INTERNAL MEDICINE

2019

A short meander around electrocardiography, clinical neurology and clinical examinations.

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Introduction

I have been a physician for 38 years now. Towards the end of my career I have become a Senior Associate Professor of Aimst University, Bedong, Kedah and teach final year medical students, just before graduating to become functional doctors.

I was both impressed with their enthusiasm and keenness to learn, and an awareness of large gaps in understanding, especially Internal medicine; general principles, and ECGs and neurology.

In a moment of enthusiasm I started writing this book, mainly directing it towards the first two years of the three clinical years of training.

A group of newly graduated doctors assisted me carrying all the laborious chores and pushing me to finish.
I am extremely grateful to
Dr Cornelius Lee Chun Yin
Dr Dharshini Saminathan
Dr Tan Wan Ying
Dr Ang Yee Quan

My sincere wish is that medical students find this book an entrance to understanding the basics of Internal Medicine

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Electrocardiography

2018

Electrocardiography 2018

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The Heart's Conduction System

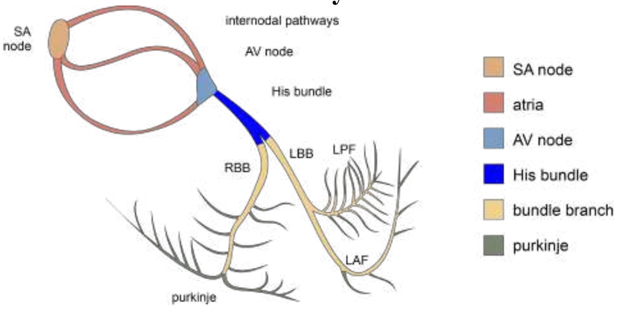
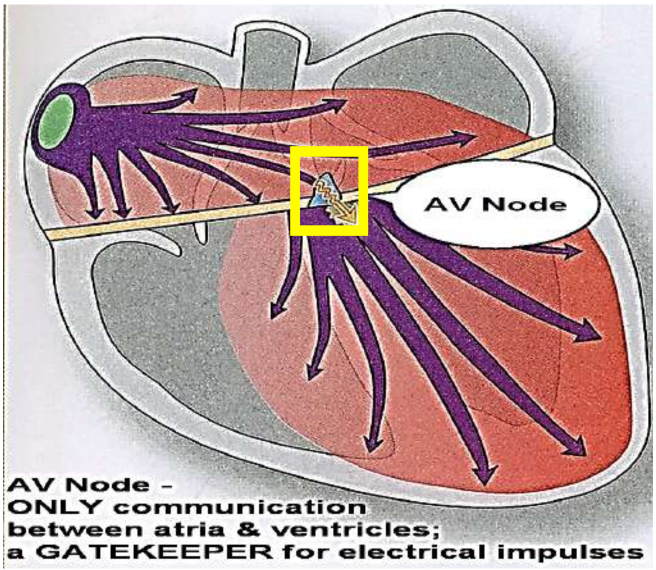


Figure 1: The conduction system of the heart

Electrically, the atria and ventricles are separated. Both atria are one, whereas both ventricles are one, and the only connection between the atrial and the ventricular conduction system is the ***atrio-ventricular (AV) node***.



The AV node is, in some ways, more important than the sino-atrial (SA) node. Many electrical impulses from the atria are blocked by the AV node and thus protect the ventricles from tachyarrhythmia (eg: if atria fires at more than 200 bpm and can even fire at 400-600 bpm). If the AV node is non-viable, then the ventricles are not protected. This may result in higher morbidity and mortality.

Physiologically, it is found that the area around the AV node (junctional area) has the same function as the AV node. The differences between the AV node and the junction are minor and insignificant. In conclusion, the AV node is equivalent to the junction, functionally.

