RADIOLOGY THROUGH IMAGES

Imaging findings in cardiac masses (Part I): Study protocol and benign tumors

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Abstract Cardiac masses represent a diagnostic challenge because decisions about treatment are based on imaging techniques. Echocardiography, magnetic resonance (MR) and computed tomography (CT) are fundamental for the detection, characterization, and staging of cardiac masses as well as for planning their treatment. Most primary cardiac tumors are benign; myxomas, papillary fibroelastomas, and lipomas are the most common. The location of the tumors and its characteristics on CT and MR orient the etiologic diagnosis in most cases.

This article describes the protocols for CT and MR studies of cardiac masses as well as the morphologic findings, predominant locations, and most useful characteristics for characterizing benign cardiac masses and establishing the differential diagnosis with malignant cardiac tumors and non-neoplastic pseudotumors.

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PALABRAS CLAVE
Masas cardíacas; Mixoma; Fibroelastoma; Lipoma; Rhabdomyoma

Hallazgos de imagen de las masas cardiacas (parte I): protocolo de estudio y tumores benignos

Resumen Las masas cardiacas son un reto diagnosticó porque las decisiones terapéuticas se basan en los hallazgos de las técnicas de imagen. La ecocardiografía, la resonancia magnética (RM) y la tomografía computarizada (TC) son fundamentales para la detección, caracterización, estadificación y planificación del tratamiento. La mayoría de los tumores primarios son benignos; los más frecuentes son el mixoma, el fibroelastoma papilar y el lipoma. La localización del tumor y sus características en la TC y la RM orientan el diagnóstico etiológico en la mayor parte de los casos.


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Introduction

Primary heart tumors are uncommon (0.002–3%) and most are benign.\(^1\)\(^2\) Clinical manifestations are usually unspecific; they can simulate other cardiovascular diseases and can be potentially deadly due to their hemodynamic repercussion.

Most of them are initially detected through ultrasound, the modality of choice due to its availability and innocuousness. However, magnetic resonance imaging (MRI) and computed tomography (CT) provide additional information for diagnosis, therapeutic decision and surgical planning.\(^3\)\(^4\)

Image findings in cardiac masses are presented in two parts. In this first part, the CT and MRI study protocols are described and the findings in benign cardiac masses, and malignant tumors and pseudotumoral lesions are described in the second part.

Protocols of image acquisition

Protocol with computed tomography

General overview

The CT is the complementary image modality in the study of cardiac masses in unstable patients who do not tolerate prolonged decubitus or cannot do apneas who have rhythm disorders that prevent electrocardiographic synchronization, and in patients with claustrophobia, since it is a quick technique that can be performed without cardiac synchronization.\(^5\)

Also it is the modality of choice to detect calcifications, establish the relation between the masses and the coronary arteries and assess the primary tumor and its spread when suspicion of metastasis.\(^5\)

Occasionally, cardiac masses are an incidental finding in examinations performed due to symptoms of unspecific thoracic pathology or during the staging of malignant neoplasms in which the study protocol is that of the suspected disease.

Study acquisition

The protocol includes the acquisition of a topogram on which the examination is planned from the cervico-thoracic union up to the diaphragm which allows assessing the vascular structures, the pulmonary parenchyma and the chest cavity; it is useful for pre-surgery planning and to analyze tumor spread to adjacent structures.\(^5\) A series is acquired without intravenous (IV) contrast followed by a second series at 60 s after the IV administration of 100–120 ml of iodized contrast through an automatic injector, followed by a bolus of 40 ml of saline solution with a flow of 3–4 ml/s.

The acquisition parameters depend on the characteristics of the machine. In a 64-detector machine, adequate images are obtained in patients weighing over 80 kg, with a collimation of \(64 \times 0.625\), a rotation time of 500 ms, 300 mA and 80 or 100 kV. The studies can be performed with or without electrocardiographic synchronism.\(^5\)

Magnetic resonance protocol

General overview

MRI is a complementary modality to ultrasound in the study of cardiac masses. It is an objective, reproducible, innocuous modality, with a high temporal and contrast resolution which allows us to use wide fields of vision to analyze the heart and the remaining thoracic structures.\(^1\)\(^5\)

MRI examinations will be performed preferably in 1.5 or 3.0 T machines, with surface phase-coupled antennas and electrocardiographic synchronization.

