PACING

- **INITIAL ASSESSMENT**
  - Successful and non-stressful manipulation of the temporary pacing system
    - What is the native underlying rhythm
    - What are the modes of pacing available
    - What you would like to accomplish

  - Patients with symptomatic tachycardia > than 170/min are rarely helped by manipulating the standard temporary pacemaker - Cardioversion (whether electrical or pharmacological) should be the mainstay of therapy.

  [note: A word of caution, those patients susceptible to JET (TOF, VSD, etc.) with unstable tachycardia are quite likely to fare as poorly with unfettered electrical cardioversion, as with sub optimal approach to pacing. It may, in fact, be quite beneficial to overdrive pace these patients at rates of 180 to 200. The bedside guidance and advice of a cardiology or intensive care consultant should be considered.]

  - All other patients have a sufficient underlying rhythm to allow for a methodical and reasoned approach to the patient.

- **CHECKING THE UNDERLYING RHYTHM IN A PATIENT WHO IS ALREADY PACED**
  a. The appropriate way to examine the patient's underlying rhythm is to gradually reduce the pacing rate, allowing the intrinsic rhythm to emerge.
  b. These underlying rhythms are overdrive suppressed by pacing and may not appear in a timely fashion after the abrupt termination of pacing. The threshold to recapture the heart after such a manoeuvre may be significantly higher than it was before pacing inhibition (the Wodinsky effect).

- **WIRES, LEADS AND CONNECTIONS**

  a. By convention, atrial wires are the rightmost, with ventricular wires closer to the midline – regardless of whether there is an abnormality in the position of the heart (dextrocardia) and chambers within the heart (heterotaxy).
  b. In case not sure, record an electrocardiogram from the wires to decide which chamber they are originating from.
  c. If convention not followed then they should be labelled between the exit point and metal connection pins.
  d. Pacing cables and the headers they are connected to are colour coded as **blue for atrial** and **white for ventricular.**
  e. The connections and cables are all electrically identical and are easily interchangeable – can lead to unexpected and potentially dangerous pacing behaviour.
  f. The headers on the pacing generator are designed to accept one end of the pacing cable but can be connected to the pins of the pacing wires if necessary.
  g. Check that the header is actually closed and engaged on the pacing cable.
  h. The polarities (+ and -) on the pacing cables and pacing generator - **The physics of pacing has electrons leaving the generator thro' the negative (–) terminal, entering the heart and then returning thro' the positive (+) terminal.** Rarely, one may find that the only one PW has contact with the heart. In this situation, reversing the polarity of the system may be useful. This is most easily accomplished by turning the pacing cable around on the headers at the top of the pacing generator.
  i. If single lead, the heart lead should be connected to the (–) terminal and the subcutaneously placed lead is connected to the (+) terminal.
  j. Temporary pacing wires are usually reliable for periods of more than 2 weeks
  k. If rapid or progressive increases in threshold are noted, new wires or early implant of a permanent pacemaker would have to be considered if the patient is pacemaker dependent.
  l. The threshold of pacing wires can be increased in the presence of **ANY** acidosis (**metabolic or respiratory) note: therefore, be cautious for sudden loss of capture and bradycardia in pacing dependent patients with unrecognised acidosis (blocked ETT tube, low cardiac output, anaemia, etc.)**

- **THE PACING GENERATOR - CHOICES**
  a. PACE - can pace and sense both atrium and ventricles
  b. Medtronic – old – can pace both atrium and ventricle but can sense only the ventricle
  c. Single chamber high rate devices

