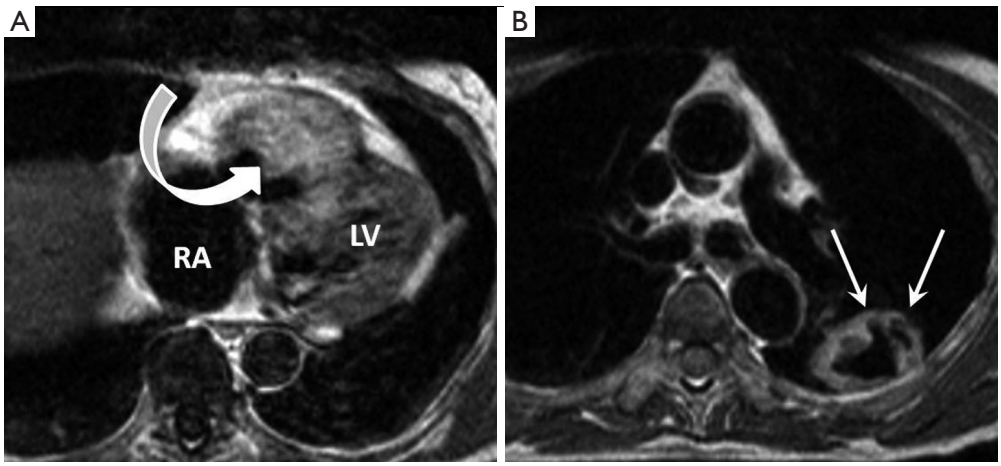

Figure 3 Rhabdomyosarcoma. (A) Axial T1-weighted delayed phase image obtained 10 minutes following gadolinium administration showing an enhancing infiltrative mass arising from the right ventricular free wall (curved arrow); (B) axial T1-weighted black blood image at the level of the left pulmonary artery showing a cavitating pulmonary metastasis within the apical segment of left lower lobe (arrows). RA, right atrium; LV, left ventricle.

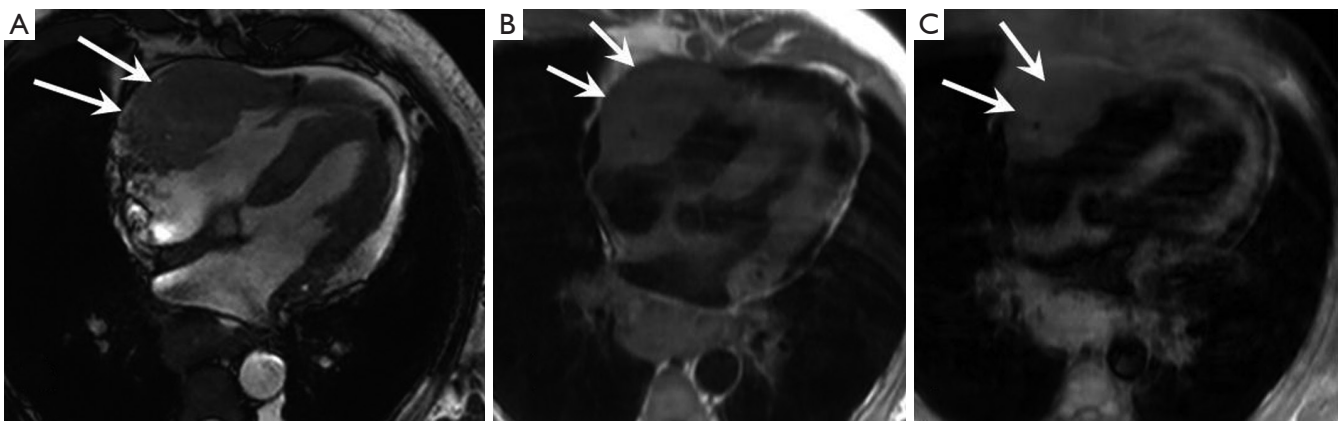

Figure 4 Primary cardiac lymphoma. (A) 4-chamber SSFP image showing a large lobulated mass within the free wall of the right ventricle (arrows); (B) axial T1-weighted black blood image showing several lobulated masses isointense to myocardium (arrows); (C) axial T2-weighted image showing the masse of slightly high signal to myocardium (arrows).

