

# Pacer Detection

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## Introduction

Monitoring ECG in patients with pacemakers presents a challenge to manufacturers of patient monitors. Misinterpreting a pacer pulse as a QRS complex can have dire consequences for the patient. Conversely, unusual circumstances or a pacer that is incorrectly set can result in repeated false alarms – which is annoying to both patients and staff and can cause the clinician to become desensitized to the monitor.

## Background

The indications to pace a patient are varied. Simply put, pacemakers are used with patients who have trouble with the natural pacemaker and/or electrical conduction cells in their heart. There are many different types of pacemakers, and they have different pulse characteristics, with different rise times and recharge characteristics. For pacemakers that can be implanted in the body, there are single-chamber pacemakers, dual-chamber pacemakers, rate-responsive pacemakers, and demand pacemakers. The variety of chambers paced, chambers sensed, and pacemaker sensing functions lead to different pulse characteristics, with different rise times and recharge characteristics. In spite of the best technology, all these factors can make it difficult to consistently differentiate pacemaker pulses from QRS complexes. Dräger Medical's pacer algorithm is exceptionally well-tuned to accommodate for the majority of pacemakers. As with all ECG applications, good skin preparation and correct electrode and lead placement will help achieve maximum results in monitoring paced patients.

## Abstract:

**Dräger Medical has developed a patented pacer detection algorithm that balances a cautious approach to avoid false positive<sup>1</sup> alarms with techniques to minimize false negative<sup>2</sup> ECG alarms. This paper discusses various aspects of pacer detection during ECG monitoring.**

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### Pacer pulses versus QRS complexes

Differentiating pacer pulses from QRS complexes is done by selective filtering, whereby each signal is classified according to its unique characteristics. The frequency band in which the heart's electrical signal typically falls is between 0.05 to 150 Hz. By contrast, the pacemaker signal frequency range is much higher, due to a much narrower pulse width of 0.2 to 2ms. Also, the amplitude of a unipolar pacer spike is usually much higher than a natural R-wave spike generated by the heart.

### Pacer pulse definition

In general the characteristics of a pacemaker pulse, which the monitor recognizes, are defined as:

Amplitude ( $a_p$ )  $\pm 2$  to  $\pm 700$  mV; Width ( $d_p$ ) 0.2 to 2.0 ms; Rise / Fall times (min.) 0.1  $d_p$ , 100 ms; Overshoot 0.025  $a_p$ ,  $a_p d_p / t_o$ ; and recharge time ( $t_o$ ) constant 4 to 100 ms.

This means the amplitude of the pulse that is measured on the body surface through the electrodes must be at least 2 mV amplitude with 0.2 ms width. However, a large number of factors play a role in the presentation of the pacemaker stimulus on the body-surface ECG. The electrode configuration of the pacing system (unipolar or bipolar), the charge generated by the pacemaker pulse (amplitude and width), the location of the anodal and cathodal electrode, pacer location, the recorded ECG lead, and lead impedance all determine the ECG presentation of the pacemaker stimulus. These factors result in a widely varied amplitude and width of the pacemaker pulse that is picked up at the body surface. More recent developments in pacemaker technology have resulted in greater use of lower pulse width (0.03ms) and lower pulse amplitudes (0.25 mV),<sup>3</sup> which fall outside the pacer detection sensitivity range. If the algorithm sensitivity of the Dräger Medical pacer detection were increased, greater artifact inaccuracies would result on

