BRADYCARDIA AND PACING

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Plan

• Introduction
• Pacing modes
• Basic timing cycles and special features
• Indications for pacing (2013 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy)
• Follow-up and common issues
• Complications
INTRODUCTION
A bit of History..

Arne Larsson 1915 - 2001
Basic Concept

According to Ohm’s law:

\[ R = \frac{\text{VOLTAGE } U \text{ (in volt)}}{\text{CURRENT } I \text{ (in ampere)}} \]

comprises:
- lead resistance
- tissue impedance

The Can

Connector

Electric component

Battery
Battery

- Lithium-iodine
- Battery voltage remains relatively flat during much of device’s lifetime, with decline only close to end of service
- Battery impedance increases continuously with a rapid rise as battery depletion approaches
Battery Depletion

- **ERI (RRT) = Elective replacement indicator (recommended replacement time):**
  - Voltage is low and impedance is high
  - ERI point is manufacturer-defined
  - May trigger a change in pacing mode (rate response turned “off”, switches to VVI)
- **EOL (EOS) = End of life (end of service):**
  - 3 months after ERI point is reached
  - The pacemaker becomes erratic and unreliable with the possibility of total system failure
- As the battery approaches end of service, the magnet-activated pacing rate gradually decreases or remains stable in some generator until ERI. At ERI → specific company/model magnet rate indicates device nearing end of service
- Importance of Remote home monitoring
Unipolar Leads

- 1 Conductor
- Stimulation and detection between tip electrode and Can
- Large stimulation spike on surface ECG
- Small lead diameter
- More sensitive to EMI
- Less stiffer than bipolar leads
- Extra-cardiac stimulation

Bipolar Leads

- 2 Conductors
- Stimulation and detection between tip electrode (cathode-) and ring electrode (anode+)
- Small stimulation spike on surface ECG
- Larger lead diameter
- Less sensitive to EMI
- Stiffer than bipolar leads
- Less sensitive to myo-potentials

Active/Passive lead
Sensitivity

- A pacemaker senses the potential difference between the two electrodes (anode and cathode) used for pacing.
- Sensitivity is a measure of the minimal potential difference required between the terminals of a pacemaker to suppress its output.
- The higher the numerical value of sensitivity, the less sensitive the pacemaker becomes.
Undersensing

Unsensed QRS

Ventricular Capture
Oversensing

No QRS complexes

VS (extrinsic signal)
Threshold

- The minimum stimulus intensity and duration necessary to reliably initiate a propagated depolarizing wavefront from an electrode is defined as the stimulation threshold.
- Stimulation threshold may vary under different physiological conditions and over time.
## Threshold

<table>
<thead>
<tr>
<th></th>
<th>Increase Threshold</th>
<th>Decrease Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antiarrhythmic drugs</td>
<td>Class I Quinidine Procainamide Flecainide Propafenone</td>
<td></td>
</tr>
<tr>
<td>Other drugs</td>
<td>Beta-Blockers</td>
<td>Catecholamines Isoproterenol</td>
</tr>
<tr>
<td>Metabolic conditions</td>
<td>Hyperkalemia Hyperglycemia Hypoxemia Hypercarbia Metabolic acidosis Metabolic alkalosis</td>
<td></td>
</tr>
<tr>
<td>Activity/other conditions</td>
<td>Sleeping Eating Viral illness Vagal tone</td>
<td>Exercise Sympathetic tone</td>
</tr>
</tbody>
</table>
**Strength-duration curve**

- **Rheobase**: the lowest stimulus voltage that will electrically stimulate the myocardium at any pulse duration (usually 1.5-2.0ms)
- **Chronaxie**: the threshold pulse duration at a stimulus amplitude that is twice the rheobase voltage.
- Chronaxie approximates the point of minimum threshold stimulation energy
PACING MODES
### Revised NASPE/BPEG Generic (NBG) Pacemaker Code