Pericardial synovial sarcoma is an extremely rare and high aggressive tumour composed of epithelial and spindle cells. Clinical presentation, prognosis and MRI features are very similar to angiosarcoma appearing as a highly infiltrative multi-lobulated mass with avid first pass and LGE (37).

Cardiac metastasis

Cardiac metastases are 100-500 times more common than primary cardiac malignancy with approximately 12% of oncology patients having myocardial or pericardial spread at autopsy although many remain clinically silent (38). Tumours that most frequently metastasis to heart are bronchogenic, breast, and melanoma (39). The pericardium and epicardium are most frequently involved with seeding occurring via haematogenous spread through the coronary arteries or via lymphatic channels. Direct invasion most often occurs with central bronchogenic tumours or via venous extension into the right atrium (renal cell or hepatocellular carcinoma). Management is mainly palliative with pericardiocentesis or creation of a pericardial window

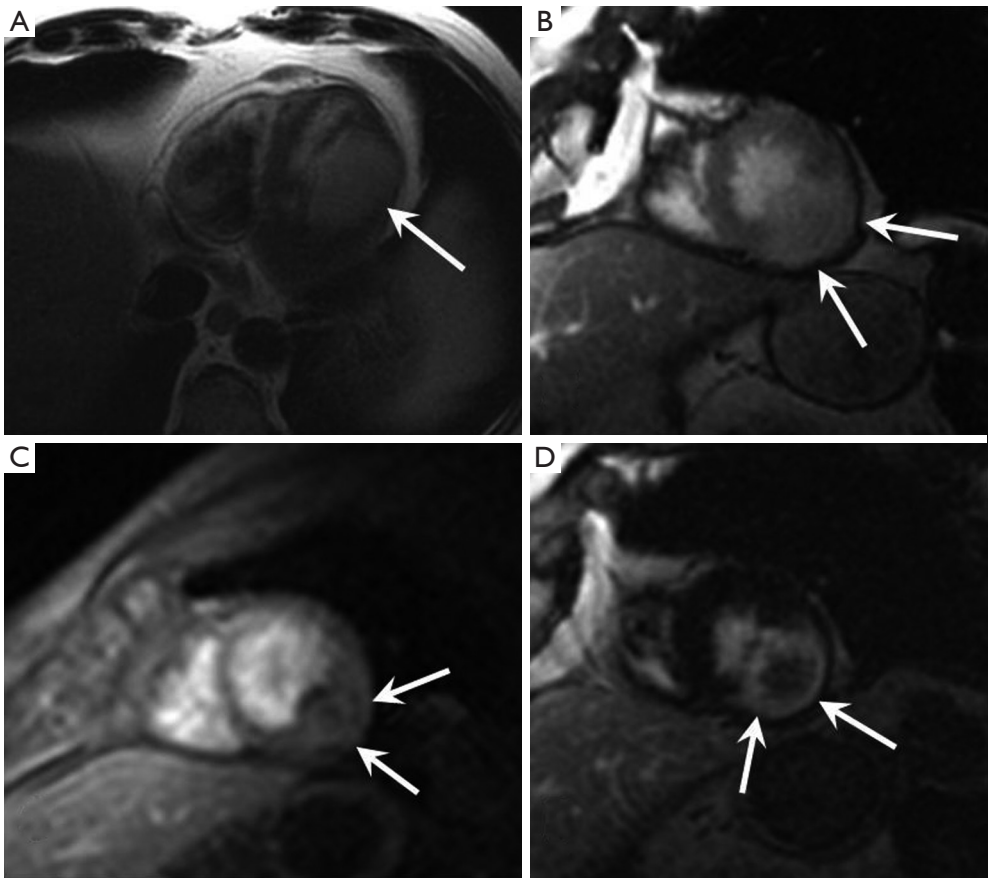

Figure 5 Metastasis to the left ventricular myocardium from primary lung adenocarcinoma. (A) Axial T2-weighted black blood image showing a large lesion within the lateral wall of the left ventricle which is of higher signal intensity than adjacent normal myocardium (arrow); (B) short axis SSFP image showing the mass indenting into the left ventricular cavity and of slightly higher signal intensity than adjacent normal myocardium (arrows); (C) short axis image from a resting perfusion study showing positive first pass contrast enhancement (arrows); (D) post-gadolinium T1-weighted short axis image showing peripheral enhancement (arrows) with a central non-enhancing (necrotic) core.

in cases of recurrent pericardial effusion/tamponade (9,39).

MRI appearances are variable and generally non-specific for the tissue of origin with the exception of melanoma which causing characteristic high T1-signal masses due to the T1 shortening effects of melanin (40,41). Lesions with a haemorrhagic component may also have some areas of high T1 signal secondary to blood breakdown products. Most other metastases usually appear of low signal intensity on T1 and of high signal intensity on T2-weighted imaging and most show prominent LGE (*Figure 5*) (41). A pericardial effusion will frequently be present.

Potential tumour mimics

A variety of lesions including some anatomical variants can mimic a cardiac tumour of which thrombus often causes the most diagnostic difficulty.

Intracardiac thrombus

Thrombus is by far the most common intracardiac mass and is always one of the main differentials for a suspected primary or secondary cardiac tumour. Thrombi are most often located within the left atrium, especially the appendage and have a particular association with atrial fibrillation. When sited in the left ventricle, they occur as sequelae of myocardial infarction, aneurysmal left ventricular segment or severe ventricular dysfunction. Right heart thrombus is much less common but may be seen in association which central venous catheter lines which can act as a nidus or in