The Heart's Conduction Pathway

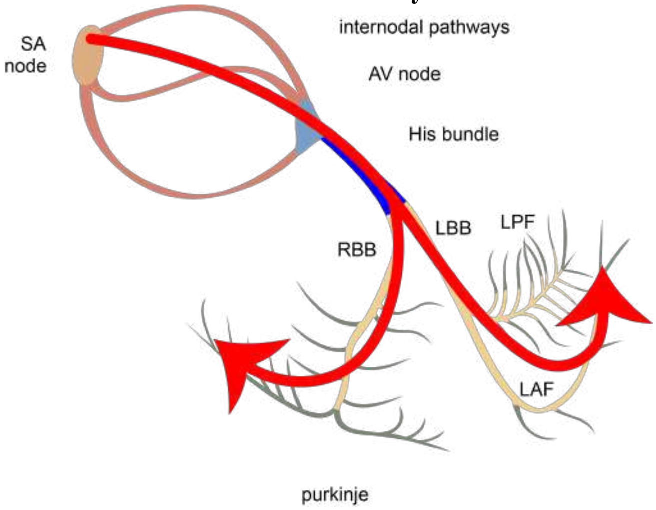


Figure 2: The conduction pathway of the heart

Physiologically, the electrical current arises from the *SA node*, travels through the *walls of the atria*, and reaches the *AV node/ junction*. From there, it is conducted down the *His bundle*, and to the *left and right bundle brunches* and to the *purkinje fibres*.
It is important to note that the left bundle brunch divides into 2 more branches, namely the

(i) *Left anterior fascicle (LAF) and the*
(ii) *Left posterior fascicle*.(LPF)

★★★★★ Why does the ECG have 12 leads? ★★★★★

Story of the elephant and 3 blind men

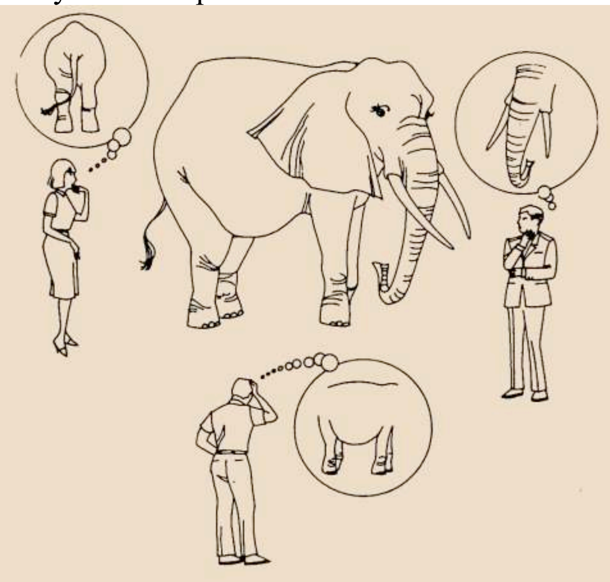


Figure 3: *"There were 3 blind men standing around an elephant. The first man touched one of the elephant's legs, and thought the elephant only consists of one leg. The second touched the trunk, and thought that the elephant only consists of a trunk. The third touched the tail, and thought the elephant only consists of a tail.*
However, none could picture the whole elephant."
Similarly in an ECG *NO **ONE** LEAD* can see the whole heart
Explanation: Each ECG lead shows the electrical activity of a part of the heart. Together, they help picture the electrical activity of the entire heart.

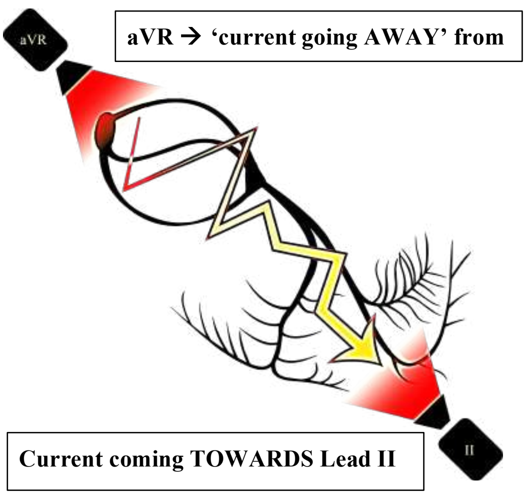


Figure 4: An illustration depicting Leads II and aVR as 'cameras' viewing the direction of electrical impulse.