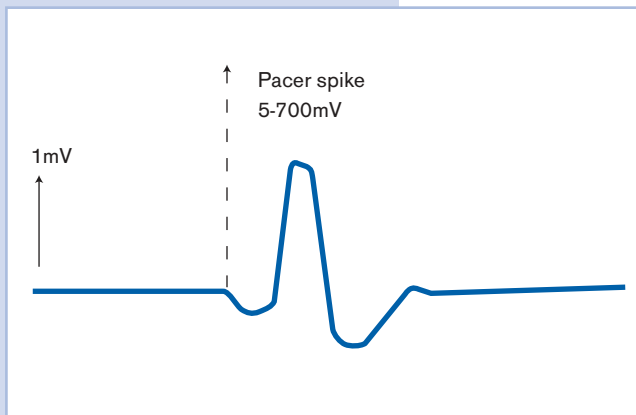


Figure 1  
Heart response to the  
pacemaker stimulus

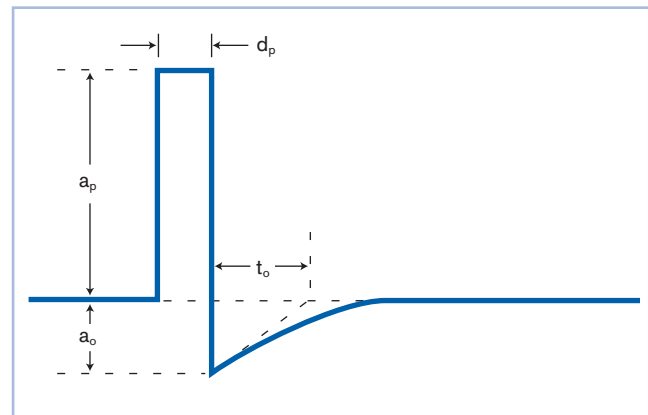


Figure 2  
Pacemaker pulse parameters

the ECG. Dräger Medical does not claim that ECG patient monitoring systems can be a substitute for adequate pacemaker diagnostics.

### Unipolar versus bipolar pacemakers

When monitoring patients with pacemakers, it is important to know whether the pacemaker is unipolar or bipolar. In a unipolar pacemaker, the distal tip of the pacing lead serves as the negative pole and the pulse generator casing is the positive pole. As a result of this wide circuit, the unipolar pacemaker signal varies between 2 to 100 mV and generates a large pacemaker artifact on the ECG. In bipolar pacemakers, both poles are in the pacing lead – resulting in a small circuit and low signal voltage. Thus, bipolar pacemakers are more difficult for physiologic monitors to detect than are unipolar pacemakers because of the lower voltage signal. The bipolar signal could be less than 2mV or even 0.2mV in amplitude with a negligible overshoot for surface ECG electrodes to sense and transmit to the monitor. Because the unipolar system requires the pulse to travel back to the pulse generator, the voltage signal is larger (varying between 2 to 100 mV) with a larger overshoot and tail. It is therefore easier to detect using body-surface ECG electrodes.

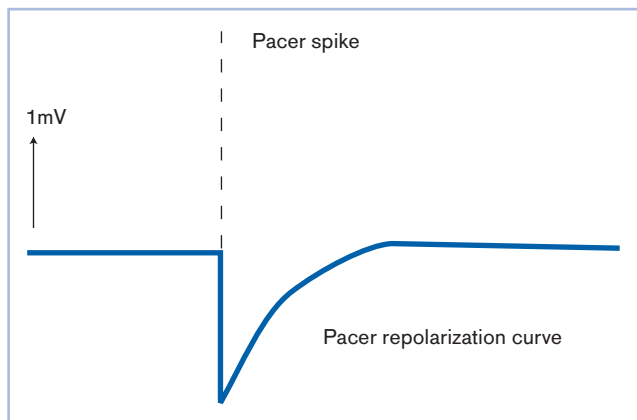


Figure 3  
Pacemaker signal

## Pacer Signal Detection

When monitoring a patient with a pacemaker, the “Pacemaker Detection” feature must be turned on to increase sensitivity of the algorithm’s pacemaker pulse detector and to reduce recording electrical artifact. The presence of pacer signals is detected by the ECG processing front-end, immediately after power line filtering. Pacer signals are blanked and therefore not shown on the monitor. However, a pacer mark is displayed on the monitor to signify when the artificial pacemaker is delivering current where the front-end detects an actual pacer spike. The pacer detection sensitivity is set to  $>1\text{mV}$  for a typical 1 ms pacer spike. This setting is carefully chosen to avoid false triggering from erroneous or spurious signals induced by 50 or 60 Hz noise from such items as heating blankets, infusion pumps, etc.

### Pacing during asystole

All pacemakers generate a repolarization curve. This repolarization curve is opposite in polarity from the original pacer spike and can fall within the same frequency band as an ECG complex.

Since most monitors detect QRS amplitudes down to  $250\text{mV}$ , the monitor must take precautions to avoid counting this pacemaker repolarization tail as a QRS signal, especially if it is large and overshoots the baseline. This is of paramount importance in patients whose ventricles are not responding to the pacer stimulus, have no cardiac output and, therefore, have no pulse. If the monitor detected the artificial pacemaker repolarization tail as a QRS complex, then clearly the consequences would be very dangerous.

To avoid this condition, in which pacer spikes are mistaken for QRS complexes, the pacer algorithm blanks the immediate repolarization signal after the pacemaker spike when Pacemaker Detection is selected. This blanking period will remove the overshoot to a minimum threshold and eliminate the detection of the overshoot as a QRS. Although a brief loss of data (40 to 80 ms) after a paced pulse is detected may not seem ideal, it is important to distinguish between electrical capture and artifact.