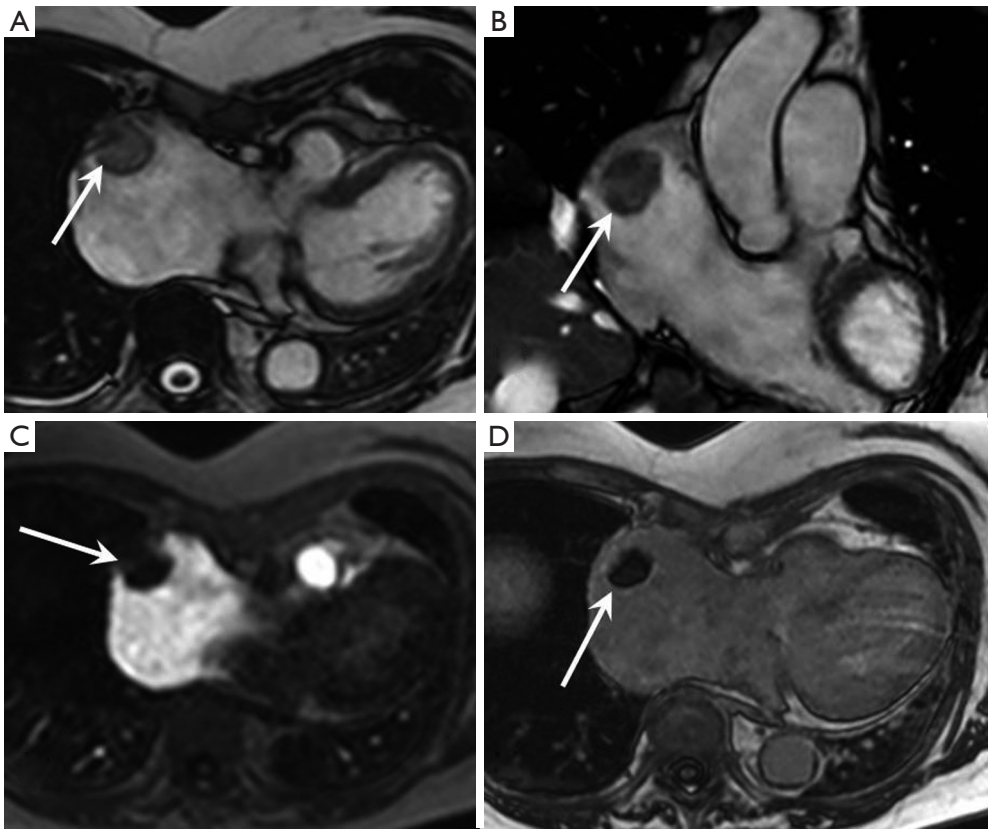

Figure 6 Right atrial thrombus in a patient with severe pectus excavatum deformity. (A) Axial SSFP image showing a 3 cm well circumscribed mass within the right atrium (arrow); (B) coronal SSFP image again showing the right atrial mass with no sign of invasion into the atrial wall (arrow); (C) axial image from a resting perfusion study showing an absence of first pass contrast enhancement (arrow); (D) axial late phase inversion recovery image with an inversion time of 600 ms post gadolinium showing the mass of uniformly low signal which is a characteristic feature of thrombus (arrow).

cases of severe pectus excavatum deformity.

The signal intensity of thrombus on T1 and T2-weighted images varies depending on its chronicity due to various phases of haemoglobin degradation. For example subacute thrombi appear of high signal on T1- and low signal on T2-weighted images due to paramagnetic effects of methaemoglobin whereas organised chronic thrombi will exhibit low signal intensity on both T1- and T2 weighted images due to depleted water content (8). In general contrast enhanced sequences are thought to be more reliable for confident diagnosis. Thrombi do not enhance on dynamic perfusion sequences whereas some tumours with vascularised tissue components will. A more specific feature for thrombi is lack of inversion on LGE sequences performed with a very long inversion time (>500 ms) in comparison with other tissues which will invert (become bright) with this nulling sequence (*Figure 6*) (42). This technique has proven efficacy for distinguishing thrombi from myxomas (42).

Pericardial cyst

These lesions are benign congenital malformations of pericardium without direct communication with the pericardial space and usually located at the right cardiophrenic angle. They are simple water-based lesions without internal septae. Most are asymptomatic and diagnosed incidentally on chest X-ray and echocardiogram but some may produce symptoms such as chest pain or persistent cough (43).

