Endocardial Electrograms from Pacemaker Catheters

By ALVIN J. GORDON, M.D., MARIA CELESTE VAGUEIRO, M.D.,
AND S. SERGE BAROLD, M.B., M.R.A.C.P.

SUMMARY
Proper placement of pacemaker catheters can be facilitated by recording endocardial electrograms from the catheters. These electrograms are also helpful in the investigation of pacemaker failure. Endocardial contact is indicated by S-T segment elevation. When bipolar catheters are used, these “contact currents” may be visible in electrograms from the tip or ring electrodes, or both.

Right ventricular cavity electrograms are characterized by their high voltage and are influenced by intraventricular conduction defects and acute myocardial infarction. Serial changes have been described indicating myocardial injury, infarction, and healing in the area underlying the catheter tip.

Additional Indexing Words:
Current of injury Myocardial injury Infarction Healing
Artificial pacemakers

The location of a catheter pacemaker within the right ventricle is critical for stable pacing. Endocardial electrocardiograms recorded from the catheter itself have been found to indicate proper contact with the endocardium and to reflect undesirable movement of the catheter tip. For proper evaluation of these tracings it is helpful to know the characteristic appearance of right ventricular endocardial electrocardiograms in paced patients, and to be familiar with changes in these electrocardiograms which may take place with the passage of time.

Methods
At the Mount Sinai Hospital, catheter pacing was first used in July 1959. A total of 308 temporary pacemaker catheters have been placed in 212 patients up to the present time: Two patients required this procedure five times, three patients four times, six patients three times, and 28 patients had it performed twice. Catheterizations were repeated because of failure of temporary or long-term pacemakers.

Endocardial electrograms were used as a criterion of catheter placement starting in September 1964. A total of approximately 150 sets of electrocardiograms were available for investigation of which 21 were chosen for intensive study. In the latter group, patients' ages varied from 10 to 93 years; sexes were about evenly divided. The catheters remained in place from a few hours to a month. Most patients suffered from complete heart block of indeterminate cause. Some cases of heart block resulted from acute myocardial infarction, one followed cardiac surgery, and a few patients exhibited slow heart rates from other causes.

Radiofrequency (RF) controlled catheter pacemakers were implanted in two patients, and the temporary catheters were left in place longer than usual for purposes of this study. The external controls on the "permanent" RF units permit discontinuance of pacing at will, and this was done at intervals to record endocardial electrograms.

Pacemaker catheters were usually inserted under image intensification fluoroscopy in the cardiac catheterization laboratory. In rare instances, when patients were too ill to be transported, the catheters were inserted at the bedside with the

From the Division of Cardiology, Department of Medicine, the Mount Sinai Hospital and the Mount Sinai School of Medicine, New York, New York.

Present addresses: Dr. Vagueiro, Santa Maria University Hospital, Lisbon, Portugal; Dr. Barold, the Mount Sinai Hospital of Greater Miami, Miami Beach, Florida.
aid of a portable image intensifier. Bipolar catheters* of size 5F and 6F were employed and passed under local anesthesia. An external jugular vein on either side was utilized when such a vein could be easily identified on the surface. If a suitable external jugular vein could not be found, the catheter was passed percutaneously through the femoral vein with the aid of a specially designed Teflon needle. Under unusual circumstances an antecubital vein was used.

Whenever possible, the catheter tip was lodged in the apex of the ventricle. When properly placed by an experienced operator, the catheter usually slides under one or more trabeculae carneae which effectively bind the catheter tip in position. On occasion (usually because the patient was critically ill) the operator was forced to accept a less-than-optimal placement of the catheter tip in the ventricle. Three criteria were employed to evaluate proper catheter placement: (1) fluoroscopic appearance, (2) low pacing threshold, and (3) satisfactory endocardial electrograms.

