Safety of MR Imaging in Patients Who Have Retained Metallic Materials After Cardiac Surgery

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OBJECTIVE. Epicardial pacing wires retained in patients who undergo cardiac surgery are thought to be a relative contraindication to MR imaging. However, to our knowledge no published evidence supports this belief. Because other metallic materials retained after cardiac surgery might represent a hazard to patients who undergo MR imaging, we sought to determine the safety of such imaging.

SUBJECTS AND METHODS. We examined 200 patients who underwent MR imaging at 1 or 1.5 T after cardiac surgery. Eighty-one were examined with ECG monitoring. The presence of temporary epicardial pacing wires, prosthetic valves, and other metal materials was confirmed by chest radiography.

RESULTS. Of the 200 patients reviewed, all had postoperative metallic material visible on chest radiographs. Temporary epicardial pacing wire, cut short at the skin, was seen in 51 patients. Of the 81 patients examined with ECG monitoring, we found that MR imaging produced no changes from baseline ECG rhythms. None of the 200 patients reported symptoms suggesting arrhythmia or other cardiac dysfunction during MR imaging.

CONCLUSION. MR imaging can be performed safely in patients who have undergone cardiac surgery and have retained metallic material, including valve replacements and temporary epicardial pacing wires cut short at the skin. MR imaging of patients with pacemakers was not evaluated, and we recommend that pacemakers remain a contraindication to MR imaging.

Performing MR imaging examinations in patients after cardiac surgery, particularly in those patients with retained segments of temporary epicardial pacing wire, has been said to be relatively contraindicated [1]. To our knowledge, no published clinical data support this position, and at some MR imaging centers the presence of temporary epicardial pacing wire is not regarded as a contraindication to MR imaging. At other MR imaging centers the presence of epicardial pacing wire is regarded as a strong contraindication to MR imaging.

Temporary epicardial pacing wires are routinely placed during cardiac surgery. Usually made of braided stainless steel, these are sutured to the epicardial surface of the heart over the right ventricle and right atrium. The wires are looped on the skin and can be connected to an external pacemaker should the patient develop heart block or bradycardia. The wires are either pulled out or, if this option is not possible, cut short at the skin just before the patient is discharged (usually 5–8 days after surgery). At least a theoretic risk exists that these wires might carry an induced current, which may cause arrhythmias, although the magnitude of experimentally derived induced currents (up to 80 μA at 1.5 T) seems unlikely to pose a realistic risk [2].

At some centers the safety of MR imaging in patients with prosthetic cardiac valves, metal sternal sutures, and mediastinal clips is still of concern, although MR imaging in the presence of these is generally thought to be safe [3]. Potential hazards from these objects include displacement by the static magnetic field and heating effects from gradient switching. Also of concern is the safety of imaging patients with cardiac failure. We reviewed our experience with the safety of MR imaging in patients after cardiac surgery, including patients with cardiac failure.

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Subjects and Methods

Contemporary chest radiographs acquired within 7 days of MR imaging and reflecting surgical status at the time of MR imaging were available for all patients examined. Patients without a contemporary chest radiograph or radiopaque material visible on the chest radiograph were excluded. All patients were examined at 1 or 1.5 T (Magnetom SP45, Impact, or Vision; Siemens Medical Systems, Iselin, NJ) with the following gradient parameters: Magnetom SP45 at 1 T, maximum gradient strength = 10 mT/m and maximum slew rate = 10 mT/m per millisecond; Impact at 1 T, maximum gradient strength = 15 mT/m and maximum slew rate = 20 mT/m per millisecond; Vision at 1.5 T, maximum gradient strength = 25 mT/m and maximum slew rate = 40 mT/m per millisecond.

For most of the sequences, with slice thickness and field of view appropriate for cardiac imaging, the gradients were used at 70–80% of maximum. The perfusion sequence described runs at the gradient limits.

