Rate Adaptive Pacing: Sensors and Programming Approaches
Basics of Cardiac Pacing
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Rate Adaptive Pacing

- Use of sensor or combination of sensors (besides the sinus node) to adjust the pacing rate to meet the patient’s metabolic needs

- Indicated for chronotropic incompetence
Agenda

● Definition of chronotropic incompetence
● Sensors for rate adaptive pacing
● Rate adaptive pacing parameters and programming
Chronotropic Incompetence
Cardiac Output

- Cardiac output is the volume of blood (in liters) ejected by the heart in one minute
- Stroke volume is the volume of blood (in liters) ejected by the heart in one beat
- When the body is under stress (physical, emotional), the heart tries to increase cardiac output … by increasing the rate and stroke volume according to this formula

Cardiac Output = Heart Rate x Stroke Volume
Normal Chronotropic Response

[Graph showing the normal chronotropic response with BPM on the y-axis and time on the x-axis. The graph indicates an increase in metabolic demand leading to an increase in heart rate, followed by a decrease in metabolic demand resulting in a decrease in heart rate.]
Chronotropic Incompetence

● If the patient’s heart cannot increase its rate appropriately in response to increased activity, the patient is chronotropically incompetent

● Chronotropic incompetence definitions:
  ○ Maximum heart rate < 90% x (220 - Age)
  ○ Maximum heart rate < 120 bpm

● Causes
  ○ Aging
  ○ Drugs
  ○ Heart disease
Diagnosing Chronotropic Incompetence

- Patient history
- Holter or telemetry monitoring
- Exercise testing
Sensors for Rate Adaptive Pacing
Sensors

- Rate adaptive pacemakers rely on sensors to detect patient activity
- The ideal sensor should be
  - Physiologic
  - Quick to respond
  - Able to increase the rate proportionally to the patient’s need
  - Able to work compatibly with the rest of the pacemaker
  - Able to work well with minimum energy demands or current drain
  - Easy to program and adjust
Types of Sensors

● Activity sensors
  ○ Accelerometers
  ○ Vibration sensors (piezoelectric sensors)

● Physiologic sensors
  ○ Impedance
    • Minute ventilation (MV)
    • Closed loop system (CLS)
  ○ Peak Endocardial Acceleration (PEA)
  ○ Temperature
  ○ Evoked response
  ○ QT interval
Activity/ Accelerometer

- Responds rapidly
- No special pacing leads required
- Easy to manufacture and program
- Cannot be “fooled” by pressure on the can
- Non-physiologic
Activity Sensor/Vibration

- Responds rapidly
- No special pacing leads required
- Easy to manufacture and program
- Can be “fooled” by pressure on the can or footfalls
- Non-physiologic
Minute Ventilation
Minute Ventilation

- Uses low-level electrical signals to measure resistance across the chest (“transthoracic impedance”)
  - Impedance (resistance) increases during inhaling, and decreases during exhaling
  - Detect respiration rate and relative change in tidal volume
  - $MV = RR \times TV$
- Requires no special sensor
- Metabolic
- Slow due to processing in pacemaker
Closed Loop System (CLS)

- Measures changes in cardiac contractility (inotropy)
- Impedance (resistance) increases during systole and decrease during diastole
- May be affected by changes in posture
Endocardial Acceleration sensor

- A microaccelerometer sensor inserted in the tip of a pacing lead for the chronic measurement of the Endocardial Acceleration (EA)
- PEA is related to the first HS, which reflects cardiac contractility
Endocardial Acceleration and Heart Sound

$E_T = \Phi t(PEA_I, PEA_{II})$

EA (g)

PHONO

BP (mmHg)

ECG

$t (s)$
PEA

- Measures changes in cardiac contractility
- Proportional to metabolic demand
- Fast
- Require special sensor
- Large lead body
Evoked Response

- Measures the QRS depolarization area
- Theory: the QRS depolarization decreases in area with exercise
- Requires no special leads
- May be affected by changes in posture
- Only works when the device is pacing
QT Interval

- Measures the interval between the pacing spike and the evoked T-wave
- Theory: This interval shortens with exercise
- Requires no special pacing lead
- Works only when the device is pacing
Temperature

- A thermistor is mounted in the lead (not the can)
- Requires a special pacing lead
- Metabolic
- Response time can be slow
Rate Adaptive Pacing Parameters: How to Program
Rate Adaptive Programming Parameters

- Base rate / Rest Rate
- Maximum sensor rate
- Threshold
- Slope
- Reaction time
- Recovery time
Rate Adaptive Pacing

- Max Sensor Rate
- Reaction Time
- Recovery Time
- Slope
- Base Rate
- Rest Rate
- Threshold
- Work Load (Activity, MV, PEA . . .)
Maximum Sensor Rate

- Maximum Sensor Rate is the fastest possible rate the pacemaker will pace in response to sensor input.
- The Maximum Sensor Rate must be a rate that the patient can tolerate.
  - Maximum heart rate formula \((220\text{-age}) \times 0.90\) is highest possible setting.
  - But if patient cannot tolerate the maximum heart rate, set the Maximum Sensor Rate to a rate they can tolerate.
Base Rate

- Minimum heart rate the pacemaker allows.
- When a patient’s intrinsic heart rates (when in rest) fall below the base rate, the pacemaker will pace at the base rate.