Generally speaking, the heart's electrical impulses travel in the direction from Lead aVR to Lead II (5 o'clock direction). In other words, Lead aVR records the current as moving **away from**, whereas Lead II records the current as moving **towards**.

It should be noted that both leads are recording the same current. The recordings on Lead II are the **reflections** of the recordings on Lead aVR.

Therefore, the ECG would appear like the illustration given in Figure 5.

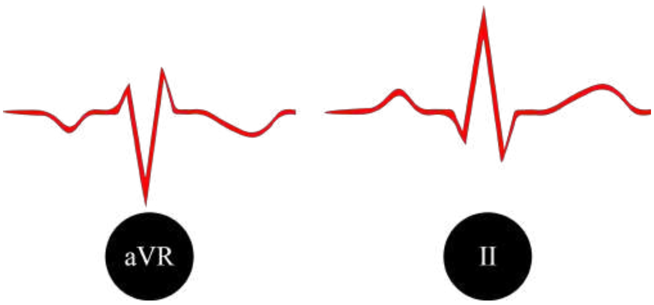


Figure 5: The appearance of ECG waves on Leads aVR and II.

Origin of electrical impulses

"The longer the journey of the current,
the longer the time taken for travel,
the wider the QRS complex on the ECG."

Electrical impulses can be considered as coming from **above** or **below** the *His bundle*.

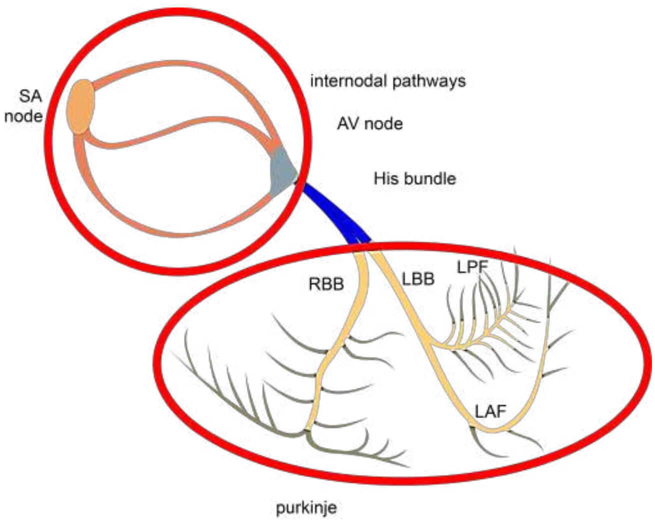
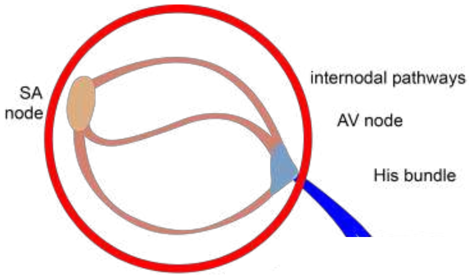
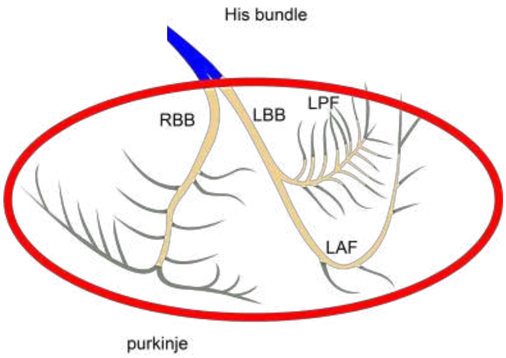


Figure 6: The red circles indicate possible origin of electrical impulses.