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber(s)</td>
<td>Chamber(s)</td>
<td>Response to</td>
<td>Rate</td>
<td>Multisite</td>
</tr>
<tr>
<td>Paced</td>
<td>Sensed</td>
<td>Sensing</td>
<td>Modulation</td>
<td>Pacing</td>
</tr>
<tr>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
</tr>
<tr>
<td>A = Atrium</td>
<td>A = Atrium</td>
<td>T = Triggered</td>
<td>R = Rate</td>
<td>A = Atrium</td>
</tr>
<tr>
<td>V = Ventricle</td>
<td>V = Ventricle</td>
<td>I = Inhibited</td>
<td>Modulation</td>
<td>V = Ventricle</td>
</tr>
<tr>
<td>D = Dual</td>
<td>D = Dual</td>
<td>D = Dual</td>
<td></td>
<td>D = Dual</td>
</tr>
<tr>
<td>(A + V)</td>
<td>(A + V)</td>
<td>(T + I)</td>
<td></td>
<td>(A + V)</td>
</tr>
</tbody>
</table>

*Pacing Clin Electrophysiol. 2002 Feb;25(2):260-4*
Asynchronous Pacing

- **AAO – VOO – DOO**
- The simplest of all pacing mode (neither sensing nor mode of response)
- Lower rate limit (LRL) = only timing cycle available
- “Magnet mode”
- **Indications/Advantages:**
  - Pacemaker-dependant patients exposed to noise (e.g. electrocautery during surgery)
  - Avoids oversensing and asystole
- **Disadvantages:**
  - Pacing regardless of intrinsic events
  - Potential risk for arrhythmia induction
VOO Pacing Mode

COMPETITIVE RHYTHM !!!

- Paced QRS complex
- Normally conducted QRS complex
- Spontaneous QRS complex
- Pacemaker stimulus

Single Chamber Inhibited Pacing

- **AAI – VVI**

  - **Indications/Advantages:**
    - AAI: sick sinus syndrome with intact AV node; preserves AV synchrony
    - VVI: AF with slow ventricular rate, single lead ICDs
    - AAI/VVI require a single lead and increase battery longevity

  - **Disadvantages:**
    - AAI lacks ventricular pacing in the event of intermittent AV block
    - VVI is associated with AV dyssynchrony (manifests as pacemaker syndrome)
    - VVI pacing has a higher incidence of atrial arrhythmias
VVI Pacing Mode

ON-DEMAND or STANDBY PACING

Sensed spontaneous QRS complexes

Pacemaker stimulus

Escape interval

Automatic interval

Spontaneous QRS inhibits the output & resets the timer

Reset

Paced QRS complex

Time

Timer

Single Chamber Triggered Without Inhibited Pacing

- **AAT – VVT**
- Will deliver pacing output every time a native event is sensed or the LRL is reached
- Deforms the native signal
- **Indications/Advantages:**
  - Historically used in pacemaker-dependant patients to assure pacing (prevent inappropriate inhibition from oversensing) with lower probability of arrhythmia induction (pace within refractoriness of myocardial tissue when the intrinsic cardiac event is sensed)
- **Disadvantages:**
  - Shortens battery life due to chronic pacing
VVT Pacing Mode

DDD(R) Pacing Mode

- = “AV sequential pacing”, “Dual chamber sensing with inhibition”, “P-synchronous pacing”

- Tracking an atrial-sensed event will only occur up to a programmable maximum tracking rate (MTR)

- Most commonly used in dual chamber devices

**Advantages:**
- Preserves AV synchrony (less pacemaker syndrome)
- Low incidence of atrial arrhythmias and improved hemodynamics

**Disadvantages:**
- Requires at least two chamber lead system and has a shorter battery longevity
DDI Pacing Mode

• Similar to DDD without tracking atrial-sensed events (no P-synchronous pacing)
• The ventricular paced rate is never greater than the programmed LRL regardless of the atrial rate!
• A-V sequential pacing will only occur at LRL if no intrinsic ventricular event is sensed after atrial pacing
• “Mode switch mode”
• Indications/Advantages:
  • Atrial fibrillation/atrial tachycardia
  • Avoid tracking of atrial tachyarrhythmias
• Disadvantages:
  • Same as DDD
  • Possible AV dyssynchrony and pacemaker syndrome
DDI Pacing Mode

INHIBITS THE ATRIAL OUTPUT BUT DOES NOT TRIGGER AN AV DELAY

VENTRICULAR PACING ONLY AT LOWER RATE (NO TRACKING)

AEI  Atrial Escape Interval

LRI  Lower Rate Interval

VDI Pacing Mode

- Allows atrial sensing but does not provide P-synchronous pacing (non tracking mode)
- No AV sequential pacing
- In sinus rhythm, there is AV dissociation in VDI mode regardless of rate

Indications/Advantages:
- Used for mode switch as it functions as a VVI (non tracking pacing mode) with additional atrial sensing