MRI shows a well-defined, often triangular shaped structure, of uniformly low T1- and high T2-signal intensity without any first pass or LGE. Occasionally high T1- and high T2-signal may be present if they contain

proteinaceous material or become secondarily infected.

Bronchogenic cyst

Bronchogenic cysts occur along the differentiating pathway of the trachea and bronchial tree and are thought to represent abnormal budding of ventral foregut tissue (44). They are most often found in the mediastinum, most commonly in the subcarinal or right paratracheal regions. On MRI these lesions are usually round and well circumscribed with variable signal intensity on T1-weighted images depending upon their protein content. T2-weighted images typically show uniformly high signal intensity (45).

Normal intra cardiac structures

Normal intracardiac structures or embryological remnants can sometimes be mistaken for tumours. The crista terminalis is a vertical crest representing the line of fusion between the right atrium and right auricle and can sometimes appear prominent along the posterior wall of the right atrium. Similarly the eustachian valve, right ventricular moderator band and false left ventricle tendon are other structures that can raise suspicion but should not be mistaken for an intracardiac mass (46).

Conclusions

Despite the low incidence of cardiac tumours, prompt evaluation and intervention is crucially important for best outcomes. Although most tumours of the heart are considered histologically benign, there remain significant risks associated with these due to local effects such as interference with conduction pathways and valvular obstruction. Evaluation of a suspected cardiac mass is a frequent and expanding indication for MRI referral due to its superb contrast resolution, multiplanar imaging capabilities and advanced tissue characterization techniques. Radiologists and imaging Cardiologists should be familiar with protocol design and key MRI findings across the spectrum of both benign and malignant cardiac tumours.

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