Origins of current *above* the His bundle:

1. ***Sino-atrial (SA) node***
2. ***Atrial tissue***
3. ***Atrio-ventricular (AV) node***



Origins of current *below* the His bundle:

1. Right ventricle
2. Left ventricle
3. Sometimes either bundle branch / purkinje system

Significance of current origin:

- ECG showing a ***narrow*** QRS complex
- (<3 sm sq / <120 ms) suggests that the current arose from *above* the His bundle. Probably 90% of ECGs appear like this.
- ECG showing a **broad** QRS complex (>3 sm sq / >120 ms), often suggests that the current arose from *below* the His bundle (eg: ectopic ventricular beats).
- In some cases, the QRS complex is **broad *even though the current arose from above the His bundle***. (eg: LBBB, RBBB with 'rabbit ears', WPW syndrome). Note that *if there is a **'P'** wave preceding the **broad QRS** complex, it suggests that the current came from **above** the His bundle.*

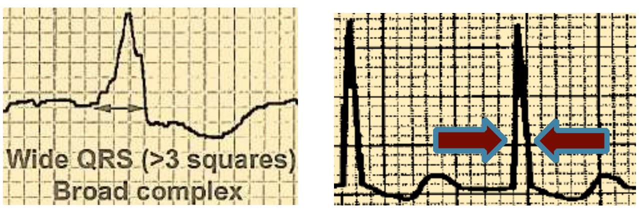
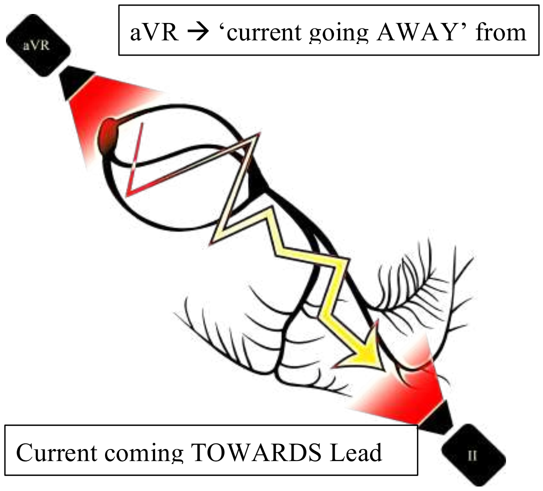


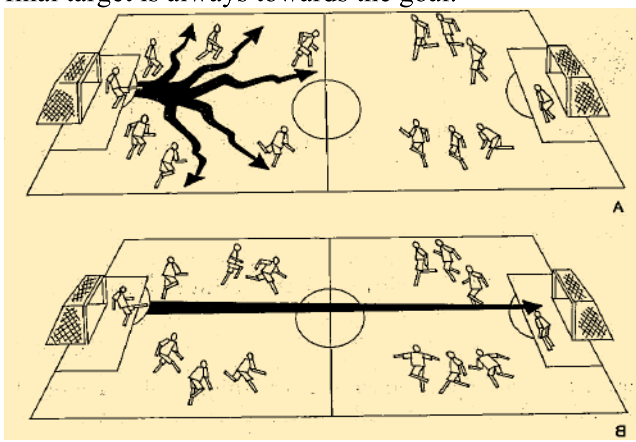
Figure 8: (**Left**) Wide QRS complex->3 small squares,
(**Right**) Narrow QRS complex- < 3 small squares

Direction of the electrical impulse

Physiologically in a 3-dimentional manner, the electrical impulse of the heart travels in a direction of the axis formed by the **tip of your right shoulder to the left 5th intercostal space at mid-clavicular line surface marking.** (Current is always travelling towards 5 o'clock direction.)



In soccer, regardless of the initial direction or pathway, final target is always towards the goal.



Similarly, though there are many small currents the final ***electrical axis*** direction is ***fixed***.

Lead placement=like "cameras" looking at heart

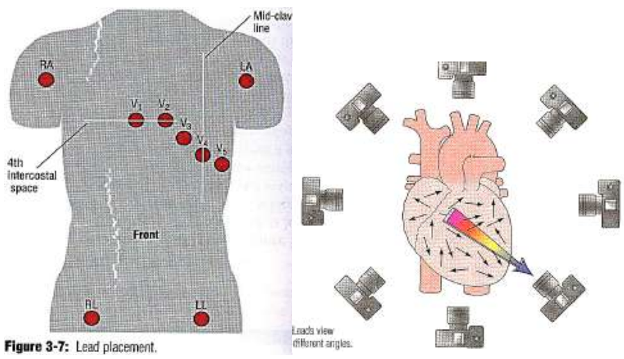


Figure 3-7: Lead placement.

