Editors and Other Contributors

Editors

Paul A. Friedman, MD, FACC, FHRS
Consultant, Division of Cardiovascular Diseases
Mayo Clinic, Rochester, Minnesota
Professor of Medicine
College of Medicine, Mayo Clinic

Melissa A. Rott, RN
Heart Rhythm Services
Division of Cardiovascular Diseases
Mayo Clinic, Rochester, Minnesota

Anita Wokhlu, MD
Fellow in Electrophysiology, Mayo School of Graduate Medical Education
College of Medicine, Mayo Clinic, Rochester, Minnesota
Assistant Professor of Medicine, College of Medicine, Mayo Clinic

Samuel J. Asivatham, MD, FACC, FHRS
Consultant, Divisions of Cardiovascular Diseases and Pediatric Cardiology
Mayo Clinic, Rochester, Minnesota
Professor of Medicine and of Pediatrics
College of Medicine, Mayo Clinic

David L. Hayes, MD, FACC, FHRS
Consultant, Division of Cardiovascular Diseases
Mayo Clinic, Rochester, Minnesota
Professor of Medicine
College of Medicine, Mayo Clinic
Contributors

Craig S. Cameron, MD, FACC, Oklahoma Heart Institute, Tulsa, Oklahoma
Gregory A. Cogert, MD, FACC, Oklahoma Heart Institute, Tulsa, Oklahoma
Connie M. Dalzell, RN, Mayo Clinic, Rochester, Minnesota
Joseph J. Gard, MD, College of Medicine, Mayo Clinic, Rochester, Minnesota
Michael Glikson, MD, FACC, FESC, Leviev Heart Center, Sheba Medical Center, Tel Hashomer, Israel
Michael J. Hillestad, RN, Mayo Clinic, Rochester, Minnesota
Nancy Y. Lexvold, RN, Mayo Clinic, Rochester, Minnesota
Madhavan Malini, MBBS, College of Medicine, Mayo Clinic, Rochester, Minnesota
Marjorie L. Martin, RN, Mayo Clinic, Rochester, Minnesota
David A. Sandler, MD, FACC, FHRS, Oklahoma Heart Institute, Tulsa, Oklahoma
Matthew J. Swale, MBBS, College of Medicine, Mayo Clinic, Rochester, Minnesota
K. L. Venkatachalam, MD, Mayo Clinic, Jacksonville, Florida
Tracy L. Webster, RN, Mayo Clinic, Rochester, Minnesota
Case 3

An 86-year-old man has had a dual-chamber pacemaker implanted for the past 11 years due to intermittent high-grade AV block. He has a history of aortic valve replacement and amyloidosis.

Device settings:

- Mode: DDDR
- Pacing rate: 70 to 120 bpm
- Paced AV delay: 150 ms
- Sensed AV delay: 120 ms
- Rate adaptive AV: on
**Q:** What phenomenon is captured on the rhythm strip in Figure 3.1?

1. Rate response accelerates rhythm and lengthens AV delay in response to activity
2. Programming head brief loss of communication with device
3. Ventricular safety pacing
4. Mode switch in response to an atrial arrhythmia
2. Programming head brief loss of communication with device

The device is a Medtronic Preva model 7088. This generation of Medtronic pacemakers responded to programmer head application by initiation of the magnet response. In this situation, the programming head had slipped off during the interrogation and then was quickly repositioned. Thus the beginning of the rhythm strip shows AV sequential pacing at the lower rate limit of 70 bpm and rate-adaptive paced AV delay of about 150 ms (Figure 3.2). The brief loss of the atrial EGM occurs when the programming head slips off and then reappears when it is repositioned over the device. The magnet response for this Medtronic device is asynchronous AV pacing of the first 3 beats at 100 bpm with a shortened AV delay of 100 ms, then to 85 bpm with the programmed paced AV delay of 150 ms. To stop the magnet rate, there is a “Cancel Magnet” button on the programmer, which must be selected to return to the regular programmed parameters.

Each company has its own specific magnet response with usual increase in pacing rate and shortened AV delay. When reviewing trans-telephonic rhythm strips, always be aware of both nonmagnet and magnet rhythm strips to watch for the difference. A change in the expected magnet response, usually a decrease in pacing rate, is indicative of battery depletion.