Endocardial electrograms were recorded on a direct writing electrocardiograph at a paper speed of 25 mm/sec. It was usually possible to “wean” the heart from the pacemaker, once pacing had been initiated, in order to record endocardial leads. “CF” leads were recorded from tip (T) and ring (R) electrodes by attachment of the chest lead to the corresponding pins on the proximal end of the catheter, or to the phone plug used to connect the catheter to the source of electric power for pacing. Bipolar (B) leads from the catheter were then registered by attachment of the tip to the right arm connection of the electrocardiograph cable, the ring to the left arm, and recording on lead I. With this technique, negativity of the tip of the catheter causes an upward deflection in the bipolar lead. The usual 12 conventional leads were then recorded with and without pacing.

Extremity leads were taken at the usual standardization (1 cm/mv); precordial leads at one-half standardization and endocardial leads (because of the high voltage usually encountered) at 3 mm/mv. Unless otherwise indicated these standards apply to all the illustrations in this paper.

Spot x-ray films were made as a record of catheter tip location; these were later repeated in many patients to identify possible movement of the catheter tip. Although gross displacement might thus be identified, it is apparent that small movement could not be recognized and one could never be certain from x-ray evidence alone that the catheter position had not changed. In a few cases the effect of different degrees of pressure of the catheter against the endocardium on the electrograms was explored. Endocardial and standard electrocardiograms were registered at various intervals after insertion of the temporary pacemaker, which was allowed to remain in place from a few days to a month (until the need for pacing had passed or until a long-term unit was installed).

**Results**

The single most characteristic feature of right ventricular endocardial electrograms was their high voltage (figs. 1 and 2). The R and S waves in a given lead occasionally added up to 17 mv and rarely measured as little as 8 mv. When the catheter was properly positioned in the apex of the right ventricle, S-T segment elevations were invariably present in the tip or ring leads—often in both. These S-T segment elevations were more marked or exclusively found in the tip electrogram, when the catheter was in optimum position as judged by fluoroscopic appearance, subsequent stability, and low pacing threshold. On the few occasions when such S-T segment changes occurred in the ring tracing alone, the catheter was in poor position, often with the tip curled upward, indicating that only the ring was in contact with the endocardium.

The bipolar lead, reflecting the difference in potential between the two electrodes, was usually of no diagnostic importance. However, in the event of a short circuit in the catheter, as pointed out by Lister and associates,4 the same endocardial electrogram would be registered from both tip and ring, but no tracing would be obtained from the bipolar lead.

The height of the S-T segment elevation was directly related to the amount of pressure of the catheter tip on the endocardium. Extreme S-T segment elevations, amounting to 8 mv (fig. 1, K.F.), were sometimes recorded. Such marked S-T segment elevations, usually associated with buckling of the catheter in the right atrium, were generally avoided because of the risk of perforation of the wall of the right ventricle. S-T segment elevations,
Endocardial electrograms from pacemaker catheters in four patients with normal intraventricular conduction ($T = CF$ lead from tip; $R = CF$ lead from ring; $B = bipolar$ lead with tip negative and ring positive. Standardization $3 \text{mm/mv}$). Note variations in S-T segment elevations.

even though marked, were never reflected in the standard leads, either paced or unpaced. Such elevation alone was no guarantee of ideal catheter placement, but the converse was true, that is, the catheter was not considered to be in good position unless S-T segment elevation was present.

The P waves could not usually be identified in the endocardial electrograms because of the low sensitivity of the recording. Other characteristics of the endocardial leads depended to some extent on the nature of the underlying electrocardiographic abnormality. In the absence of acute myocardial infarction and bundle-branch block (or its electrocardiographic equivalent), QRS intervals in the endocardial leads were of normal duration, R and S waves were usually present, often of high voltage, and U waves often could be identified (fig. 1). T waves tended to be inverted when visible.

When there was right bundle-branch block or its equivalent pattern (caused by pacing from the left ventricle) in standard leads, endocardial leads tended to exhibit taller slurred R waves, and often showed an RR' pattern (fig. 2). S waves were usually deep and T waves were inverted and coved except in the presence of marked S-T segment elevations. In left bundle-branch block there were wide slurred QS deflections with late S-T segment elevations, and some T-wave inversions. The contrast between right and left bundle-branch block is clearly evident.
in figure 2 (R.H.) where alternating bundle-branch block occurred during the recording. In the presence of acute myocardial infarction, small R waves or Q waves were often seen.