Sinus Rhythm

*"A **sinus rhythm** on ECG produces 'normal' beats, termed **sinus beats**."*

"The patient is clinically dead with severe brain damage when there is no heart beat for more than 4 minutes."

A **sinus** rhythm refers to a **P wave** that is **immediately followed by a QRS** complex in the ECG. This means there is an atrial systole ('P' wave) occurs ***first*** followed by a ***ventricular systole.*** ('QRS')
With this, the atrium pumps 20-30% of blood volume into the ventricles. This increases the ejection fraction by 20-30%. (*Atrial Kick) The normal ejection fraction of the left ventricle is 55-65%.

In sinus rhythm, subsequent P waves are regular and easy to predict.

*__Atrial kick__ is defined as the *force contributed by atrial contraction immediately before ventricular systole. It increases the efficiency of ventricular ejection due to increased preload.*

Parameters of ECG interpretation

"This is how the current behaves"

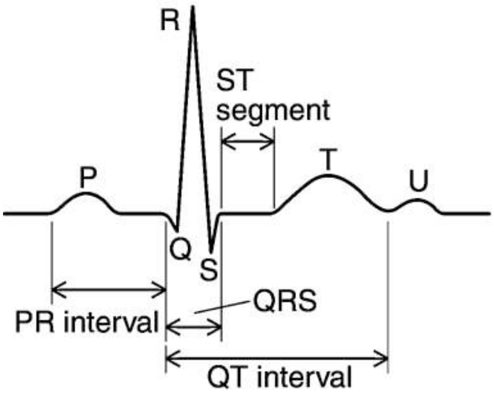


Figure 9: The components of an ECG wave.

ECG parameters for interpretation:

1) Heart rate
2) Rhythm
3) QRS complex
4) Cardiac axis
5) P-R interval
6) ST segment

1) Heart rate

< 60 bpm	60 – 100 bpm	> 100 bpm
Bradycardia	Normal	Tachycardia

** Resting heart rate of ~40 bpm is normal for athletes.*

2) Rhythm

** No such thing as **regularly regular or irregularly regular** rhythm.*

- Regular
- Regularly irregular
- Irregularly irregular

3) QRS complex

Rule 1 *"Every **P** wave should have a **QRS** complex. Every **QRS** should have a **P** wave."*

Rule 2 *"What is **QRS** width?"*
*< **3** small squares?*
*> **3** small squares?*

Rule 3 *" Are **P**s related to **QRS** ?*
– How? 1:1 ?
*/ more **P**s vs **QRS***
*/ less **P**s vs **QRS***
*/ **NO** relation between **P** and **QRS***

Rule 4 *" heart rate "*

*The 3 "**R**s" **R**ate / **R**elation of **P** to **QRS** / **R**egular*

4) Cardiac Axis

** Cardiac axis of electrical activity.*

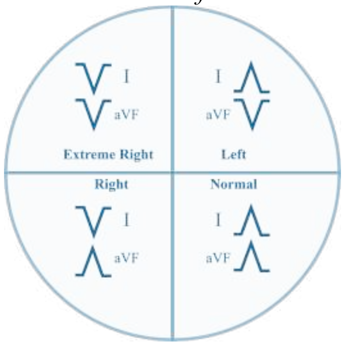
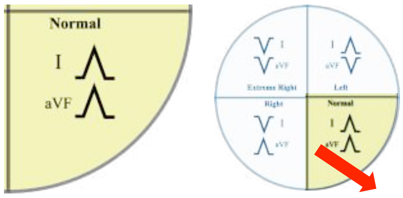


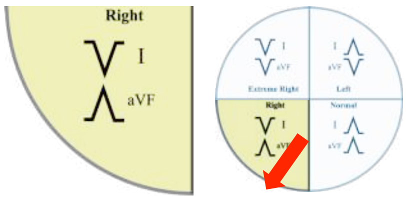
Figure 10: ECG appearance of cadiac axis.

*"Leads **I** and **aVF** are usually enough"*

The normal Cardiac axis is
Lead I positive (+), **aVF positive** (+)
pointing to '5 o'clock' direction.