Answer 1 is incorrect, for while rate response does increase the rate and that increase in rate could result in a shortened AV delay, the increase occurred in just one beat from 70 bpm immediately to 100 bpm, which is too fast for rate response to initiate. Answer 3 is incorrect, for ventricular safety pacing would not change the rate, only the AV delay, in which case would be to 80 ms and not 100 ms. In addition, the marker channel would show an additional marker for ventricular safety pacing. Answer 4 is incorrect because the mode does not actually change; the device continues in DDDR mode and there is not a sudden flurry of A sensed events to trigger the mode switch.
Figure 3.2 The first 6 events are presenting rhythm of AP-VP with rate-adaptive AV delay. The next 3 events, the rate increases to 100 bpm with shortened AV delay of 100 ms. In the last 6 events the rate decreases to 85 bpm with programmed paced AV delay of 150 ms (or 180 ms).
Case 6

A 52-year-old female undergoes dual-chamber pacemaker implantation for intermittent AV block. Right atrial and right ventricular leads are placed. Shortly after implantation the ECG shown in Figure 6.1 is obtained.
What is the most logical first step after seeing this ECG?

1. Shorten the AV interval
2. Chest x-ray
3. MRI of chest
4. Reprogram atrial sensitivity
2. Chest x-ray

The ECG demonstrates an RBBB, which usually indicates activation of the left ventricle. With a lead placed in the coronary sinus either intentionally or inadvertently, RBBB could be seen but the intention in this patient was to place the ventricular lead in the right ventricle.

RBBB could also be a result of the lead being placed across an atrial or ventricular septal defect (or patent foramen ovale) or by perforation of the right ventricle and advancement of the lead through the pericardial space to the left ventricular surface.

A chest x-ray should be obtained to definitively determine the position of the right ventricular lead. In the chest x-ray shown in Figure 6.2, the lead has a high “take-off” on the PA film, ie, it crosses to the left at the level of the atrial lead as opposed to being more inferior and crossing the tricuspid valve before being directed to the left. On the lateral film the lead is directed posteriorly, consistent with a left ventricular lead position.

When recognized acutely, the lead should be repositioned (Figure 6.3). Prior to doing so, it would be prudent to perform an ECG to determine the location and size of the defect and whether there is any significant degree of right-to-left shunting. If significant right-to-left shunting is present, the potential embolic risk of chronic transvenous pacing should be considered.

Figure 6.2  Patient’s chest x-ray after implantation.

Figure 6.3  Patient’s chest x-ray after repositioning of the ventricular lead.
Following repositioning of the right ventricular lead, the ECG and chest x-ray shown in Figure 6.4 were obtained. On the chest x-ray the "take-off" for the ventricular lead on the PA film is now considerably lower, and on the lateral film the lead is now directed anteriorly.

Other than a RBBB morphology of the paced QRS, no pacing abnormalities are noted on the original ECG. Lead change artifacts are present. Nothing would be accomplished by reprogramming any parameters, answers 1 and 4.

MRI, answer 3, was not necessary to make the diagnosis in this patient, and generally MRI is a relative contraindication unless the patient has an MRI-resistant pacing system in place.
Case 32

A 73-year-old female has a history of paroxysmal atrial flutter with variable AV block and symptomatic bradycardia. At the time she presented for consideration of pacing, an ambulatory monitor demonstrated a predominant underlying rhythm of atrial flutter with intermittent normal sinus rhythm. The patient recorded symptoms of “light-headedness” and “feeling like I could pass out,” at which times tracings demonstrated atrial flutter with ventricular response rates of 30 to 38 bpm. A pacemaker was implanted.

The patient now presents to your institution without her pacemaker identification card or any other information regarding the device or current programming. The tracing shown in Figure 32.1 was obtained in the device clinic.

Without the benefit of the programmed parameters, and by analyzing only this single tracing, you need to attempt to determine the underlying rhythm, the programmed pacing mode, and if the tracing represents normal or abnormal device function.
Q: Based on your ECG diagnosis, what is your next step?

1. Make ventricular channel more sensitive
2. Increase ventricular output
3. Lengthen ventricular blanking period
4. Do nothing
1. Make ventricular channel more sensitive

The underlying rhythm is clearly atrial fibrillation/flutter. Determining the pacing mode in this example is confusing if not assessed carefully. The first step is to identify the number of pacing artifacts and the chamber(s) being stimulated. Is there 1 pacing artifact per timing cycle stimulating either the atrium or the ventricle, or are there 2 artifacts per timing cycle, which would conventionally indicate dual-chamber pacing? Also, note the relationship between the pacing artifacts and intrinsic rhythm.

In this example, there is evidence of paced and intrinsic ventricular complexes, as well as pacing artifact, which sometimes fails to capture. In 3 of 6 cycles with pacing artifacts there is a single artifact and in the remaining 3 cycles, there are 2 artifacts. In the 3 cycles with 2 artifacts, the first of the 2 artifacts is preceded by an intrinsic ventricular complex within 80 to 240 ms, suggestive of ventricular undersensing. In addition, the second artifact always follows the first at an interval of approximately 80 ms.

