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Differentiation of Tumor from Viable Myocardium using Cardiac Tagging with MR Imaging

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Abstract

We report the application of myocardial tagging by MR to define tissue planes and differentiate contractile from noncontractile tissue in a neonate with congenital cardiac rhabdomyoma. Using custom-written pulse programming software, six 2 mm thick radiofrequency (RF) slice-selective presaturation pulses (tags) were used to label the chest wall and myocardium in a star pattern in diastole, ~60 ms before the R-wave gating trigger. This method successfully delineated the myocardium from noncontractile tumor, providing information that influenced clinical management. This RF tagging technique allowed us to confirm the exact intramyocardial location of a congenital cardiac tumor.

Keywords

Magnetic resonance imaging; techniques—Heart; neoplasms—Heart; ventricles

In the evaluation of neonatal thoracic tumors, precise localization of the tumor and differentiation from viable myocardium are critical in planning surgical treatment. We previously reported the use of myocardial tagging (1) using slice-selective radio-frequency (RF) presaturation followed by MR imaging in the orthogonal plane to evaluate regional left-ventricular (LV) function. In this article we report the application of myocardial tagging by MR to define tissue planes and to differentiate contractile from noncontractile tissue in a patient with presumed congenital cardiac rhabdomyoma.

CASE REPORT

A 3-day-old infant was referred for MR evaluation of a thoracic mass detected first on fetal ultrasound and confirmed later by postnatal echocardiography. Following an uncomplicated vaginal delivery, the patient demonstrated persistent mild respiratory distress with tachypnea, tachycardia, hypoxemia, and hypercapnia. Physical examination showed a well-developed newborn girl with no evident external anomalies. Subcostal retractions and nasal flaring were noted and, on auscultation, a systolic ejection murmur was heard. There was no evidence of congestive heart failure.

Chest roentgenography showed a very large cardiac silhouette with compression of the left lung (Fig. 1). Electrocardiography (ECG) showed greatly increased LV forces with marked

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abnormalities of the ST segments and T waves. Two-dimensional echocardiography revealed a large left chest mass contiguous to the LV free wall. A smaller lesion in the subaortic region did not appear to be causing significant obstruction. Because the origins of the larger mass could not be clearly defined, uncertainty remained as to whether the mass was intramyocardial or pericardial. A CT study defined severe compression of the left lung but failed to clearly delineate the origins of the mass. In view of the patient's persistent respiratory compromise secondary to lung compression, surgery to debulk the mass was contemplated. The patient was referred for MR to define a possible plane of dissection of the tumor.

The patient was imaged in a 17 cm diameter extremity coil in a GE 1.5 T whole body scanner. The T1-weighted ECG-gated spin-echo images revealed a large intramyocardial tumor involving the LV apex, interventricular septum, and portions of the LV free wall. To assess myocardial function, gradient-echo cinegraphic acquisitions were obtained in the axial plane through the ventricles and tumor (TR 110 ms, TE 16 ms, 16 phases during the cardiac cycle, 128×256 matrix, 2 averages, 2 min with first-order gradient moment nulling). These images demonstrated marked reduction in left ventricular chamber size and global contractility.

To differentiate the tumor from the myocardium, a routine cardiorespiratory-gated T1-weighted multiphasic spin-echo acquisition was obtained at five phases in systole (24, 61, 98, 135, and 172 ms after the QRS) at five coronal locations. The multiphasic acquisition required only 9 min (128×256 matrix, 2 averages) because of the patient's tachycardia.

The T2-weighted images differentiated the thymus from the heart. However, the myocardial mass had the signal intensity of muscle on both T1- and T2-weighted images and was indistinguishable from the myocardium on the spin-echo and gradient-echo images.