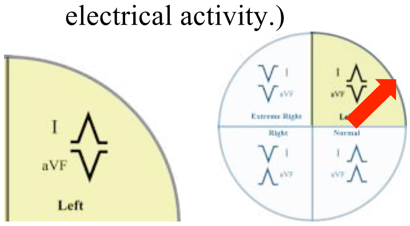


If **Lead I negative** (-), **aVF positive** (+)
Right axis deviation
(Prominent right sided electrical activity.)



If **Lead I positive** (+), **aVF positive** (-)

- *Left axis deviation* (Prominent left sided electrical activity.)



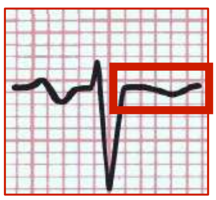
5) P-R interval

** Normal PR interval: 3-5 sm sq / 120-200 ms.*

- Prolonged PR interval (> 5 sm sq or > 200ms)
- (often seen in *1st Degree Heart Block*)

6) ST segment

- ST elevation
  (may suggest MI, pericarditis)
- ST depression



★★★★★
List 4 causes of Right Axis Deviation
★★★★★

Answer:
1. Cor-pulmonale
2. COPD
3. Right ventricular hypertrophy
4. RBBB

Normal appearance of the chest leads (V_1–V_6)

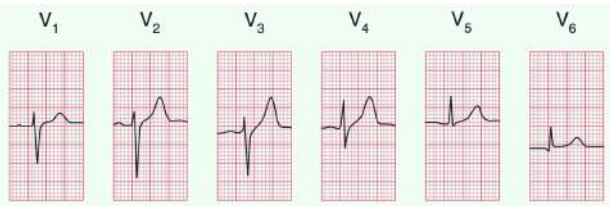


Figure 11: Normal ECG appearance of $V_1 – V_6$.
- 'R' ***increases*** 'S' ***decreases***
- V1 is like inverted image of V6.
- V1 has short R waves and deep S waves
- V6 is smaller than V5

Biphasic P waves in V1 in right atrial hypertrophy.
Biphasic P waves seen in lead V1.
Deep second phase is seen in patients with left atrial hypertrophy.

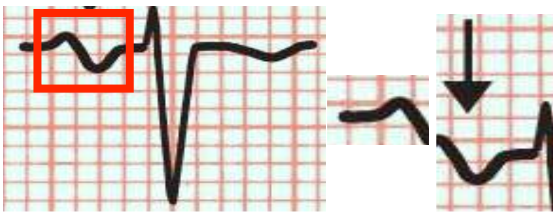
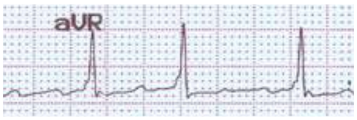


Figure 12: Right atrial hypertrophy. Biphasic P waves showing *short R* and *deep S* waves. The ***first upstroke*** represents Right Atrium depolarization, and the following ***down stroke*** represents Left Atrium depolarization.

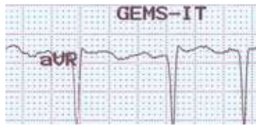
★★★★★
First rule of ECG interpretation
★★★★★

***** 1st rule(s) of ECG interpretation:**
1. Look at lead aVR. (To c*onfirm correct placement of the limb leads.*
   *If **aVR is positive**, then ECG lead placement is wrong.*)

aVR +ve



aVR -ve



EXTRA : * Differential diagnosis for aVR +ve is
(1) Wrong lead placement (2) Dextrocardia

1. Identify the lead you're interpreting.
2. Look for ALL the sinus beats PRESENT.
3. Lastly look at the abnormal beats
   (i) Look for premature beats
      a. (R-R interval shorter)
      b. Find their 'P' waves
   (ii) Look for WIDE QRS beats
      → any 'P' wave BEFORE the wide QRS?

*"Get comfortable with the patient's **sinus beats**. Once you're comfortable, you can focus on the **abnormal rhythms/ beats**."*

*"You cannot **assume** the lead if it is not marked."*

★★★★★
3 questions MUST be asked
★★★★★

"ECGs are not scribbles on a paper. Rather, they show the electrical activities of the heart!"