The initial assessment could certainly be that this is a dual-chamber pacemaker because the 2 artifacts are temporally related. However, why would dual-chamber pacing be evident in only certain cycles, and what does the 80-ms interval between the 2 artifacts suggest? If this were a dual-chamber pacemaker, an AV interval of 80 ms at what appears to be a lower pacing rate would be very short. For ventricular safety pacing, the R to stimulus artifact interval is also typically short in order to either rescue the patient from atrial crosstalk or ensure harmless delivery during ventricular depolarization if crosstalk, in fact, is not present. However, 80 ms would be of shorter duration than the usual ventricular safety pacing interval of 100 to 120 ms, and there is no evidence of ventricular oversensing. Also, in the second instance when 2 artifacts are seen, the second artifact intermittently captures the ventricle.

In this example note that the backup pacing artifact is consistently smaller than the initial pacing artifact (Figure 32.2). In the earlier generations of this feature, the device was designed such that the initial pulse would be of unipolar configuration and the backup pulse would be of bipolar configuration, which likely accounts for this electrocardiographic appearance.

This is a VVIR pacemaker with AutoCapture. There is intermittent ventricular undersensing. Whenever the undersensing occurs and a ventricular pacing stimulus is subsequently delivered, the ventricle is refractory, resulting in functional failure to capture. The AutoCapture algorithm recognizes failure to capture when the ventricular pacing stimulus is delivered, and a high-voltage backup pulse is delivered 80 ms later. In the tracing, the second undersensed complex occurs at a longer interval following the intrinsic beat, and the backup pulse results in successful capture. In the other 2 cycles with ventricular undersensing, the backup pulse results in functional failure to capture due to proximity to the intrinsic ventricular beat and myocardial refractoriness.

Neither lengthening the ventricular blanking period, answer 3, or increasing ventricular outputs, answer 2, would correct this abnormality. If the abnormality was rarely observed, doing nothing, answer 4, might not sacrifice patient safety significantly but if a noninvasive programming change can correct a pacing abnormality, it should be utilized.
Figure 32.2 Pacemaker determination.
Case 34

The surface telemetry strip in Figure 34.1 is obtained the morning after device implantation in a patient with left ventricular dysfunction. The device is a dual-chamber Medtronic pacemaker programmed to rates of 60 to 140 bpm.
**Figure 34.1 is compatible with which of the following?**

1. Ventricular oversensing
2. An algorithm to minimize ventricular pacing
3. Dynamic AV delay
4. Safety pacing due to crosstalk
2. An algorithm to minimize ventricular pacing

This is a classic demonstration of an algorithm designed to minimize ventricular pacing. Such algorithms may be misinterpreted as device malfunction.

An annotated version of the rhythm strip is shown in Figure 34.2. Initially, the device appears to be in AAIR mode.

The first 2 complexes demonstrate atrial pacing followed by ventricular sensing at a very long AR interval of 280 ms. The device allows this long AR interval until there is failure of atrioventricular conduction, as seen in the third complex in which a dropped ventricular beat occurs. This triggers a ventricular backup pulse after the next atrial beat (fourth complex) This occurs with a short, nonphysiologic AV interval (80 ms). However, the last (fifth) complex demonstrates an atrial paced beat followed by an intrinsic QRS, after a markedly prolonged AR delay, consistent with reversion back to AAIR mode.

This is a demonstration of the Managed Ventricular Pacing (MVP) algorithm available on Medtronic devices. The algorithm is designed to promote intrinsic atrioventricular conduction and to minimize ventricular pacing. As seen here, the algorithm paces in AAIR mode with ventricular “surveillance.” Ventricular pacing with the next pacing cycle occurs only if a nonrefractory atrial event is not conducted. It is readily identified by a short, nonphysiologic AV delay. If multiple failures to ventricularly sense occur, the device switches to a dual-chamber mode such as DDDR with a more appropriately programmed AV delay for a certain period of time. Periodic checks for return of atrioventricular conduction are performed to allow the switch back to AAIR.

The principle behind algorithms to minimize ventricular pacing is concern that unnecessary right ventricular apical pacing promotes dysynchrony and can predispose to left ventricular dysfunction. Other pacing avoidance algorithms include the AAISafeR algorithm from Sorin Medical, the Search AV hysteresis function in Boston Scientific defibrillators, or autointrinsic conduction search in St. Jude devices, which prolong the AV interval.

Answer 1 is incorrect because the failure to Vpace is not due to intermittent ventricular oversensing but to AAIR mode. Answer 3 is incorrect because the marked and sudden variation in AV intervals is not in keeping with algorithms for dynamic AV delay, and there is no associated increase in heart rate, as would be expected when dynamic AV delay is activated. Answer 4 is not the best answer because although a ventricular backup pulse with a short AV delay suggests ventricular safety pacing, this tracing is not consistent with a typical dual-chamber mode. The AV delay is very long and the atrial-based timing allowing for a considerable ventricular pause is unusual.
Figure 34.2 Annotated rhythm strip.