All dedicated cardiac studies were supervised by a staff cardiologist or a fellow trained in cardiovascular imaging. Cardiac studies were performed with continuous ECG monitoring and routinely included ECG-gated spin-echo and gradient-echo sequences. For ECG-gated spin-echo MR imaging, typical imaging parameters included TR/TE, R-R interval/25; matrix size, 160–192 × 256; signals acquired, three; section thickness, 6 mm; and typical acquisition time, 4–5 min depending on R-R interval. For ECG-gated cine MR angiography, typical imaging parameters included 26 or 30/10; flip angle, 30°; matrix size, 160 × 256; signals acquired, two; section thickness, 5 mm; and typical acquisition time, 4–5 min depending on R-R interval. For ECG-gated segmented K-space breath-hold MR angiography, imaging parameters included 20/10; 16 lines of K-space acquired during each R-R interval; acquisition window, 300 msec, flip angle, 40°; matrix size, 128 × 256; signals acquired, one; section thickness, 4 or 5 mm; and typical acquisition time, 15–20 sec depending on R-R interval. For perfusion ECG-gated turbo fast low-angle shot MR imaging, imaging parameters included 12/6; inversion time, 100 or 400 msec; flip angle, 12°; matrix size, 64 × 256; signals acquired, one; section thickness, 10 mm; and typical acquisition time, up to 60 sec depending on R-R interval (20–30 images; one image every other cardiac cycle).

Noncardiac studies included at least three imaging sequences in addition to scout imaging. The total imaging time (i.e., time when sequences were actively being acquired) exceeded 10 min in all cases. After safe early experience with monitored postoperative patients, noncardiac studies were performed without ECG monitoring.

Contemporary chest radiographs (reflecting cardiac surgical status at the time of MR imaging) were reviewed to determine the presence of prosthetic valves, segments of epicardial pacing wires, sternal sutures, and mediastinal surgical clips. Patients with permanent pacemakers and implantable cardioverter-defibrillators were excluded from scanning [1, 4]. Any available chest radiographs acquired within 3 days of MR imaging and cardiac MR imaging were also reviewed for evidence of cardiac failure.

Results

We examined 200 patients who had undergone cardiac surgery and had residual postoperative material visible on a contemporary chest radiograph. All 200 had MR imaging examinations, 81 had ECG-monitored examinations, 52 had coronary bypass surgery only, and 25 had valve replacement (with or without coronary bypass surgery). Fifty-one patients had temporary epicardial pacing wires, 187 had sternal wires, and 178 had mediastinal surgical clips. Fifty-four patients had cardiomegaly, 36 had pleural effusions, 36 had cardiac failure revealed by chest radiography, and six had collapse of the left lower lobe.

For the ECG-monitored patients, cardiac surgery was usually coronary artery bypass grafting alone (52 patients) or valve replacement with or without coronary artery bypass grafting (25 patients). In the 81 patients having cardiac or aortic MR imaging, continuous ECG rhythm monitoring during entry into the magnet, on initiating pulse sequences, and throughout the MR imaging examination showed no changes from the baseline cardiac rhythm in 79. Two patients were examined to elucidate the cause of recurrent but self-terminating ventricular arrhythmias that did not change in frequency from baseline. In both cases imaging was terminated because of poor image quality from gating irregularity during ventricular arrhythmias.

Temporary external pacing wires were seen on contemporary chest radiographs in 51 patients. All wires had been cut short at the skin soon after cardiac surgery. Thirty-six patients had objective features of cardiac failure on chest radiographs at the time of the MR imaging study. Images of diagnostic quality were obtained in all but two patients (the two with the ventricular arrhythmias). None of these patients experienced worsening of symptoms during MR imaging.

Although some patients reported feelings of claustrophobia, no symptoms suggesting worsening of cardiac function, arrhythmia, or other adverse events related to MR imaging were reported. Fourteen patients received dipyridamole as part of an MR imaging stress perfusion protocol, and one patient requested early cessation of the examination because angina developed after injection of the dipyridamole [5]. On reversal of the stress agent with aminophylline, the symptoms subsided, and no evidence showed that this outcome was related to the MR imaging sequences.