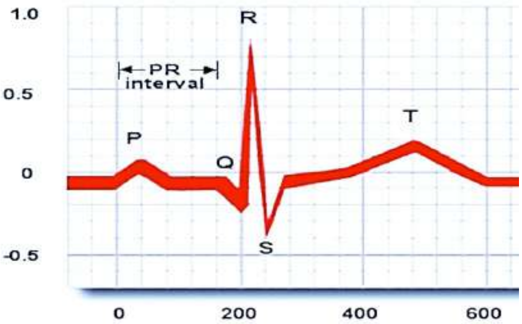
1. Where is the current **originating** from?
2. Which direction is it **travelling** towards?
3. Where does the current **end**?

Sample answer:
1. SA Node
2. Atrial Tissue
3. AV node / Bundle of His/ Bundle Branches
4. Purkinje Fibres / ventricles

★ 10 Rules for a Normal ECG ★

1. The normal PR interval should be 0.12 – 0.20s (3-5 sq)
2. The width of QRS complex should not exceed 0.11s (less than 3 sq)
3. QRS complexes are usually dominantly upright in Lead I and Lead II.
4. In limb leads (I, II, aVR, aVL, aVF) QRS and T waves tend to have the same general direction.
5. All waves are negative at lead aVR.
6. The R waves in pre-cordial leads must grow from V_1 to at least V_4. S waves must grow from V_1 to at least V_3 and disappear in V_6.
7. ST segment should start isoelectrically except in leads V_1 and V_2 where they may be elevated.
8. P waves should be upright at Lead I, II, and V2 to V6.
9. There should be no Q waves or only small qs in I, II, V2 to V6.
10. T wave must be upright in I II, V_2 to V_6.

1) Normal PR interval should be 0.12-0.20s (3-5sq)



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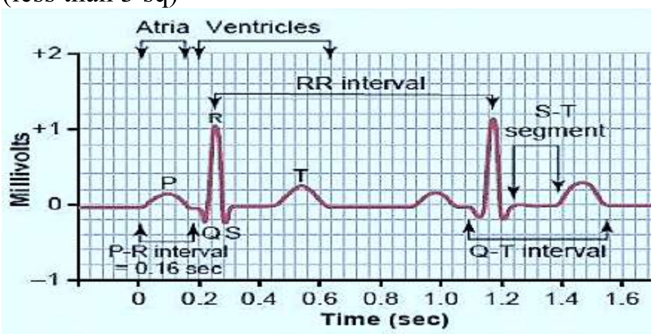
2) The width of QRS complex should not exceed 0.11s (less than 3 sq)



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3) QRS complexes are usually dominantly upright in Lead I and Lead II.

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4) In limb leads (I, II, aVR, aVL, aVF) QRS and T waves tend to have the same general direction. (*lead III exception*)

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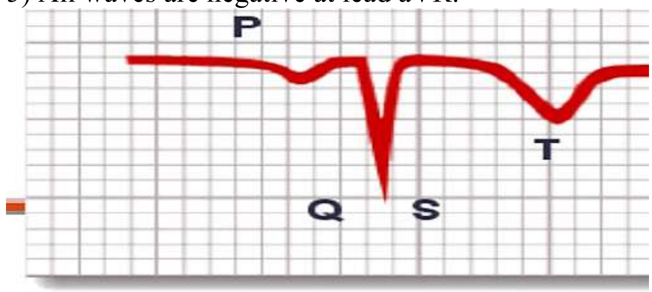
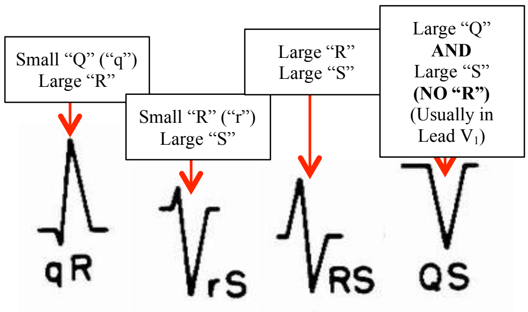
5) All waves are negative at lead aVR.



