Echocardiographic Evaluation of Intracardiac Pacing Catheters: M-Mode and Two-Dimensional Studies

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SUMMARY Thirty patients with right ventricular (RV) and 15 with coronary sinus (CS) pacing catheters were studied by M-mode echocardiography. RV catheters, detected in 23, appeared as linear echoes in the right ventricle during mitral valve recordings in 12, adjacent or superimposed on the tricuspid valve (TV) in 14, and immediately anterior to aortic root and pulmonary valve echoes in two with a redundant loop in RV outflow. In three with complete heart block, prominent systolic anterior movements of the TV occurred when atrial systole coincided with ventricular systole, probably due to catheter-induced TV "buckling" or exaggerated TV annular motion. Catheter echoes mimicked TV recordings in three, since its motion pattern was similar, although delayed and mimicked prolapsing right atrial myxomas in two because of multilayered complexes behind TV, while reverberations clutching the left ventricle simulated structural echoes present in that cavity. CS catheters, detected in 14 as linear echoes in the area of atrial septum recorded behind the TV, showed typical small humps in late diastole/early systole. Cross-sectional echocardiography with a mechanical sector scanner demonstrated RV catheters at the RV apex in five of seven patients, while CS catheters were detected near the base of the atrial septum in three of five patients. Echocardiography has the potential to localize pacing catheters which are occasionally difficult radiologically or electrocardiographically. Failure to recognize catheter echo patterns may result in errors in echocardiographic interpretation.

TRANSVENOUS INTRACARDIAC CATHETERS have been identified by both M-mode and two-dimensional echocardiographic techniques.1,4 However, no definite studies have been performed to evaluate echocardiography in the presence of transvenous pacing catheters. In this communication we define the role of echocardiography in determining the location of intracardiac pacing catheters and describe the various pitfalls associated with erroneous interpretation of echoes from intracardiac pacing catheters that mimic cardiac structures.

Materials and Methods

Routine M-mode echocardiographic exams were performed on 30 patients (28 adults and two children) with permanent transvenous pacemakers positioned at the right ventricular apex and on 15 patients (all adults) with coronary sinus pacing catheters. Pacemaker catheter positions were verified by fluoroscopy and ECG in all. M-mode tracings were obtained with a commercially available Picker echograph and a 2.25 MHz transducer. Continuous records were recorded at 125 mm/sec on 35 mm film using a slave oscilloscope and a Fairchild record camera.

Seven of the patients (six adults, one child) with right ventricular and five with coronary sinus pacing catheters were examined by two-dimensional echocardiography using a commercially available Picker mechanical sector scanner. The transducer was placed in the left parasternal region and the long axis of the left and right ventricles were scanned. Next, the transducer was placed in the region of the left ventricular apex, and directed medially where a four chambered view (right atrium, right ventricle, left atrium, left ventricle) of the heart was obtained with visualization of the right ventricular apex.

Results

Intracardiac catheters were identified as thick linear complexes of intense echoes within right heart cavities. Frequent reverberations were recorded next to the main catheter echo (fig. 1).

M-Mode Studies

Right Ventricular Catheters

Right ventricular catheters were detected in 23 of 30 patients. These appeared as thick linear echo complexes in the right ventricular cavity during recordings of the mitral valve in 12 patients (fig. 2) and were detected in two when the beam was angled off the tips of the mitral valve leaflets to record the left ventricular dimension. Thick linear echoes from the catheters were superimposed on or adjacent to the tricuspid valve in 14 patients (fig. 3). In two individuals with redundant catheter loops in the right ventricular outflow tract, they were also seen immediately anterior to the aortic root and pulmonary valve (fig. 4). Catheters were identified adjacent to the anterior right ventricle-
ular wall in 12 patients (fig. 5) or the right atrial portion of a right ventricular catheter was visualized as a thick echo complex just in front of the posterior right atrial wall deep to the tricuspid valve in 10 patients.

Catheter motion was dependent on transducer angulation, but generally exhibited anterior motion with the onset of diastole, remained flat thereafter, and then moved posteriorly with the beginning of systole (fig. 6). Its motion was similar to that of the tricuspid valve, although its velocity of movement toward and away from the transducer was slower. In two patients, catheter echoes presented as multilayered complexes behind the tricuspid valve in diastole and systole mimicking right atrial myxomas or vegetations (fig. 7). Reverberations from right heart catheters were occasionally observed in the left ventricle and simulated structural echoes in that cavity (fig. 1).

