Temporary epicardial pacing

Rhythm disturbances after cardiac surgery are common. Iatrogenic injury to the conducting fibres of the heart, cardioplegia and therapeutic effects of drugs can cause brady-arrhythmias requiring pacing. When weaning from CPB heart rates of 70 to 90 beats per minute are usually preferred because the ventricle's compliance tends to be lower in the immediate postoperative period. Alternative options to pacing are positively chronotropic drugs such as atropine, dopamine, isoprenaline or adrenaline though the later may worsen the myocardial oxygen supply-demand ratio. Also various types of tachyarrhythmia are common after cardiac surgery, and many of them can be treated effectively by pacing and without the side effects of pharmacotherapy or DC cardioversion.

Epicardial pacing wires

Towards the end of the CPB, epicardial wires are placed on the RA and / or RV and brought out from the chest wall for temporary pacing. By convention, atrial wires are brought out to the right of the heart and ventricular to the left.

Temporary epicardial pacing may be achieved with bipolar or unipolar wires.

- Unipolar wires constitute a single conductor lead, with an electrode at the wire tip, attached to the heart. The positive terminal of the pacemaker is attached to the patients skin.
- Bipolar wires contain two isolated conductors within a single lead with two electrodes spaced at the tip of the wire. Bipolar pacing may also be achieved by the application of two unipolar wires to one cardiac chamber.
- Unipolar pacing requires higher current and therefore has less longevity and makes the system more prone to far field disturbance (oversensing).

Epicardial wires usually last for 5 to 7 days before they dislodge or stop working due to an inflammatory reaction at the wire-myocardium interface resulting in localized fibrosis (a process called "maturing"). If the intrinsic rhythm does not recover by then, a permanent system will need to be implanted.

blue = female
white = learmore.

Figure 45: Two unipolar wires constituting a bipolar circuit

Common pacemaker modes

Pacemaker functions can be remembered by the acronym 'PSA':
P – chamber paced (A – atrium, V – ventricle, D – dual, i.e. both chambers). The heart chamber is paced by the delivery of an electrical current measured in mA.
S – chamber sensed (A – atrium, V – ventricle, D – dual, i.e. both chambers). The electrical activity of the heart chamber is sensed by measuring the potential difference in mV.
A – action, i.e. response to sensing (I – inhibited, T – trigged, D – dual, i.e. both trigging and inhibition is possible, depending on the sensed intrinsic electric activity of the chambers, implies always the presence of both A- and V- wires.

Mode	Features	Advantages	Disadvantages	Comments
AAI	Atrial pacing Atrial sensing Inhibition of pacemaker output by intrinsic atrial depolarisation	Improves cardiac output - Atrial contraction contributes to ventricular filling Ventricular synchrony is preserved (interventricular filling dependence) No risk of R on T pacing	Dependent on intact intrinsic AV conduction Does not work in AF	Unable to pace if AV conduction abnormalities occur
VVI	Ventricular pacing Ventricular sensing Inhibition of pacemaker output by intrinsic ventricular depolarisation	Suitable in (chronic) AF Mode of choice in life threatening brady-arrhythmias	Less efficient than endogenous depolarization due to AV- and inter-ventricular dyssynchrony	Often used as back-up, if the endogenous rhythm is sufficient upon weaning from CPB
DDD	Dual pacing Dual sensing Dual action	Maintains atrial contribution to ventricular filling Makes use of the intrinsic conduction system if the PR interval is shorter than the PM AV-delay (usually sett to 120-200 ms)	Advanced mode, prone to mismanagement Risk of sensing errors resulting in pacemaker induced tachy- and brady-arrhythmias	Flexible pacemaker mode Requires a certain degree of user skills and knowledge, especially about sensing errors.
DOO / VOO	Dual / ventricular pacing No sensing!	Emergency modes, especially when oversensing is suspected, i.e. use of diathermy machine in OT	Risk of pacemaker induced VT or VF due to pacing on an intrinsic T wave	Never leave a patient in ICU on DOO / VOO mode, if there is intrinsic activity

Table 7. Features of the different pacing modes

Practical approach to pacemaker check:

After admission, always check the epicardial pacing system, once the patient is settled, sedated, cardiovascular stable and all monitoring is attached. Further pacemaker check is recommended on a daily basis.

Recommended order

1. Make sure the pacemaker is in a synchronous mode (AAI, VVI, DDI or DDD) to enable sensing and to avoid the risk of pacing on an intrinsic T-wave.
2. Check underlying rhythm:
   Make sure sensing (mV) is set to an appropriate level. Slowly turn down the pacemaker rate until the endogenous rhythm appears on ECG trace and the sense indicator starts flashing.