Disadvantages:
- Similar to VVI, as it is associated with AV dyssynchrony and potential atrial arrhythmias
VDD Pacing Mode

• The most common use of this pacing mode is in devices with a single-pass lead which integrates an atrial-sensing electrode with a ventricular-pace/sense electrode

• **Indications/Advantages:**
  • Appropriate sinus node function with AV node disease
  • Dual chamber with high atrial pacing threshold (but adequate sensing) to minimize battery depletion

• **Disadvantages:**
  • Lack of atrial pacing
  • Potential AV dyssynchrony at lower rate limit
DVI Pacing Mode

- Pacing is only inhibited and reset by ventricular-sensed events
- Asynchronous atrial pacing at LRL
- Ventricular pacing will never be greater than LRL (due to lack of atrial sensing)
- First generation pacemaker

**Indications/Advantages:**
- Severe sinus bradycardia/standstill and atrial lead malfunction (oversensing)

**Disadvantages:**
- Asynchronous atrial pacing
- Potential AV dyssynchrony
BASIC TIMING CYCLES
LRI

- Lower Rate Interval (LRI)
- LRI is the longest interval between consecutive ventricular stimuli without an intervening sensed event or from a sensed ventricular event to the succeeding ventricular stimulus without an intervening sensed event.
AVI

- The atrio-ventricular interval (AVI) is the interval between an atrial event (either sensed sAVI, or paced pAVI) and the scheduled delivery of a ventricular stimulus.
- Appropriate programming of the AV interval depend on whether the atrium is sensed or paced.
- Because some atrial activation already has occurred at the time that the sensing amplifier detects the presence of a P wave, the AV interval based on sensed atrial activity should be shorter (20-50ms) than when the atrium is paced.
PVARP

- Post-ventricular atrial refractory period (PVARP): 250 – 310ms
- Programmable interval in dual chamber pacing modes with atrial sensing (DDD, DDI, VDD)
- Initiated after a **sensed or paced** ventricular event
- Avoids inappropriate tracking of sensed signals due to ventricular repolarization or retrograde P waves (PMT)
- If an atrial event occurs during PVARP, timing cycles are not reset
- TARP = AVI + PVARP
- Sensing of atrial signals during PVARP **allows proper mode switch** when AF, AT, AFI occurs
PAVB

- Post atrial ventricular blanking (PAVB): 10-60ms
- Covers the immediate interval that **follows an atrial pacing** output signal in order **to eliminate post-pacing signal oversensing** (crosstalk)
- If this blanking period is not long enough, another programmable safety feature that can be used to minimize consequences of cross-talk: **Ventricular safety pacing (VSP)**
- Minimize risk of asystole in pacemaker dependant patients

![Image of ECG waveforms with annotations]

![Diagram of pacing waveforms with labels]
VSP

• Ventricular safety pacing (VSP): 100-110ms
• Starts at the time of the atrial stimulus
• If sensing occurs in this time interval → a ventricular pacing stimulus is initiated
• Does not prevent crosstalk, it simply prevents its consequences!

![Diagram showing VSP]
Ventricular Refractory Period

- VRP: 200-350ms
- After VP or VS
- Any signal during the refractory period cannot initiate a new lower rate interval (LRI)
- Beyond the VRP, a sensed ventricular event inhibits the pacemaker and resets the LRI
- To prevent QRS double counting and T-wave oversensing
Upper Rate Behaviour – 2:1 Block

- Occurs when PP intervals are shorter than TARP
- 2:1 block point = \( \frac{60'000}{\text{TARP}} \) (example here: \( \frac{60'000}{500} = 120\text{bpm} \))
Upper Rate Behaviour – Wenckebach Response

- Addition of a 7th timing cycle to avoid abrupt 2:1 block: URI
- Wenckebach response occurs if:
  - URI > TARP and SAI > TARP but < URI
Upper Rate Behaviour

<table>
<thead>
<tr>
<th>Ventricular Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Ventricular Pacing</td>
</tr>
<tr>
<td>LR</td>
</tr>
<tr>
<td>1:1 Atrial Tracking</td>
</tr>
<tr>
<td>Wenckebach</td>
</tr>
<tr>
<td>TARP</td>
</tr>
</tbody>
</table>

- UTR
- Atrial Rate

- LR
- UTR
- TARP

= Ventricular Pacing
Rate Adaptive Pacing (R)

- **Sensor**: device that converts non-electrical data into electric signals. The response of the indicator to the body function determines the magnitude and frequency of the electrical signal.