Study acquisition

The usual study protocol consists of (Table 1):

1. Multiplanar locator with electrocardiographic synchroniztion and in respiratory apnea in order to know the position of the heart in the thorax.
2. Functional sequences, cine-MRI, of “white blood” based on gradient echo (GE) (fast imaging with steady-state precession, SSFP). They are sequences with mixed T2 and T1 weighting (T2/T1), with great differentiation in the signal intensity of the blood and the myocardium which facilitates the detection of intracavitary lesions. In addition, its high temporal resolution allows us to obtain cine-MR images with electrocardiographic synchronization in order to analyze the functional repercussions of the masses and quantify the ventricular function.
3. Morphological and tissue characterization sequences, of “black blood” based on turbo or fast spin echo (TSE), usually with double or triple inversion pulse to improve the intracavitary flow cancelation. T1- and T2-weighted sequences will be obtained and optionally, fat-suppression sequences.
4. First-step perfusion during IV administration of gadolinium chelates. Ultrafast T1-weighted sequences in GE with high temporal resolution to analyze the arrival of the contrast bolus, and assess myocardial perfusion.\(^5\)
5. Late enhancement sequences (black myocardium). T1-weighted sequences with a 180° inversion pulse applied in a given time (inversion time) to cancel the signal of the healthy myocardium. They can be turbo or fast gradient echo (TGE) or phase-sensitive inversion-recovery (PSIR) sequences.

The inversion time to cancel the myocardium ranges from 150 to 300 ms. However, a 500–550 ms inversion time in 1.5 T machines and 850–900 ms in 3 T machines is useful to differentiate tumor thrombi.⁶

The late enhancement sequences allow us to outline the tumor more clearly and they are essential to detect and characterize the thrombi.⁷

Planes/views of acquisition
Cine-MR images are usually obtained on the transversal plane toward the thorax and on intrinsic cardiac planes on the long horizontal axis (three cameras), the long vertical axis (two cameras), four cameras and short axis.

TSE-T1 and TSE-T2 sequences (with or without fat suppression) and the first-step perfusion sequences will be obtained on the plane from which the lesion is better observed.

**Table 1** Magnetic resonance (MR) protocol for the study of cardiac masses.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Acquisition</th>
<th>Views</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localizer</td>
<td>Multiplane</td>
<td>Transversal</td>
<td>In mild breathing apnea</td>
</tr>
<tr>
<td></td>
<td>Multicut-multiphase</td>
<td>Coronal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sagittal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transversal</td>
<td>In mild breathing apnea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 chambers</td>
<td>In mild breathing apnea</td>
</tr>
<tr>
<td>Cine-RM SSFP</td>
<td></td>
<td>2 chambers</td>
<td>In mild breathing apnea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 chambers</td>
<td>In mild breathing apnea</td>
</tr>
<tr>
<td>TSE-T1</td>
<td>2D multicut</td>
<td>Depending on the location</td>
<td>Optional, suppression of fat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of the mass</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transversal or 4 chambers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>or short axis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TSE-T2</td>
<td>In mild breathing apnea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depending on the location</td>
<td>Optional, suppression</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of the mass</td>
<td>of fat,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transversal or 4 chambers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>or short axis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>First-step perfusion</td>
<td>Gadolinium contrast. Dose:</td>
</tr>
<tr>
<td></td>
<td>2D or 3D multicut</td>
<td>Depending on the location</td>
<td>0.05–0.1 mmol/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of the mass</td>
<td>Flow of 3–7 ml/s. Saline solution (30 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 chambers or short axis</td>
<td>in adults and twice as much contrast</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>volume in children)</td>
</tr>
<tr>
<td>Delayed enhancement</td>
<td>TEG-T1 with 3 chambers</td>
<td>Gadolinium contrast. Dose:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>or 2D or 3D multicut PSIR</td>
<td>2 chambers</td>
<td>0.1–0.2 mmol/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 chambers</td>
<td>Delay time: 10 min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short axis</td>
<td>Inversion time: 150–300 ms.</td>
</tr>
</tbody>
</table>

PSIR: phase sensitive inversion-recovery.

**Benign tumors**

Primary tumors of the heart are usually benign. They can have an intracavitary location and be attached to the endocardium or the myocardium through a broad implantation base or a pedicle, or they can be intra-myocardial. The myxoma, the papillary fibroelastoma and the lipoma are the most frequent ones.