   Safety issues:

   - Always keep an eye on the blood pressure! In case of instability when reducing the pacing rate, regard the patient as being pacemaker dependent and restore the pacemaker rate to previous setting. This pacing system is very precious and any dislodgment or malfunction might result in severe haemodynamic instability. Do not proceed to step 3 and / or 4.
   - Do NOT press the "pause" button, remove the wire from the pacing box or turn down the pacemaker output in order to observe the underlying rhythm. There might be none, and there are cases described where capture could not be restored after a prolonged pause.

3. Check sensitivity:
   - Ensure the patient is not pacemaker dependent (the sensitivity cannot be checked with no intrinsic rate) and that the pacemaker is in a synchronous mode.
   - Set pacemaker rate at least 10 BPM below intrinsic rate.
   - Check atrial and ventricular sensing separately.
   - Reduce output for the respective wire to 0.1 mA to avoid relevant pacemaker output on an intrinsic T wave.
   - Decrease the sensitivity by increasing the threshold (numerical sensitivity value in mV) until the sense indicator stops flashing. Asynchronous flashing of the pace indicator should ensue once sensing is lost.
   - Slowly increase sensitivity again until the sense indicator flashes for every intrinsic beat observed, and the pace indicator stops flashing (as sensing is now inhibiting pacing). This represents the sensing threshold.
   - Set pacemaker sensitivity to half of the sensing threshold.
   - Proceed to capture testing or restore the previous rate and output values.

   Safety issues:

   - In all patients with an intrinsic rhythm of around 40 bpm or more, test the sensing threshold *before* the capture (or pacing) threshold to avoid pacing R on T during capture threshold testing.
   - In pacemaker dependent patients without significant intrinsic activity, set sensitivity to a reasonable value (for example 2

mV) and observe for ECG features of sensing failure.

4. Check capture threshold:
    - Ensure the pacemaker is in a synchronous mode and is sensing appropriately if there is intrinsic activity.
    - Set pacemaker rate at least 10 BPM above intrinsic rate.
    - Check atrial capture (P wave) and ventricular capture (QRS complex) separately.
    - Decrease output: Slowly turn down the pacing current until the ECG and BP trace show electrical and mechanical loss of capture (LOC). The box will still be pacing at this point but the output current is insufficient to cause myocardial depolarisation. The pace indicator will flash at the set rate and the sense indicator should flash concurrently with the instrinsic beats.
    - Increase output: Slowly turn the pacing current up again until ECG and BP show consistent capture. This value is called the stimulation or capture threshold (usually 1-4 mA).
    - Set pacemaker output value 2 to 3 times greater than stimulation threshold for safety reasons. Excessive pacing current should be avoided since it will reduce the longevity of the wires.
    - Restore pacemaker rate to previous value.

Use of the emergency key

Activates DOO at the maximum output.

- Indicated if there is failure to pace with haemodynamic instability
- Asynchronous mode eliminates the chance that failure to pace is caused by over-sensing (sensitivity threshold testing only prevents under-sensing)

Precautions:

- High output current causes maturing of the leads and should therefore be adjusted as soon as possible
- Asynchronous pacing should not be used if there is intrinsic activity. In case of persistent failure to sense, set pacemaker at least 10-20 BPM above intrinsic rate to avoid R on T pacing related to "break through" of the intrinsic rhythm.

Troubleshooting

Failure of pacing output

No pacing spikes on ECG

Priorities in the event of pacing failure:

- Check patient and for signs of haemodynamic instability
- Check integrity of the pacemaker circuit: pacing box switched on and connections intact
- Press emergency button, alternatively:
    - Increase pacing output to maximum
    - Switch to asynchronous mode (VOO) to exclude sensitivity issues
- Set pacemaker rate at least 10 BPM above intrinsic rate
- No amenable cause identified within 1 minute:
    - CPR if cardiac standstill / instability
    - Prepare for transcutaneous / transvenous pacing
- If the patient had two unipolar wires and only one wire is

dislodged from the heart, create unipolar circuit by removing the dislodged wire and connecting the positive lead with a needle to the patient's skin