- **Indications for sensor driven pacing**:
  - Sick sinus syndrome, tachy-brady syndrome (DDDR, AAIR)
  - Slow conducted chronic AF (VVIR)

- **Open loop sensors** (use external input to optimize the sensor response):
  - Sensors of body motion (accelerometer)
  - Vibration sensors (piezoelectric crystals): detects mechanical pressure and vibration
  - Minute ventilation sensors

- **Closed loop sensors** (relies on intrinsic positive or negative feed-back):
  - RV impedance sensor
  - QT interval sensor
INDICATIONS FOR PACING
# Persistent Bradycardia – SND

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Sinus node disease.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Pacing is indicated when symptoms can clearly be attributed to bradycardia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Sinus node disease.</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>Pacing may be indicated when symptoms are likely to be due to bradycardia, even if the evidence is not conclusive.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Sinus node disease.</td>
<td>III</td>
<td>C</td>
</tr>
<tr>
<td>Pacing is not indicated in patients with SB which is asymptomatic or due to reversible causes.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Persistent Bradycardia – AV Block

<table>
<thead>
<tr>
<th>4) Acquired AV block.</th>
<th>5) Acquired AV block.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacing is indicated in patients with third- or second-degree type 2 AV block irrespective of symptoms.</td>
<td>Pacing should be considered in patients with second-degree type I AV block which causes symptoms or is found to be located at intra- or infra-His levels at EPS.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIa</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

6) Acquired AV block. Pacing is not indicated in patients with AV block which is due to reversible causes.
# DDD vs VVI Pacing Mode

<table>
<thead>
<tr>
<th>Outcome</th>
<th>References</th>
<th>Dual-chamber benefit over ventricular pacing</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause deaths</td>
<td>2, 11–15</td>
<td>No benefit</td>
<td></td>
</tr>
<tr>
<td>Stroke, embolism</td>
<td>2, 11–15</td>
<td>Benefit (in meta-analysis only, not in single trial)</td>
<td>HR 0.80&lt;sup&gt;12&lt;/sup&gt;. Benefit higher in SSS.</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>2, 11–15</td>
<td>Benefit</td>
<td>HR 0.81&lt;sup&gt;12&lt;/sup&gt; and 0.76&lt;sup&gt;13&lt;/sup&gt;. Benefit higher in SSS.</td>
</tr>
<tr>
<td>HF, hospitalization for HF</td>
<td>2, 11, 12, 14, 15</td>
<td>No benefit</td>
<td></td>
</tr>
<tr>
<td>Exercise capacity</td>
<td>15</td>
<td>Benefit</td>
<td>Overall standardized mean improvement of 35%. Not significant compared to VVIR.</td>
</tr>
<tr>
<td>Pacemaker syndrome</td>
<td>11–13, 15</td>
<td>Benefit</td>
<td>Documented in up to 25% of VVI patients.</td>
</tr>
<tr>
<td>Functional status</td>
<td>11, 12, 15</td>
<td>No benefit</td>
<td></td>
</tr>
<tr>
<td>Quality of life</td>
<td>11–13, 15</td>
<td>Variable</td>
<td>Consistent direction of effect on quality of life, but the size cannot be estimated with confidence.</td>
</tr>
<tr>
<td>Complications</td>
<td>2, 11–13, 15</td>
<td>More complications with dual-chamber</td>
<td>Higher rate of lead dislodgment (4.25 vs. 1.4%) and inadequate pacing (1.3 vs. 0.3%).</td>
</tr>
</tbody>
</table>
Choice of Pacing Mode

Sinus node disease:
- Persistent
  - Chronotropic incompetence: 1 choice: DDDR + AVM, 2 choice: AAIR
  - No chronotropic incompetence: 1 choice: DDD + AVM, 2 choice: AAI
- Intermittent

AV block:
- Persistent
  - SND
    - No SND
      - AF
      - VVIR
      - DDD + AVM (VVI if AF)
  - VVIR
- Intermittent

Consider CRT if low EF/HF

European Heart Journal (2013) 34, 2281–2329
doi:10.1093/eurheartj/eht150
ESC GUIDELINES
Intermittent Bradycardia - Documented