Using custom written pulse programming software, six 2-mm thick RF slice-selective presaturation pulses (tags) were used to label the chest wall and myocardium in a star pattern in diastole ~ 60 ms before the R-wave gating trigger. The RF pulses produced planes, but, because the imaging plane was orthogonal to them, the tags appeared as a number of lines that could be individually oriented within the image. Multiphasic T1-weighted cardiac-gated spin-echo images were then acquired at five time points in systole (24, 61, 98, 135, and 172 ms after the R-wave trigger) and at five coronal locations corresponding to the patient's 4-chamber axis. The multiphasic acquisition required only 9 min. The RF tags on the stationary chest wall remained stationary; however, the twisting motion of the myocardium relative to the chest wall became visible due to the displacement of the tags (Figs. 2 and 3). The motion of the tags allowed us to differentiate the contractile part of the myocardium (open arrows) from the noncontractile tumor (white arrows). The motion of the tumor with the myocardium confirmed the intramyocardial origin of the mass. Because no plane of cleavage was defined, and the mass appeared entirely intramyocardial, surgical debulking was not considered feasible. The patient was observed and remained stable with supplemental oxygen therapy. She was discharged and on follow-up visits has been noted to have normal growth and development. Chest roentgenography and echocardiography have revealed some regression in the size of the primary mass with complete disappearance of the mass in the LV outflow tract.

DISCUSSION

Primary cardiac tumors in infants are uncommon, having an incidence in autopsy series of 3 in 10,000 (2). Rhabdomyomas, which are multiple in 90% of cases, are the most common type at this age. Of patients with rhabdomyomas 30-50% will eventually manifest tuberous sclerosis (3). Since spontaneous regression of this tumor has been well documented, surgery is indicated only for palliative partial resection to relieve life-threatening outflow obstruction or lung compression (4,5).

Echocardiography, cine CT, and angiography have all been used to evaluate intracardiac tumors. However, echocardiography may not allow us to sufficiently evaluate surrounding mediastinal structures, such as the compressed lung seen in this case, and CT and angiography both subject a patient to the risks of contrast medium injection and radiation in repeat studies. Recent literature indicates that MR may in some instances be superior to two-dimensional echocardiography in evaluating the size and relationship of the cardiac tumor and extension to great vessels (6). The addition of MR cine and multiphasic gated spin-echo acquisition techniques allows global evaluation.

The use of MR in the anatomical assessment of intramyocardial and intracavitary cardiac tumors is also well documented. Lund et al. reported that in 53 of 61 patients with cardiac masses, most of whom had previous two-dimensional echocardiography, MR provided additional information that influenced clinical management (7). Our case report documents for the first time the application of the method of tagging by MR in the evaluation of cardiac masses. Our use of custom software allowed generation of precise and thin RF tags for superior anatomical planar definition (1). The total RF deposition with these tags was substantially below the FDA recommended limit of 2 W/kg. The normal T1 relaxation of myocardial tissue results in the RF tags fading with time. However, at 1.5 T, myocardial T1 (~400 ms) is sufficiently long, and tags can be seen throughout systole and early diastole (~400 ms). It is possible to image in any oblique plane, including the echocardiographic equivalents of the short-axis, 4-chamber, and long-axis views. It is also possible to arbitrarily orient RF tags in other angles to evaluate optimally a particular tissue interface.

Observation of the relative motions of the myocardium and the tumor, as demonstrated by RF tagging, represents an important adjunct to MR evaluation of cardiac tumors. If the relative motions show a displacement between the tumor and the myocardium, a plane of dissection may be demonstrated that renders the tumor potentially operable. An advantage of MR over ultrasound is its ability to look simultaneously at the airway, the aortic arch, and other mediastinal structures. Magnetic resonance demonstrated that our patient's respiratory distress was due to marked compression of the left lung by the congenital tumor and not by obstruction of the airway or main stem bronchus. In the evaluation of intramyocardial or intracavitary tumors, multiphasic acquisitions may also be important in demonstrating dynamic narrowing of the ventricular outflow tracts during systole. In addition, tethering of tumor tissue and normal myocardium can be uniquely demonstrated by this technique.

This report documents the first clinical application of an MR RF tagging technique to confirm the exact intramyocardial location of a congenital cardiac tumor. The application of myocardial tagging has provided regional function quantification and tissue plane definition (1) that may be of use not only in the evaluation of possible neoplasms but also in the functional evaluation of other cardiac pathologies.

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FIG 1.
Chest X-ray film shows enlarged cardiothymic silhouette with compression of left lung and deviation of nasogastric tube.

FIG 2. End-diastolic, axial image with MR tagging (see text). Tag lines (arrows) are contiguous with chest wall.

FIG 3. End-systolic, axial image with MR tagging (see text). Tag lines in noncontractile intramyocardial tumor remain straight (large arrowheads), whereas in the normal portion of the LV, myocardial contraction is demonstrated by tag distortion (small arrowheads). Myocardial/pericardial boundary is demonstrated by tag line separation with twisting motion of the heart (arrow).