**Myxoma**

The myxoma is the most frequent primary heart tumor (25–50%).¹ The vast majority are sporadic and they affect women of between 40 and 70 years of age. They are usually asymptomatic or they occur with heart failure, embolism, syncope or sudden death, mainly when they prolapse through the mitral valve; 7% is part of the Carney complex-autosomal dominant syndrome characterized by myxoma, hyperpigmentation and extracardiac tumors.⁹

They are more frequent in the left atrium (LA) (75%), they are usually attached by a pedicle to the interatrial septum, close to the fossa ovalis, and they can prolapse through the atrial-ventricular valves (Fig. 1). Other locations are the right atrium (RA) (Fig. 2), the right ventricle (RV), the left ventricle (LV), the aortic valve and the inferior vena cava.¹

Myxomas kick in as intracavitary oval, heterogeneous masses of variable sizes (1–15 cm), due to the presence

*It must be remembered that MRI is a complementary modality to ultrasound in the study of cardiac masses.*
We need to remember that myxomas are the most common heart tumors, they are usually located in the LA and they are attached to the interatrial septum by a pedicle. Its MRI signal is variable and its enhancement is heterogeneous.

The papillary fibroelastoma

Papillary fibroelastomas account for 10% of primary heart tumors.\textsuperscript{14,15} They are often asymptomatic and do not usually cause valvular dysfunction\textsuperscript{14,16}; 90% of them are located on the endocardial surface of the aortic (29%) or mitral (25%) valves.\textsuperscript{9}

They are small (<1 cm), well-outlined lesions, showing soft-tissue attenuation in the CT and hypointense or intermediate signals in the T1-weighted sequences, intermediate signals in T2-weighted sequences and hypointense in cine-MR SSFP sequences. They are not usually enhanced after the administration of contrast (Fig. 5).\textsuperscript{14,16}

Differential diagnosis is established with the endocarditis warts that are usually associated with valvular destruction and insufficiency and intracavitary thrombi.

Lipoma

Lipomas (8% of the heart tumors)\textsuperscript{17} are more frequent in obese adults but they can be detected at any age. They are generally solitary, although multiple cases have been described associated to tuberous sclerosis and congenital heart conditions.\textsuperscript{18} They do not cause symptoms or show rhythm disorders or with clinical manifestations of hemodynamic affection due to obstruction or compression of adjacent structures.

The most frequent location is endocardivary in the RA and the LV; other locations are the cardiac valves, intramyocardial (25%) and pericardial (25%).\textsuperscript{17,19}

In the CT and the MRI, endocardivary lipomas occur as small sessile homogeneous masses attached to the
interatrial septum or the atrial roof; and the intramyocardial ones, as oval well-outlined, homogeneous masses. In CT without contrast, they are of low attenuation (−50 UH) and they do not enhance after the administration of contrast. In the MRI, they are hyperintense in T1-TSE weighted sequences and hypointense in specific fat suppression sequences, and they usually show one hypointense capsule (Fig. 6).

Differential diagnosis in children must be performed with teratoma and in adults with lipomatous hypertrophy of the interatrial septum and with liposarcoma. Unlike intracavitary lipomas, lipomatous hypertrophy infiltrates the interatrial septum and respects the fossa ovalis in a peculiar way. Liposarcoma is a lipomatous tumor with attenuation and intensity of heterogeneous signal that is enhanced after the administration of contrast and capable of infiltrating adjacent structures.

Surgical resection will depend on its size, location and functional repercussion; CT is essential to establish the relation between the lipoma and the coronary arteries as well as to plan surgery.

We need to remember that attenuation in the CT and signal characteristics in the MRI of lipomas are enough to establish diagnosis.

Rhabdomyoma

Rhabdomyoma is the most frequent heart tumor in children. They are often diagnosed in the neonatal period, in isolation or associated with tuberous sclerosis and most relapse spontaneously. They are usually asymptomatic, but they can cause obstruction of the ventricular outflow tract or arrhythmias.

Rhabdomyomas are usually multiple (90%) and intramyocardial. They are isointense in the MRI in T1-weighted sequences and slightly hyperintense in T2-weighted sequences. With IV contrast, enhancement is minimal or absent (Fig. 7).

We need to remember that rhabdomyomas are the most common tumors in children; they are often multiple and intramyocardial and most relapse spontaneously.

Fibroma

The fibroma is the second most frequent benign heart tumor in children. It can be asymptomatic or occur with...
arrhythmia or sudden death. There is increased prevalence in the Gorlin and Gardner syndromes.\textsuperscript{9,18}