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Sinus node disease (including brady-tachy form). Pacing is indicated in patients affected by sinus node disease who have the documentation of symptomatic bradycardia due to sinus arrest or sinus-atrial block.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>2) Intermittent/paroxysmal AV block (including AF with slow ventricular conduction). Pacing is indicated in patients with intermittent/paroxysmal intrinsic third- or second-degree AV block.</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

European Heart Journal (2013) 34, 2281–2329
doi:10.1093/eurheartj/eht150
Suspected Bradycardia - BBB

1) BBB, unexplained syncope and abnormal EPS.
Pacing is indicated in patients with syncope, BBB and positive EPS defined as HV interval of ≥70 ms, or second- or third-degree His-Purkinje block demonstrated during incremental atrial pacing or with pharmacological challenge.

| 1 |  B |

2) Alternating BBB.
Pacing is indicated in patients with alternating BBB with or without symptoms.

| 1 |  C |

3) BBB, unexplained syncope non diagnostic investigations.
Pacing may be considered in selected patients with unexplained syncope and BBB.

| IIb |  B |

4) Asymptomatic BBB.
Pacing is not indicated for BBB in asymptomatic patients.

| III |  B |
Undocumented Reflex Syncope

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Carotid sinus syncope. Pacing is indicated in patients with dominant cardioinhibitory carotid sinus syndrome and recurrent unpredictable syncope.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>2) Tilt-induced cardioinhibitory syncope. Pacing may be indicated in patients with tilt-induced cardioinhibitory response with recurrent frequent unpredictable syncope and age &gt;40 years after alternative therapy has failed.</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>3) Tilt-induced non-cardioinhibitory syncope. Cardiac pacing is not indicated in the absence of a documented cardioinhibitory reflex.</td>
<td>III</td>
<td>B</td>
</tr>
</tbody>
</table>
FOLLOW-UP AND POTENTIAL ISSUES
Follow-up frequency of CIED

- **Pacemakers/ICDs/CRT:**
  - Within 72h of CIED implantation *(In Person)*
  - 2-12 weeks post implantation *(In Person)*
  - Every 3-12 months pacemaker/CRT-P *(In Person or Remote)*
  - Every 3-6 months ICD/CRT-D *(In Person or Remote)*
  - Annually until battery depletion *(In Person)*
  - Every 1-3 months at signs of battery depletion *(In Person or Remote)*

- **Implantable loop recorder:**
  - Every 1-6 months depending on patient symptoms and indication *(In Person or Remote)*

- More Frequent in person or remote monitoring may be required for all above devices as clinically indicated.
Follow Up

Pacemaker follow-up: are the latest guidelines in line with modern pacemaker practice?

Erik O. Udo1,2*, Norbert M. van Hemel1, Nicolaas P.A. Zuithoff2, W. Arnold Dijkstra3, Carla A.M. Hooijschuur3, Pieter A. Doevendans1, and Karel G.M. Moons2

1Department of Cardiology, University Medical Center Utrecht, Heidelberglaan 100, 3584 CX Utrecht, The Netherlands, 2Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Universiteitsweg 100, 3584 CX Utrecht, The Netherlands, and 3Department of Cardiology, University Medical Center Groningen, Hanzeplein 1, 9713 EZ Groningen, The Netherlands

Europace (2013) 15, 243–251
doi:10.1093/europace/eus310

CLINICAL RESEARCH
Pacing and resynchronization therapy
Electromagnetic Interference (EMI)

- Possible responses to EMI in Pacemakers:
  - **Asynchronous pacing** (activation of noise algorithms) → risk of stimulation in vulnerable period
  - **Safety pacing**
  - **Inhibition of atrial and/or ventricular pacing**
  - **Magnet mode**
  - **Upper-mode behaviour** (oversensing in the atrial channel)
- The rate of adverse effect is higher when sensing configuration in **unipolar**, if compared with bipolar configuration
- Importance of **noise algorithm** → EMI is sensed and recognized by a device as noise.
- **Non-Medical** sources of EMI:
  - Cellular phones, digital music players, headphones, household appliances, security systems, external electric equipment
- **Medical** sources of EMI:
  - Electrocautery in surgery, catheter ablation, external defibrillation, lithotripsy, LVAD, MR
Electromagnetic Interference (EMI)

• **Cellular phones:**
  - Highest probability of interference if placed directly over the Pacemaker. Correct and normal use → very low incidence of interference with no clinically significant events¹
  - Interactions are observed only during the ringing phase when the cellular phone is placed <10cm from the device²
  - Activation of noise-detection algorithms → asynchronous pacing²
  - To ensure safety during a phone call → hold cellular phone **contralateral** to the device²