Ventricular septal motion was altered in five patients with right ventricular catheters. In these patients, a prominent posterior septal movement occurred 40–90 msec (mean 60 msec) after the pacing spike and lasted 40–50 msec, and was followed by normal septal motion. In addition, the normal ventricular septal anterior notch occurring during isovolumic relaxation appeared exaggerated. In three patients
with complete heart block, prominent systolic anterior motion of the tricuspid valve was seen. It occurred when atrial systole coincided with ventricular systole and was not present when the P wave occurred in diastole. Masking of intracardiac structures adjacent to the right ventricular catheters, such as the ventricular septum and anterior right ventricular wall, was noted when low-gain settings were used to reduce the intense echoes and reverberations produced by the catheters.

**Figure 3.** M-mode echo demonstrating the right ventricular pacing catheter (PC) in relation to the tricuspid valve (TV). Small variations in beam angulation result in the recording of either the right atrial or right ventricular portions of the catheter as it passes through the tricuspid valve. The right ventricular portion of the catheter is imaged anterior to the tricuspid systolic segment (top), while the right atrial portion is recorded posterior to it (bottom).

**Figure 4.** M-mode echo of the aortic root with a redundant portion of a right ventricular pacing catheter visualized in the right ventricular outflow tract. CW = chest wall; arrow points to the catheter; AV = aortic valve.
Coronary Sinus Catheters

Pacing catheters in the coronary sinus were detected in 14 patients as multilayered echo complexes in the region of the atrial septum recorded behind the tricuspid valve (fig. 8). They exhibited gradual anterior motion in systole similar to that of the atrial septum, but included additionally prominent circumscripted anterior movement which occurred just before the beginning of the QRS complex. Beam scanning revealed that the catheter echoes were at the same depth or slightly deeper than the echoes obtained from the mitral valve or posterior aortic wall (fig. 9). Frequently, the prominent echoes generated by the catheter tended to obscure the image of the atrial septum. Catheter echoes could be detected in the right atrial cavity but were never seen in the right ventricular cavity. Expansion of the left ventricular cavity produced normally by atrial systole appeared more prominent in patients with coronary sinus pacemakers.

Two-Dimensional Studies

The position of the right ventricular pacing catheters in the apical region was demonstrated in five of seven patients using a long axis scan of the right ventricle (fig. 10). A major portion of its length could also be scanned using the same procedure (fig. 11).

Coronary sinus pacing catheters could be identified...
Figure 7. M-mode echo demonstrating a right ventricular pacing catheter passing between the anterior and septal leaflets of the tricuspid valve and mimicking a right atrial myxoma or valvular vegetation. TV = tricuspid valve; C = pacing catheter; AS = atrial septum, arrow points to the septal leaflet.

near the base of the atrial septum in three of five patients (fig. 12). They were, however, not seen in the coronary sinus itself.

Discussion

Using M-mode and two-dimensional echocardiographic techniques, transvenous right heart pacing catheters can be visualized in the majority of patients with catheters at the right ventricular apex or in the coronary sinus. Two-dimensional echocardiography, with its capacity for scanning the right ventricular cavity to its apex as well as accurately determining the relationship of structures to the atrial septum, is particularly helpful in differentiating between right ventricular and coronary sinus pacing catheters. Such a technique might be particularly helpful in the occasional patient in whom the location of the pacemaker cannot be determined confidently by ECG or fluoroscopy. On the other hand, M-mode echocardiography is less useful in this area, since the right ventricular apex cannot be routinely scanned or identified, neither the length nor tip of the pacing catheter can be visualized, and the region of the atrial septum cannot be examined in detail. Failure to demonstrate pacing catheters in some patients by two-dimensional echocardiography is probably related to our small experience with this new technique.

Of particular interest to the echocardiographer is the fact that some of the echocardiographic patterns resulting from pacing catheters can mimic other intracardiac structures or abnormal cardiac pathology.

The echocardiographic motion pattern of a right ventricular pacing catheter resembles that of an atrioventricular valve, except that its velocity of motion is slower compared with the tricuspid valve or mitral valve, and probably is related to catheter inertia. The catheter echo may be mistaken for a tricuspid valve recording when the stronger echoes from the catheter mask the relatively weak ones from the normal tricuspid valve.