Signal loss because of susceptibility effects was seen with all valves and was more prominent with gradient-echo sequences. Susceptibility effects from epicardial pacing wires (Fig. 1) did not interfere with diagnostic quality, except in the assessment of the patency of coronary artery bypass grafting (in two of 15 patients, the

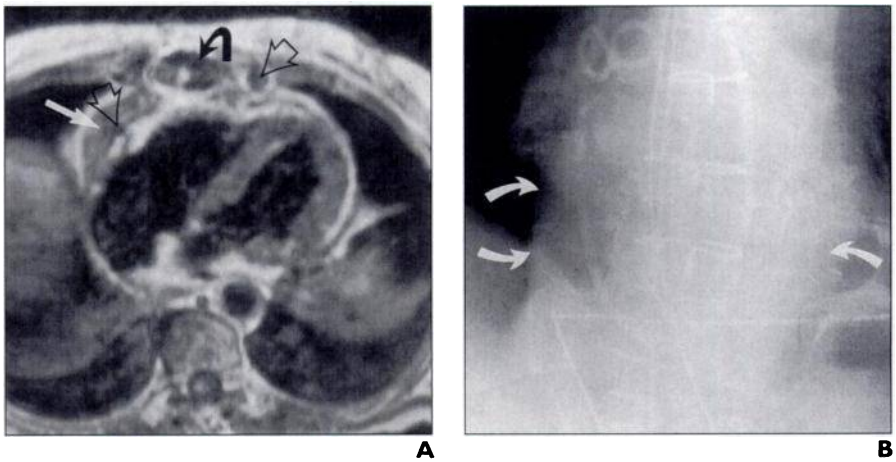

Fig. 1.—76-year old woman who had undergone coronary artery bypass grafting and in whom pericardial effusion subsequently developed.
A, Axial spin-echo MR image shows pericardial effusion (*straight arrow*) and susceptibility effects from epicardial pacing wires (*open arrows*) and sternal sutures (*curved arrow*). Susceptibility effects do not impair diagnostic quality.
B, Close-up view from portable chest radiograph taken of same patient on day before MR imaging. Epicardial wires (*arrows*) are clearly visible over surface of right atrium.

distal parts of one or more saphenous vein grafts were obscured).

Discussion

The risks of complications from MR imaging in patients with permanent pacemakers were recognized early in the development of MR imaging [4, 6]. Therefore, the presence of a pacemaker has been regarded as a strong contraindication to MR imaging [1, 3, 7]. Suggestions that, by using appropriate imaging strategies, performing MR imaging in patients with permanent pacemakers may be acceptable seem unreasonable considering the reported mortality rate of 5% in such circumstances [8]. Many have interpreted the advice about avoiding MR imaging in patients with pacemakers as including patients with temporary epicardial pacing wires.

In our experience, MR imaging of patients after cardiac surgery is safe. Retained temporary epicardial pacing wires did not increase the risk of arrhythmia or cause any other adverse effects. Induced currents may vary depending on orientation of the pacing wires relative to the magnetic field, field strength, and slew rates. The static magnetic field does not seem to have any effect on cardiac excitability or fibrillation threshold [9].

In animal studies, atrial defibrillation can be achieved by DC shocks of less than 0.5 J, but to achieve this level a voltage of more than 100 V (suggesting a DC of at least 20 mA) was required [10]. High energies are required to achieve experimental ventricular fibrillation, unless recent myocardial infarction or other major physiological abnormalities are present, in which case ventricular fibrillation may occur at 10 mA [11]. Although lower energies may be required, the currents and voltages necessary to cause other arrhythmias are higher than those (up to 80 μA at 1.5 T) likely to be generated in short lengths of temporary epicardial pacing wire [2]. Thresholds for ventricular pacing (usually >0.5 V) are also well above voltages likely to be induced in epicardial pacing wire. The results of our study provide clinical confirmation that these facts hold true even in patients with cardiac failure, postoperative electrolyte disturbances, or recent myocardial infarction.

The presence of prosthetic valves did not appear to pose a risk, confirming the findings of Randall et al. [12] and our clinical experience. No symptoms occurred to suggest any significant heating effects in sternal wires or other postoperative metal material.

Patients with cardiac failure may have difficulty staying in the magnet for prolonged periods, but obtaining diagnostic images in these patients is usually possible. The presence of epicardial pacing wires, prosthetic valves, and other inert materials left behind in patients who have undergone cardiac surgery is not a contraindication to examination with MR imaging.

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