• **Digital music players and headphones:**
  - Minimal interaction with digital music players (possible telemetry interference)
  - Little in-ear headphones do not interact with CIEDs
  - Portable headphones creates a big magnetic field and produce EMI if <3cm of the device³

• **Household appliances** (micro-wave, radios, TV, toaster…):
  - When household appliance is malfunctioning, the possible current dispersion may cause EMI with CIED

---

Electromagnetic Interference (EMI)

- Security systems, and airport and bank screening devices:
  - No relevant interactions between CIEDs and surveillance devices (antitheft gates, metal detectors) during 10-15sec exposure time\(^1\)
  - Prolonged exposure (2min, within 15cm of the gate) near the security system can generate EMI\(^1\)
  - Asynchronous pacing, atrial oversensing with rapid ventricular pacing, ventricular oversensing with pacemaker inhibition\(^2\)
  - Recommendation: “Do not linger, do not lean” and simply move through the security system at a normal pace\(^3\)
  - Hand-held metal detectors contain magnets and have a greater potential for interactions → scanning of these patients should be avoided and minimize the time the detector is held near the device\(^3\)

Electromagnetic Interference (EMI)

- **Industrial Welding Machines**
  - Welding equipment in the range of 100-200A is unlikely to produce significant EMI
  - Welding with **high power greater than 500A** may inhibit pacemakers so these should be strictly be avoided
  - In any pacemaker-dependant patient, evaluation of potential EMI due to arc welder should be done (make certain the pacemaker is not inhibited)
  - In non-pacemaker-dependant patients, evaluation of welding equipment on pacemakers can be achieved with telemetry monitoring to evaluate any interference
  - In patients with ICD, a technician or engineer should evaluate the patient’s work environment to rule out inappropriate ICD detections and therapy delivery

Chest X-Ray
Chest X-Ray
Chest X-Ray
Chest X-Ray
ECG – Mean QRS Axis in RV Pacing

ECG – DDD Pacing
## Driving restrictions after PPM Implant

<table>
<thead>
<tr>
<th></th>
<th>Private drivers</th>
<th>Commercial drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESC(^1)</td>
<td>1 week</td>
<td>Any persistent symptoms are disqualifying (Re-) licensing may be permitted after at least 6 weeks have elapsed</td>
</tr>
<tr>
<td>CCS(^2)</td>
<td>- 1 week</td>
<td>- 4 weeks after implant</td>
</tr>
<tr>
<td></td>
<td>- No impaired level of consciousness after implant</td>
<td>- No impaired level of consciousness after implant</td>
</tr>
<tr>
<td></td>
<td>- Normal sensing and capture</td>
<td>- Normal sensing and capture</td>
</tr>
<tr>
<td></td>
<td>- No evidence of pacemaker malfunction at regular pacemaker clinic checks</td>
<td>- No evidence of pacemaker malfunction at regular pacemaker clinic checks</td>
</tr>
<tr>
<td>AHA/HRS(^3)</td>
<td>1 week</td>
<td>4 weeks</td>
</tr>
</tbody>
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COMPLICATIONS
Complications

• Multiple studies show that the majority of complications emerge shortly after implantation

• Short-term complications (≤2 months post implant) 12.8%:
  • Independent predictors: Male gender, age at implantation, BMI, history of cerebrovascular accident, CHF, anticoagulant drugs, passive atrial lead

• Long-term complications (>2 months post implant) 9.2%:
  • Independent predictors: Age, BMI, HTA, dual-chamber devices

### Complications

**Table 3** Complications within 2 months and during long-term follow-up occurring in 1517 patients with a first pacemaker