Fibromas are usually single, well-outlined tumors, often located in the interventricular septum and the lateral wall of the LV (Fig. 8).\textsuperscript{18} They show heterogeneous, hypointense or hyperintense signals in T1- and T2-weighted sequences. In first-step perfusion they show hypointense and hyperintense signals in late enhancement sequences, occasionally with central hypointensity. Calcifications are frequent (25\%) and easier to detect in CT studies without contrast.\textsuperscript{9,18}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image1.png}
\caption{Papillary fibroelastoma. (A) The TC with IV contrast identifies one small node of soft tissue attenuation (arrow heads) attached to the atrial surface of the tricuspid valve. (B) In the cine-MR images the node shows a hypointense signal (arrow).}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image2.png}
\caption{Lipoma in a 67-year-old woman with incidental finding of one mass in an ultrasound. The T1-TSE-weighted sequences in the transversal (A) and sagittal (B) views show one intracavitary mass (arrows) originating in the posterior wall of the left atrium of homogeneous and hyperintense signal. In the T1-TSE-weighted sequences with selective suppression of fat (C) the mass is hypointense (arrow head).}
\end{figure}
Figure 7  Rhabdomyoma in a newly born female baby with arrhythmia. The transversal TSE-T1 (A) and TSE-T1 (B) images show one large mass in the right ventricle (asterisk) of hyperintense, heterogeneous signal. The mass is similar to the myocardium (arrows) in the cine-MR SSFP sequences (C).

Figure 8  Fibroma in an asymptomatic 8-year-old girl. Cine-MR in the short axis view (A) and T2-STIR sequences (B). Myocardial mass in the anterior part of the interventricular septum—homogeneous and isointense (arrow) in the cine-MR sequence and hyperintense and heterogeneous (arrow heads) in T2-STIR sequences.
Table 2  More characteristic findings of benign cardiac tumors.

<table>
<thead>
<tr>
<th>Tumor</th>
<th>Localization</th>
<th>CT attenuation</th>
<th>T1 SI</th>
<th>T2 SI</th>
<th>Enhancement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myxoma</td>
<td>LA</td>
<td>Heterogeneous (necrosis, calcifications, bleeding)</td>
<td>Similar to myocardium</td>
<td>Hyperintense</td>
<td>Minimal Heterogeneous</td>
</tr>
<tr>
<td>Lipoma</td>
<td>RA, LV</td>
<td>Fat</td>
<td>Hyperintense</td>
<td>Hypointense</td>
<td>Hyperintense with selective suppression of fat</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hypointense</td>
<td>Hypointense</td>
<td>Absent</td>
</tr>
<tr>
<td>Fibroelastoma</td>
<td>Aortic valve, Mitral valve Pedicle</td>
<td>Similar to myocardium</td>
<td>Similar to myocardium</td>
<td>Hypointense</td>
<td>Absent</td>
</tr>
<tr>
<td>Rhabdomyoma</td>
<td>Myocardium</td>
<td>Similar to myocardium</td>
<td>Similar to myocardium</td>
<td>Hypointense</td>
<td>Minimal Heterogeneous</td>
</tr>
<tr>
<td>Fibroma</td>
<td>Intraventricular septum, LV</td>
<td>Similar to myocardium (25%) Calcifications, central necrosis</td>
<td>Heterogeneous</td>
<td>Hypointense</td>
<td>Hyperintense</td>
</tr>
<tr>
<td>Paraganglioma</td>
<td>Pericardium</td>
<td>Heterogeneous Central necrosis</td>
<td>Similar to myocardium</td>
<td>Hypointense</td>
<td>Hyperintense periferal</td>
</tr>
</tbody>
</table>

RA: right atrium; LA: left atrium; SI: signal intensity; CT: computed tomography; LV: left ventricle.

Paraganglioma

Paragangliomas are uncommon neuroendocrine neoplasms more common between 10 and 60 years of age. Its usual location is the pericardium. They can be isolated or associated with paragangliomas in other locations (20%) or with bone metastasis (5%).

In the CT, they appear as heterogeneous masses with central necrosis and intense enhancement of peripheral predominance. They rarely calcify. In the MRI, they are usually iso-/hypointense in T1-weighted sequences and hyperintense in T2-weighted sequences. Occasionally, they are hyperintense in T1 due to intratumor bleeding. With IV contrast they usually show intense enhancement of peripheral predominance.

Conclusion

The location of being heart tumors guides the etiologic diagnosis in most cases. The densiometric characteristics of the CT and signal characteristics of the MRI help us establish the diagnosis and distinguish them from malignant neoplasms and pseudo-tumors (Table 2).

Ethical responsibilities

Protection of people and animals. The authors declare that no experiments with human beings or animals have been performed while conducting this investigation.

Data confidentiality. The authors declare that in this article there are no data from patients.

Right to privacy and informed consent. The authors declare that in this article there are no data from patients.

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5. Data analysis and interpretation: CMD, ERG, RSF.
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7. Reference search: CDA, ARS, RSF.
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9. Critical review of the manuscript with intellectually relevant remarks: CMD, ERG, RSF, MMD.
10. Approval of final version: CDA, ARS, CMD, ERG, RSF, MMD.

Conflict of interests

The authors declare no conflict of interests.

References