- **THE PACING GENERATOR CONTROLS**
  - **SENSING**
    - **Amount of energy it takes for the pacemaker to recognize that a native complex or depolarisation has occurred.** Degree that pacemaker detects impulse, lower mV = more sensitive.
    - Note the numbers on the sensing panel represent the minimum size of the ventricular signal that the pacemaker will recognise thus higher numbers are less sensitive.
    - Sensing problems are often the root cause of abnormal pacing behaviour. **If the pacemaker is putting out pacing spikes "on top of" the patient's underlying rhythm, it could be that the sensitivity number needs to be reduced. for example, reducing the sensitivity from 2mv to 0.5mv means that, now, the pacemaker will electrical activity down to 0.5mv as the patient's underlying native activity. on the other hand, lower numbers for sensitivity also may mean that the pacemaker could be fooled by the patient's muscle activity, tremors, or bedside care into thinking that real underlying heart beats are occurring, when, in fact, all that is going on is arm or chest movement.**
    - Just as systole is only as good as diastole, pacing is as good as sensing.
    - Sensing ranges from 0.1 to 20 mV.
    - Inappropriate sensing may be the cause if there is possibility of competition of the patient's rhythm.
  - **OUTPUTS (ATRIAL AND VENTRICULAR)**
    - The current delivered (during a fixed pulse width) through the wires to the heart. Most patients need at least 1mA to capture (see thresholds below) and some will have either skeletal or diaphragmatic capture, particularly thro' the atrial leads, at outputs above 10mA. **It is also possible that higher outputs on the atrial wires may actually be captured by the ventricle.**
    - Threshold - Minimum stimulus needed to consistently capture.
  - **RATE – VENTRICULAR**
    - Determines the number of milliseconds from the previous ventricular event (whether sensed or paced) that the pacemaker waits before the ventricular channel fires.
    - Max rate on PACE is 180.
    - Rapid rate pacing under special parameters for overdrive pacing.
  - **AV INTERVAL**
    - Determines the number of milliseconds **after an atrial signal (paced or sensed) that the pacemaker will wait for native ventricular activity, before going on to put in its own ventricular pacing spike** (regardless of what the atria are doing).

- **PACING – CONFIGURING THE CONTROLS**

  - **SENSING - FIRST – DETERMINE THE VENTRICULAR SENSING – SET THE FOLLOWING**

    - The ventricular and atrial outputs to a min of 0.1 mA and
    - Ventricular rate to a minimum of 30
    - The ventricular sensitivity to the lowest number 1.0mV
    - Turn on the pacemaker
    - See the display and the patient's ECG
    - Turn the sensitivity up until the sensing R no longer flashes up in time with the QRS or you begin to see the V flashing or both
    - The maximum value at which there is consistent sensing defines the sensing threshold.
    - Usual practice is to have a sensing margin of at least 2 times – e.g. if the pacemaker senses at 8, set it at 4 or less.

  - **VENTRICULAR THRESHOLD**

    - Once you have establishes that the pacemaker is sensing safely, you can move on to determining the ventricular threshold without concern about asynchronous pacing and pro-arrhythmia
    - Turn the vent rate up to a number above the patient's own rate, until you see the V flashing consistently
    - Note that your ventricular output should still be at 0.1 mA and thus no change should be evident on the ECG.
    - Now, while watching the ECG (not the pacemaker) increase the vent output until you see both a change in QRS morphology and a change in the rate to what you set

- The minimum value when you see a consistent pacing defines the pacing threshold.
- Usual practice is to have a pacing safety margin of at least 2 times (or 3 times if the patient has an unstable escape rhythm) – if the pacing threshold is 3, set at 7 (or 10).

Note that pacing temporary wires at unnecessarily high outputs may lead to premature carbonisation of the leads and degradation of wire function.

- **ATRIAL THRESHOLD**
  - This is most easily done in the patient with intact AV nodal conduction
  - Patients with slow or unstable rhythms should be configured in ventricular pacing initially, and then the atrial output adjusted as described in AV sequential pacing.
  - With the pacemaker sensing the safely the ventricular and the vent output at a minimum
  - Set the rate to a number above the patient's own rate
  - Now watching the ECG, (not the pacemaker) increase atrial output until you see a change in the rate to what you set
  - You should also see each atrial pacing spike, usually followed by a p wave then a narrow QRS after a brief delay at the AV NODE
  - If you are pacing the atrium and the QRS complex becomes abruptly wide without a P wave or AV interval then what you believe to be your atrial wires may not be. **but also, because atrial wires are often placed near the purse-string suture used to close the right atrial bypass cannulation site, it is quite possible for higher output atrial pacing to be easily captured by the patient's ventricle. if one checks an anatomically correct picture or specimen, one can see the right atrial appendage lies over the anterior surface of the right ventricle.**
  - The minimum atrial output that consistently captures the atrium and conducts to the ventricle defines the pacing threshold

- **AV INTERVAL**
  Threshold may vary at different AV Intervals

- **PHYSIOLOGY OF PACING**
  - Mechanical contraction of the ventricles most efficient when depolarisation occurs via the normal His-Purkinje system. In a patient with sinus bradycardia and intact AV conduction, atrial pacing is more efficient than either dual chamber or ventricular pacing.
  - In a patient with AV block, dual chamber pacing that maintains AV synchrony is superior to ventricular pacing alone. Optimal AV delay (PR interval) for dual chamber pacing in a very young paediatric patient tends to be short (70 to 120 milliseconds); longer AV delays can result in atrial cannon waves and elevated filling pressures.
  - **The benefit of AV sequential pacing may not be manifest in increase in BP but rather augmentation in cardiac output and a decrease in left and/or right atrial line pressures ("filling pressures").**