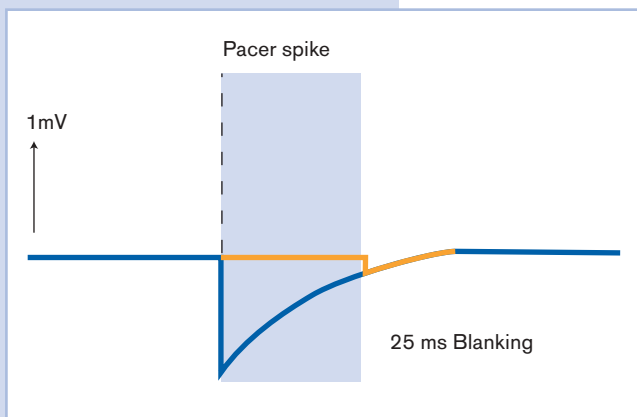


Figure 4  
Pacer non-capture protection

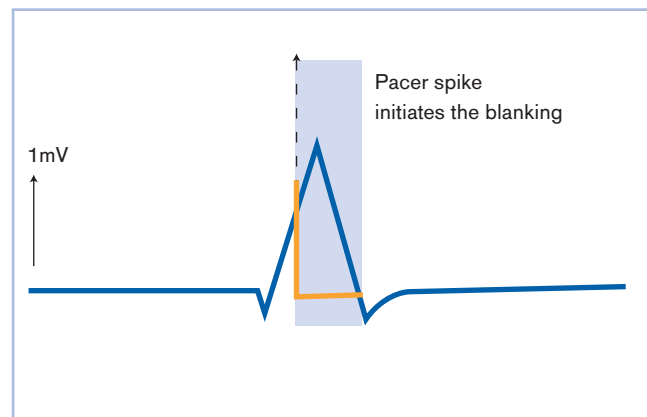


Figure 5  
Pacemaker stimulus  
superimposed on the QRS

## False low heart rate or asystole calls

During the condition of pacing during asystole, it is desirable for the monitor to alarm for a low heart rate or asystole. However, an opposite problem can occur when the ventricles contract either too quickly following the pacer spike, or at the same time as the pacer spike. This usually occurs when the artificial pacemaker sensor sensitivity setting of ventricle activity is set too low (i.e., the voltage threshold is set too high) and the pacemaker fails to recognize the initiation of a normal ventricular depolarization. This means a pacer stimulus is initiated in the middle of the QRS complex, causing the blanking period to wipe out most of the QRS signal. As a result, the QRS complex will not be counted and the monitor will detect and alarm for a low heart rate or false asystole.

What is the common strategy to deal with this issue? The Association for the advancement of Medical Instrumentation (AAMI), in conjunction with the American Heart Association (AHA), has created a monitoring specification that is very explicit in testing and verifying the performance of pacer detection and rejection capability. It is also very explicit about placing warnings in the operating manual stating that in some rare circumstances there is the possibility of counting a pacemaker spike as QRS or not counting a QRS when ventricular pacemaker sensitivity settings fail to recognize natural ventricular activity (false low HR or asystole due to blanking period). Dräger Medical's Infinity monitors have demonstrated the highest immunity against pace repolarization triggering a QRS count based on these AAMI tests. However, because of the highly variable circumstances, paced patients should always be under close surveillance.

## Minimizing false alarms

If the monitor is persistently calling false low heart rate or asystole alarms, the electrodes can be repositioned (per Figure 6) away from the standard Einthoven triangle. Positioning the electrodes away from the pacemaker conduction leads will help reduce signal distortion. This approach puts the pacemaker vector in the opposite direction to the lead II vector, thus reducing the effects of the repolarization curve. However, in this approach the ECG amplitude will be reduced. It is therefore important that lead II be selected for the top channel display and the amplitude be at least 500mV.