Of great interest was the finding of progressive changes in serial records. Although such records over a period of several days were available for many of the patients, in only two patients was it possible to make observations for as long as 24 days after catheter passage.

In general when S-T segment elevations were extreme, they began to regress within hours, but subsequent return to the base line did not occur until 1 to 3 weeks later. More detailed progressive changes may best be illustrated by reference to the two patients with the longest period of observation. In one patient (fig. 3, A.G.), a striking progressive lowering of the R wave occurred, reached its nadir at 3 weeks, and then began to rise. Rapid flattening of the S-T segment ensued, ending in slight S-T segment depression and progressive inversion and coving of T waves.

In the second patient (fig. 4, J.B.) with acute infarction of diaphragmatic wall and no intraventricular conduction defect, a small initial R wave progressed to a deep Q wave within about a week. The R wave then gradually returned. Marked S-T segment depression was present in the initial ring electrogram which persisted in milder form until the end of the period of observation.

The value of serial recording was demonstrated in another patient, in whom premature loss of the S-T segment elevation in the tip electrogram coincided with perforation of the wall of the ventricle.
Figure 2
Electrograms of a patient with left bundle-branch block (S.T.), of another with right bundle-branch block (E.R.), and below from R.H., tip and ring tracings. R.H. had alternating bundle-branch block (RBBB in first half and LBBB in second). These two tracings were not taken simultaneously. Note tall wide slurred R wave and deeply inverted T wave in RBBB, and deep Q wave, wide and slurred QRS interval, and shallower T waves in LBBB.

Circulation, Volume XXXVIII, July 1968
Serial endocardial electrograms of a patient with right bundle-branch block, but no acute infarct. Progressive changes of myocardial injury, infarction, and healing are apparent.
Figure 4

Serial records of a patient with acute infarction of diaphragmatic wall of ventricle. The first record dated 11/9/66 was taken with a photographic recorder with 1-mv calibration for T and R indicated on the left of T, and the calibration for B at its left. Paper speed, 50 mm/sec; time lines, 0.04 sec. The standard leads showed no intraventricular conduction delay. Except for early development of Q waves, there is little difference from figure 3.
Discussion

Recording of endocardial electrograms during pacemaker catheter insertion is a simple matter and may be repeated whenever the catheter has to be exteriorized or when the battery of totally implanted units is being changed. To avoid the hazard of electric shock, the electrocardiograph must be properly grounded and no other line-operated instrument must touch the patient at the same time.\(^{6}\) This applies not only to cardiac monitors, but equally to such common appliances as electric razors, television and radio sets, and so forth.

Failure to record satisfactory electrograms is prima facie evidence of catheter breakage. Intermittent discontinuity will be manifested by interruption of the endocardial electrograms by flexing maneuvers, which may actually localize the break if it is proximal. Threshold and impedance studies\(^{7}\) could of course be conducted concurrently.

Although endocardial electrograms from the right ventricular cavity have been described before, there has been no previous attempt, to the authors' knowledge, to study their serial evolution. Not surprisingly, progressive changes have been noted here which indicate injury, infarction, and healing of heart muscle. Anatomic evidence that such changes occur subjacent to pacemaker catheters both in experimental animals and in humans has been adduced by Parsonnet and colleagues.\(^{8}\)

Acknowledgment

The authors are indebted to the following members of the Cardiac Catheterization Team at the Mount Sinai Hospital who participated in these studies: Drs. Gabriel Jenkins, Ludwig Klein, Jerry J. Lasser, Moossa Nejat, John Pantazopoulos, and Eric Silove.

References

Endocardial Electrograms from Pacemaker Catheters
ALVIN J. GORDON, MARIA CELESTE VAGUEIRO and S. SERGE BAROLD

Circulation. 1968;38:82-89
doi: 10.1161/01.CIR.38.1.82
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1968 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/38/1/82

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/