Rest Rate

- Few companies provide the rest rate.
- When a patient takes a prolonged rest, the pacemaker lowers the base rate to the rest rate.
- Fixed or Dynamic
  - Static: programmed by time (10 pm – 7 am, for example)
  - Dynamic based upon activity
Threshold

- Threshold is the amount of activity needed to cause sensor activity
- Programmable from low (least activity required to generate sensor signals) to high (most activity)
- Can also be set to AUTO
Threshold

Pacing Rate

Sensor Signal

Workload

Threshold 1 2 3 4 5 6 7

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Threshold Programming Considerations

- AUTO allows the pacemaker to automatically adjust to the patient’s changing activity levels
  - Updates automatically (i.e., every 18 hours)
- AUTO with Offset can further fine-tune the settings
  - A negative value makes it more sensitive (less activity is needed to start rate response)
  - A positive value makes it less sensitive (more activity is needed to start rate response)
- Considerations
  - Patient age, lifestyle, everyday activities
  - Patient’s fitness level (how likely is he to go jogging?)
Slope

- Slope describes the sensor-drive pacing rate for a given level of activity
- It is programmable from low to high (i.e., 1-16)
- All other things being equal, a slope of 1 will increase the rate less than a slope of 16
- AutoSlope
  - Based on recent activity levels
  - Offset values can be programmed to further fine tune rate response
Slope
Slope Programming Considerations

- Slope determines “how much” rate response is given for a specific activity.
- When selecting a slope, consider:
  - The patient’s age, activities, lifestyle
  - How well patients can tolerate rapidly paced activity
  - How much rate response they need
Reaction Time

- When the sensor determines the patient needs rate response, the Reaction Time parameter regulates how quickly rate response is delivered.
- Programmable to: Fast, Medium, Slow
- Consider the patient’s age, lifestyle, activities, and how quickly patients would need rate response.
Reaction Time

![Diagram showing reaction time and pacing rates with different speeds: Very Fast, Fast, Medium, Slow.](chart)

- **Sensor Indicated Rate (SIR)**
  - Very Fast
  - Fast
  - Medium
  - Slow

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Recovery Time

- Recovery time determines the minimum time it will take the sensor-driven rate at the maximum sensor rate to go back down to the programmed based rate
- Similar to Reaction Time
- Programmable as Fast, Medium, Slow, and Very Slow
- Programming considerations are the usual:
  - Patient age, lifestyle, activity levels
  - Tolerance of rate transitions
Recovery Time

Sensor Indicated Rate (SIR)

Very Fast

Very Slow

Pacing Rate

Base Rate

Time
Programming Rate Response
PASSIVE Sensor Setting

- Patients do not receive any rate response (the sensor does not control the rate) but the sensor reports what it would have done in a diagnostic report.

- Benefits of PASSIVE
  - Test sensor parameters before they are programmed.
  - Check how changes in sensor settings will work for a particular patient without exposing the patient to possibly uncomfortable sensor settings.
  - Makes it easier to fine-tune the sensor.
Rate Response Optimization

- A two-minute exercise test and the programmer can gather enough data to recommend optimal rate-responsive parameter settings
- Allows the clinician to fine-tune rate response for an individual patient
  - Without difficult exercise testing
  - Quick and easy
  - Recommends settings for better decision making
Rate Response Optimization

Rate Response Optimization collects exercise data to support selection of patient-appropriate Sensor parameters. The test will require the patient to perform exercise for a total of 6 minutes.

Rate Response Optimization Results

The test is not available because data integration is not complete.

Auto Threshold

A rate threshold decision (base average Sensor rate) is required for new sensor calibration. It requires the patient to rest quietly for 30 minutes.

End Session
Conclusion

- Rate adaptive pacing is almost a “standard feature” today
- Pacemaker patients often suffer from varying degree of chronotropic incompetence
  - Many who are not chronotropically incompetent now will become chronotropically incompetent with disease progression
- Automated options make programming easier
- There is no “perfect” sensor
  - Combination of sensors
- Rate response optimization is a valuable and actually time-saving feature