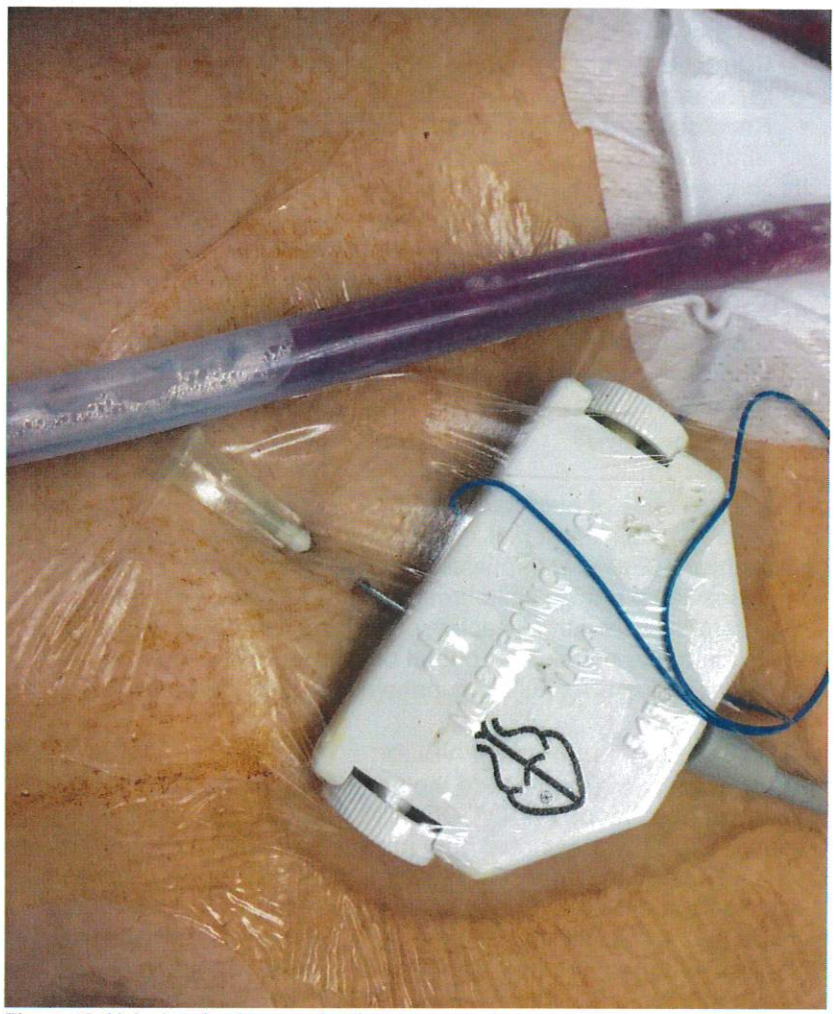

Figure 46: Unipolar circuit created with one ventricular wire.

Pacing output but loss of ventricular capture

Visible pacing spikes on ECG but no electrical capture on ECG and no corresponding cardiac contraction on BP waveform

Priorities:

- Check patient and assess for signs of instability
- Increase output to maximum
- Identify and if possible correct exacerbating causes (electrolyte/metabolic abnormalities, myocardial ischaemia)
- Reverse bipolar leads, create unipolar circuit (the negative usually lead matures first)
- No amenable cause identified within 1 minute:
  - CPR if cardiac standstill / instability
  - Prepare for transcutaneous / transvenous pacing

Failure to sense / ventricular under-sensing

The sensing light will not flash with intrinsic cardiac beats, the pacemaker will operate like it is asynchronous mode and paced beats may immediately after intrinsic beats (risks R on T).

- Check the pacemaker is not in asynchronous or emergency mode
- Increase sensitivity (decrease threshold value) to the minimum
- Increase the pacing rate to supress intrinsic beats
- Technical / mechanical failure – may occur concurrently with loss of capture
- Correct exacerbating causes (electrolyte/metabolic disturbance, myocardial ischaemia)
- Reverse bipolar leads; create unipolar circuit

It is possible that a pacemaker fails to sense but can still pace on the same wire-lead connection, especially if the wire is connected to ischaemic tissue. The intrinsic current of the heart is too weak to be sensed across the ischaemic tissue but the output is still high enough to induce electric activity. Since there is increased risk of inducing VF in ischaemia, it is paramount to reassess frequently and make sure that the pacemaker rate is set appropriately to minimise the risk of pacemaker induced R on T.

Over-sensing

Suspect in case of output failure or pacemaker-induced tachycardia

Background: External impulses like diathermy, or internal far field impulses like a pacing spike from another heart chamber, are misinterpreted as intrinsic activity. This can lead to either: (a) inhibition of the pacemaker output or (b) trigger an inappropriate pacemaker output, resulting in pacemaker-induced tachycardia.

Over-sensing leading to inhibition

Treat as output failure – once the pacemaker is switched to an asynchronous mode (VOO/DOO) all over-sensing problems will be eliminated. The rate should be a minimum of 10bpm higher than the intrinsic rate to minimise the likelihood of R on T pacing. If the patient is stable the pacemaker may be switched back to a synchronous mode and the sensitivity reduced (absolute value increased) to attempt to correct the over-sensing. It may be prudent to reduce the A-output if AV-cross talk is suspected (the ventricle senses the atrial pacing impulse and inhibits the ventricular impulse) before switching back to DDD or DDI. AV-crosstalk has become infrequent, since most modern pacemakers provide "blanking periods", which disable ventricular sensing during and shortly after atrial output.