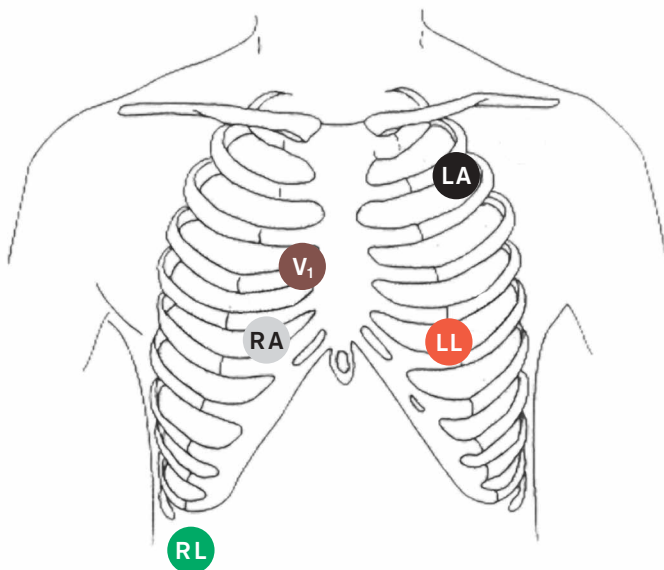
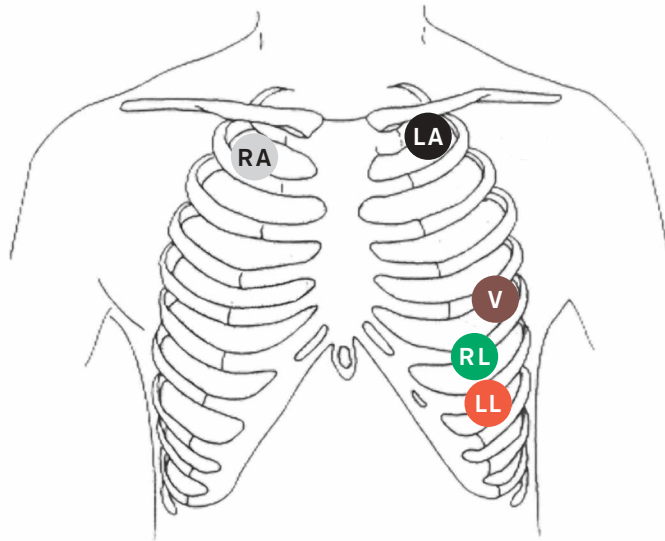
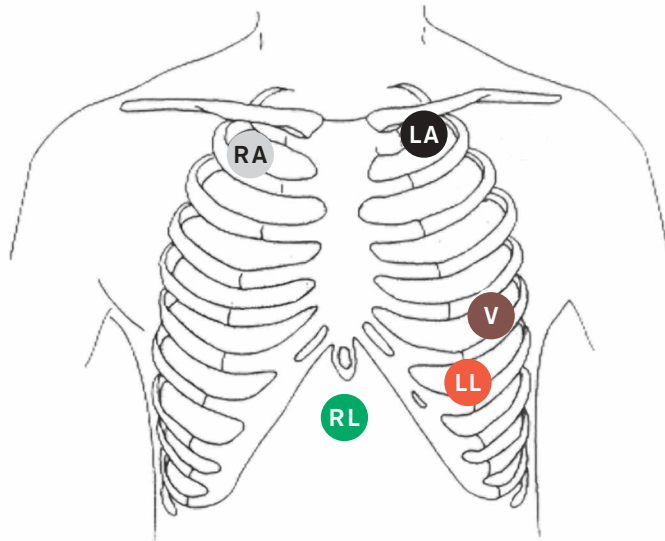
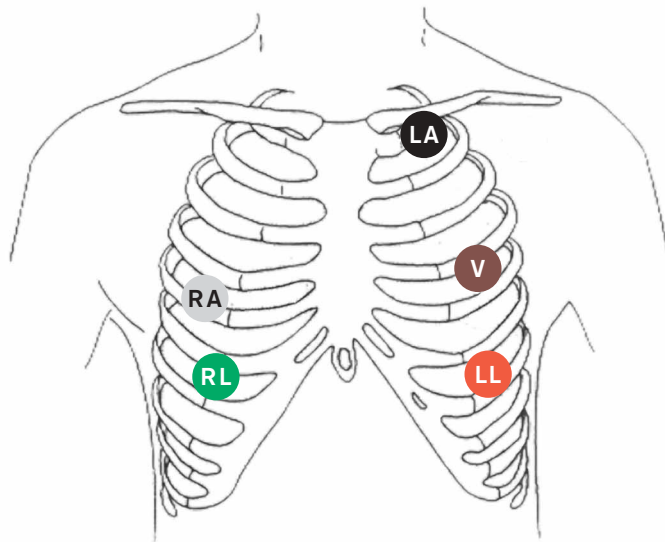


Figure 6  
ECG electrode positions for  
pacemaker patients

American Heart Association  
(AHA) recommendation for five-  
lead electrode placement in  
paced patients

Figure 7  
Alternate electrode placements  
for pacemaker patients



## Conclusion

The challenges of pacemaker detection are well known and can be a clinical issue if not managed correctly. Dräger Medical's patented pacer algorithm works with utmost attention to the detection of true asystole. Good skin preparation, appropriate electrodes, and the modified electrode placement for paced patients is highly recommended for optimum results, along with activating Pacer Detection in the ECG algorithm. In the interim, the advancement of technology is assisting us in our continued research toward developing even more sophisticated pacer detection algorithms.

## References

- 1) False positive alarm: an alarm which sounded, but a real alarm condition did not exist
- 2) False negative alarm: an alarm which did not sound, where a real alarm condition did exist
- 3) Source: Medtronic 2001

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