- **MODES OF PACING**
  - **Emergency ventricular pacing (VOO) –** to be used in patients who are either asystolic or have severe bradycardia with hemodynamic compromise.
    - Set mode on VOO, turn vent output to 20mA, turn to asynchronous mode
    - Adjust the ventricular rate
    - If no capture, try reversing the polarity of the pacing cables, and check integrity of connections
    - Note that many of these patients may have other confounding problems (ischaemia or acidosis) and their capture thresholds are quite high until their circulation or myocardium is resuscitated by other means
    - Pacemaker dependent patients with poor thresholds or safety margins should have an alternative modality of pacing immediately available. Note that if you are asynchronously pacing, if the patient develops their own rhythm or significant ectopy there is a risk of inducing ventricular tachycardia or fibrillation.
    - Usually patients sick enough to require VOO pacing are sick enough to justify to presence of a defibrillator at the bedside – if one is not yet present, take the time now to bring it over. Most defibrillators also have the ability to do transcutaneous pacing – another good reason to have it available.

  - **Demand ventricular pacing (VVI)**
    - To be used in patients who need a backup in case of sudden unexpected bradycardia or in patients with identified AV conduction block in whom AV synchrony is not thought to be

necessary or achievable (e.g. if no atrial wires are placed). Note that this mode requires the establishment of satisfactory ventricular sensing. Once this is done, you can easily establish a ventricular capture threshold and then set a minimum rate at which you wish the pacemaker to start pacing.

- **ATRIAL PACING**

  Useful in patients with sinus bradycardia or sinus arrest, but who have intact AV conduction. Also useful in junctional tachycardias

  - **AOO –** advantage of simplicity but may require ongoing adjustment if the patient's underlying rhythm changes. It is asynchronous in the atrium, and thus carries the risk of inducing an arrhythmia (usually not ventricular, but still potentially hemodynamically embarrassing.
    - Turn the ventricular output and sensing all the way to minimum (minimum output and asynchronous).
    - Set the AV interval to 0msec, which serves as a reminder to others that you are not AV pacing, and does not influence pacemaker behaviour in this mode.
    - Select your pacing rate using the 'ventricular rate' adjustment then gradually increase the atrial output until you see evidence of capture.

  - **AAI – advantage of adding the atrial systolic contribution to the cardiac output**
    - Check atrial sensitivity
    - Check threshold and set voltage

- **DVI – (AV sequential) Usual indication is AV conduction block.**
  - First establish a satisfactory VVI pacing mode – hopefully will stabilise the hemodynamics somewhat and then give time to adjust the remainder of the set up.
  - While VVI pacing, set the AV interval to a high number – 200msec
  - Watching the ECG, gradually increase the atrial output until you see evidence of atrial capture (P waves following the A pacing spike)
  - You should see evidence in the invasive pressure tracings that you have achieved hemodynamic AV synchrony
  - Cannon waves should disappear from CVP, RA and LA lines and if there was beat-to-beat variation in arterial pressures, it should have vanished too.
  - Note that many patients with AV block in the CCU will have an underlying sinus tachycardia 'hiding' in the ECG baseline
  - Thus in order to achieve AV Synchrony, you must be pacing faster than the underlying sinus tachycardia. Usually the sinus rate is measurable from the wire study you should have already done o establish the diagnosis of AV Block. Once you have established AV synchrony you can adjust the AV interval to achieve the most favourable hemodynamics.

- **DDD – (AV Universal)**
  - Paces and senses the atrium and ventricle and can act in different modes depending on the underlying rhythm
  - If AV conduction is intact, but the rate is slow, the pacemaker may appear as an AAI system, pacing the atrium but allowing AV conduction to result in intrinsic QRS complex.
  - In the presence of AV block but an adequate atrial rate, the pacemaker can track the atrial rate, time out a programmed AV delay in the pacemaker (generally anywhere from 70 to 240 milliseconds) and pace the ventricle when an intrinsic ventricular event is not sensed in the allotted AV delay time interval
  - The DDD mode in AF or A Fib can result in a rapid ventricular rate depending on programmed timing cycles.

RAPID OVERDRIVE PACING

- Only applicable for re-entrant SVT including atrial flutter
- Applied for short time – 3-5 seconds, rate 10-40 bpm higher than the tachyarrhythmia
- Risk of accelerating ventricular rhythm

OTHER PACING AVAILABLE

a. Transcutaneous pads
b. Transvenous
c. Oesophageal

Aparna Hoskote