Over-sensing leading to pacemaker induced tachycardia

Observation: Rapid pacemaker activity on the ECG – in DDD mode only! The ventricular pacing spikes are misinterpreted as atrial activity, triggering a further ventricular impulse. This cycle repeats itself leading to a pacemaker-induced tachycardia. Occasionally, external stimuli can lead to a similar picture.

- disconnect the A-wire
- switch to asynchronous mode (DOO)
- if the patient is stable, reduce V-output and / or A- sensitivity (increase sensing threshold value) before switching back to DDD mode

Retrograde conduction resulting in pacemaker-induced tachycardia

Observation: Rapid pacemaker activity on the ECG – in DDD mode only! (ventricular impulses are conducted back to the atrium and sensed by the A-wire. This triggers a further ventricular impulse that

is again conducted back to the atrium. The cycle repeats producing a pacemaker-induced tachycardia. Retrograde p-waves can be identified as inverted on the ECG trace as the direction of depolarisation is the reverse of sinus rhythm.

- Disconnect the A-wire
- Switch to asynchronous mode (VOO)
- If patient stable, try reducing atrial sensitivity (increase sensing threshold) or increasing the PVARP (post-ventricular atrial refractory period) before switching back to DDD. During the PVARP (which occurs after the ventricular impulse) the atrial lead is blocked from sensing in an effort to stop pacemaker-induced tachycardia. By increasing the PVARP, the total atrial refractory period (TARP) is prolonged. The TARP is the sum of the PVARP and the AV delay. If the TARP is increased from 500ms to 600ms, the upper atrial rate the pacemaker can sense is reduced from 120bpm to 100bpm.

AV dyssynchrony

Observation:
Loss of atrial component to ventricular filling (atrial kick). Seen in VVI/VOO or with improper timing of atrial and ventricular contraction in dual chamber modes

- Decrease in cardiac output
- Cannon A-waves
- Loss of A wave on transmitral flow pattern on echo

Troubleshooting:
Change to DDD/DDI pacing (+ adjust AV delay manually and reassess CO)

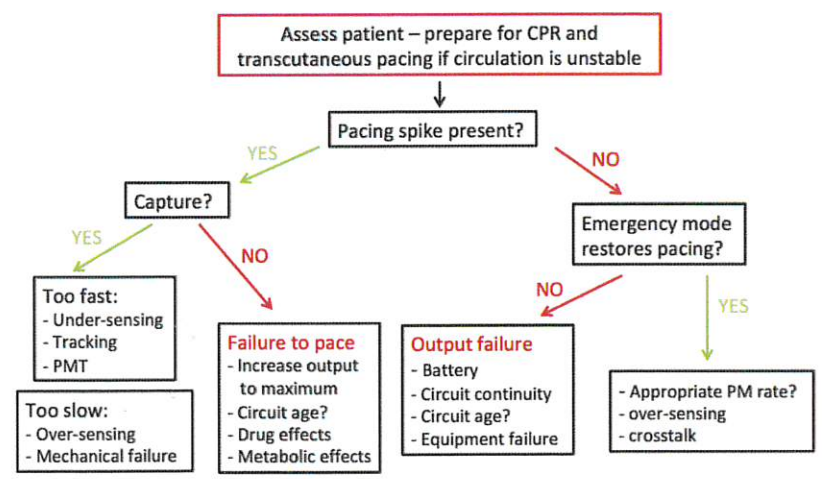

Figure 47: emergency algorithm for suspected pacemaker malfunction

Overdrive pacing:

Most atrial and ventricular tachyarrhythmia can be controlled by pacing, with exception of atrial and ventricular fibrillation and sinus-tachycardia.
Before attempting overdrive-pacing:

- review a recent long strip and 12 lead ECG to correctly diagnose

the arrhythmia
- correct electrolytes and other metabolic derangements if possible
- ensure resuscitation equipment is readily available

AV junctional tachycardia, re-entrant SVT, atrial flutter

- make sure the ventricle is not paced and/or sensing by choosing the RAP (rapid atrial pacing) function or AOO/AAI mode
- set pacemaker rate at least 20% above intrinsic atrial rate (e.g. 400bpm for atrial flutter)
- observe for 1:1 atrial capture
- reduce gradually until sinus rhythm appears

Ventricular tachycardia

VT might respond to ventricular pacing but there is a risk of inducing VF, which should be balanced against the risks of DC cardioversion.

Recommended additional reading:

M.C. Raede: Temporary epicardial pacing after cardiac surgery: a practical review. Part 1 and 2. Anaesthesia, 2007. 62 p. 264-271 and p. 364-67