<table>
<thead>
<tr>
<th>Complication</th>
<th>Within 2 months</th>
<th>During follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Traumatic complications—total</td>
<td>42</td>
<td>2.77</td>
</tr>
<tr>
<td>Perforation of cardiac structure</td>
<td>6</td>
<td>0.40</td>
</tr>
<tr>
<td>Pneumo(hemo)thorax</td>
<td>34</td>
<td>2.24</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td>Lead related complications—total</td>
<td>84</td>
<td>5.54</td>
</tr>
<tr>
<td>Lead fracture*</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td>Lead dislocation or disconnection*</td>
<td>50</td>
<td>3.30</td>
</tr>
<tr>
<td>Insulation problem*</td>
<td>4</td>
<td>0.26</td>
</tr>
<tr>
<td>Infection (ie, endocarditis)*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Stimulation threshold problem</td>
<td>12</td>
<td>0.79</td>
</tr>
<tr>
<td>Diaphragm or pocket stimulation</td>
<td>11</td>
<td>0.73</td>
</tr>
<tr>
<td>Diaphragm or pocket stimulation*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other†</td>
<td>5</td>
<td>0.33</td>
</tr>
<tr>
<td>Pocket complications—total</td>
<td>72</td>
<td>4.75</td>
</tr>
<tr>
<td>Hematoma</td>
<td>44</td>
<td>2.90</td>
</tr>
<tr>
<td>Difficult to control bleeding*</td>
<td>4</td>
<td>0.26</td>
</tr>
<tr>
<td>Infection</td>
<td>10</td>
<td>0.66</td>
</tr>
<tr>
<td>Infection*</td>
<td>4</td>
<td>0.26</td>
</tr>
<tr>
<td>Discomfort due to pocket or pacemaker</td>
<td>1</td>
<td>0.07</td>
</tr>
<tr>
<td>Discomfort due to pocket or pacemaker*</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td>Skin erosion</td>
<td>7</td>
<td>0.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Complication</th>
<th>Within 2 months</th>
<th>During follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Pulse generator problem—total</td>
<td>5</td>
<td>0.33</td>
</tr>
<tr>
<td>Problem with connection screw</td>
<td>5</td>
<td>0.33</td>
</tr>
<tr>
<td>Manufacturer recall</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Manufacturer recall*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reset to default settings</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Device cannot be programmed</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pacemaker tachycardia</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Malfunction of software algorithm</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total number of complications in need of reoperation</td>
<td>64</td>
<td>4.22</td>
</tr>
<tr>
<td>Number of patients experiencing a complication</td>
<td>188</td>
<td>12.4</td>
</tr>
</tbody>
</table>

*Complication is managed with reoperation. Numbers do not add up, because patients can experience multiple complications.
†See text for details.

Subclavian Vein Thrombosis
Pocket Infection
Pocket Erosion/Infection
Atrial Lead Perforation
Ventricular Lead Perforation
Pocket Hematoma
## Strategy for management of antiplatelet and anticoagulation in peri-implantation period

<table>
<thead>
<tr>
<th>Antiplatelet therapy</th>
<th>Suggested strategy</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary prevention</td>
<td>Withhold antiplatelet therapy for <strong>3-7 days</strong> before implant depending on the drug</td>
<td>Non-randomized large observational studies</td>
</tr>
<tr>
<td>Dual antiplatelet therapy after stent placement and acute coronary syndromes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-high risk period</td>
<td><strong>Continue aspirin</strong> (low increase in bleeding risk)</td>
<td>Non-randomized large observational studies; expert consensus</td>
</tr>
<tr>
<td>High-risk period</td>
<td><strong>Continue dual antiplatelet therapy</strong> (high increase in bleeding risk)</td>
<td>Non-randomized large observational studies; expert consensus</td>
</tr>
<tr>
<td>Warfarin therapy</td>
<td>Withhold warfarin in <strong>3-5 days</strong> before implant or continue warfarin (lower end of recommended INR) according to a risk evaluation performed by the physician</td>
<td>International expert consensus</td>
</tr>
<tr>
<td>Novel oral anticoagulant</td>
<td>Withhold anticoagulant <strong>1-3 day</strong> before implant or continue according to a risk evaluation performed by the physician and restart as soon as effective haemostasis has been achieved</td>
<td>Expert consensus</td>
</tr>
</tbody>
</table>
Ventricular Lead Dislocation
Atrial Lead Dislocation
Ventricular Lead Malposition
Take Home Messages

• Be familiar with the basic pacing indications and choose the appropriate mode of pacing for each condition, including conditions in which the rate response must be enabled (AF, sick-sinus syndrome, chronotropic incompetence)
• Be familiar and inform the patient with all the restrictions after a pacemaker implant and potential sources of EMI
• Make an appropriate outpatient follow-up and recognise any potential issues that can arise during FU and take the appropriate actions
• Importance of optimal anticoagulation/antiplatelet therapy strategy during the peri-procedural period (avoid LMWH and Heparin bridging if possible!)
Thank you for your attention!