Multilayered catheter echoes behind the tricuspid valve in diastole and occasionally in systole may mimic those produced by a right atrial myxoma or tricuspid valve vegetation. Awareness that the patient has a pacing catheter may prevent misdiagnosis. A right ventricular catheter may form a large loop which projects into the right ventricular outflow tract and

Figure 8. M-mode echo demonstrating the characteristic motion pattern of a coronary sinus pacing catheter (PC) behind the tricuspid valve (TV).
may be detected in front of the aortic root or pulmonary valve recordings, although its tip is at the apex. Presence of a catheter echo in the right ventricular outflow tract should therefore not be construed as evidence of catheter malposition.

The space between the catheter echo and the chest wall may be mistaken for pericardial effusion when the anterior right ventricular wall is suppressed by low-gain settings. Higher gain settings will record the relatively thin echoes from the anterior right ventricular wall in front of the prominent catheter images and clarify the true nature of the findings.

Reverberations from a right ventricular catheter may be imaged in the left ventricular cavity and may erroneously indicate the presence of a catheter in that chamber. Reverberations may be present even though the catheter itself is not imaged in the right ventricular cavity. Scans to the tricuspid valve and right ventricular cavity will reveal the true origin of these spurious echoes.

The tricuspid valve may show a prominent systolic anterior movement in the presence of complete atrio-ventricular block. This occurs only when atrial systole coincides with ventricular systole and is not observed.

**Figure 9.** M-mode beam sweeping from the aortic root to the coronary sinus pacing catheter demonstrating that the pacing catheter is at the same depth as the posterior wall of the aortic root. AV = aortic valve; TV = tricuspid valve; C = catheter.

**Figure 10.** Two-dimensional echo of the tip of a right ventricular pacing catheter localized at the right ventricular apex is shown on the left. Schematic expansion of the sector image is on the right. CW = chest wall; VS = ventricular septum; TV = tricuspid valve; LV = left ventricle; RV = right ventricle; C = catheter; RA = right atrium; AS = atrial septum; F = central fibrous junction.
when the P wave falls in diastole. A small amplitude systolic anterior motion of the tricuspid valve may also be observed in patients with complete heart block who do not have pacing catheters. The abnormal motion of the tricuspid valve is probably due to altered movement of the tricuspid annulus resulting from simultaneous contractions of both atria and ventricles and augmented by the presence of a catheter in the tricuspid orifice.5
Electrical depolarization of the heart by a pacing catheter positioned in the right ventricular apex may produce a characteristically prominent brief, posterior

Figure 11. Two-dimensional echo of a portion of the length of a right ventricular pacing catheter in the right ventricular cavity in front of the ventricular septum (left). Schematic expansion of the sector image is on the right. CW = chest wall; RV = right ventricle; C = catheter; VS = ventricular septum; LV = left ventricle; TV = tricuspid valve; F = central fibrous junction; MV = mitral valve; RA = right atrium; LA = left atrium; AS = atrial septum.

Figure 12. Two-dimensional echo of a coronary sinus pacing catheter directed toward the base of the atrial septum (arrow) is shown on the left. Schematic expansion of the sector image is on the right. CW = chest wall; MV = mitral valve; VS = ventricular septum; C = catheter; RV = right ventricle; LV = left ventricle; TV = tricuspid valve; RA = right atrium; AS = atrial septum; F = central fibrous junction.
motion of the ventricular septum followed by normal septal motion with an exaggerated septal notch during isovolumic relaxation. Absence of the early posterior ventricular septal movement has been reported with improper pacemaker positioning. Patients with left bundle branch block without pacemakers may also show a similar posterior septal deflection, but it is followed by abnormal anterior septal motion during the remainder of systole. This initial ventricular septal motion abnormality has been attributed to early activation and contraction of the ventricular septum by the artificial pacemaker. Vectorcardiography has shown septal activation to be different in natural left bundle branch block when compared with left bundle branch block induced by an artificial pacemaker. The septal activation induced by the artificial pacer (with its initial superior and posterior orientation of the QRS loop) prevents the delay in left ventricular free wall activation which occurs in natural left bundle branch block and results in the paradoxical motion of the ventricular septum. A prominent early ventricular septal motion of this type, together with an exaggerated septal notch during isovolumic relaxation, has also been reported in individuals with type B or group 1 Wolff-Parkinson-White Syndrome (preexcitation of the anterior right ventricle).

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