All waves are negative in lead aVR

Labeling QRS by size of each wave



*Unable to decide if it's a Q or and S, therefore QS was chosen.

- "Q" first downward deflection.
- "S" **any** downward deflection **AFTER** ➔
- **Any** upward deflection ➔ (that will be called "R")

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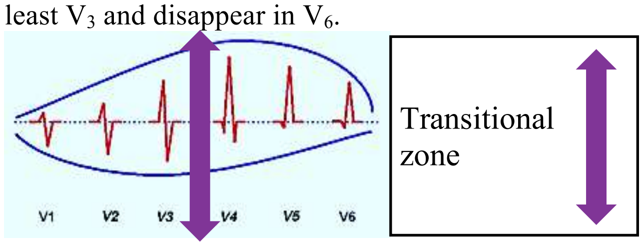
6) The R waves in pre-cordial leads must grow from V_1 to at least V_4. S waves must grow from V_1 to at least V_3 and disappear in V_6.



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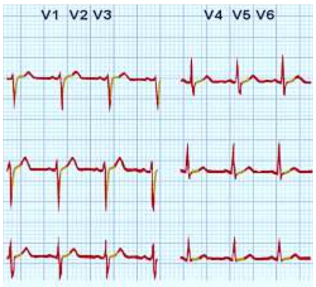
7) ST segment should start isoelectrically except in leads V_1 and V_2 where they may be elevated.



The following rules (*8, 9 and 10*) are identical for waves P, Q or q, T in
Leads I, II, V_2 to V_6.

---

8) P waves should be upright at Lead I, II, and V_2 to V_6.

Figure shows: Upright P waves

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9) There should be no Q waves or only small q wave in I, II, V_2 to V_6.

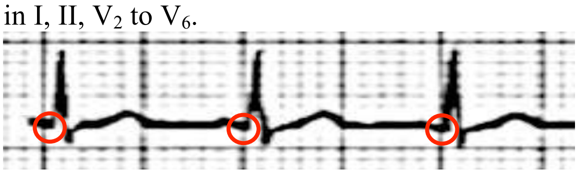

Figure shows: No Q waves

Figure shows: Small q waves

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10) T wave must be upright in I II, V_2 to V_6.

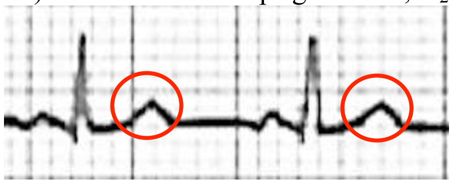

Figure shows: Upright T waves.

Summary

★ 10 Rules for a Normal ECG ★

1. The normal PR interval should be 0.12 – 0.20s (3-5 sq)
2. The width of QRS complex should not exceed 0.11s (less than 3 sq)
3. QRS complexes are usually dominantly upright in Lead I and Lead II.
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Waves P, Q or q, T in
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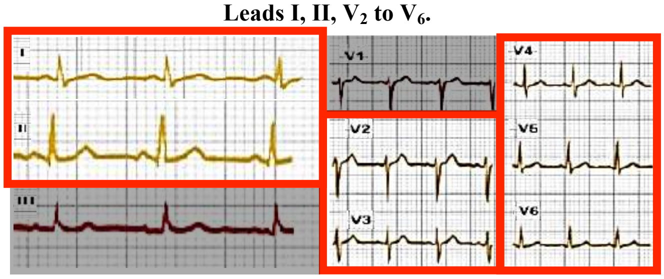

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10. T wave must be upright in I II, V_2 to V_6.

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Premature *vs* Escape beats

*'A **premature** beat comes **earlier than expected** (R-R interval shortened), whereas an **escape** beat comes **later than expected** (R-R interval lengthened)'*

*'You may be able to suppress premature beats, but you **should never suppress** escape beats.'*

The condition whereby the SA node fails to work is **Word did not find any entries for your table of contents.**a sinus arrest, appearing in the ECG as an abnormally shaped P wave.

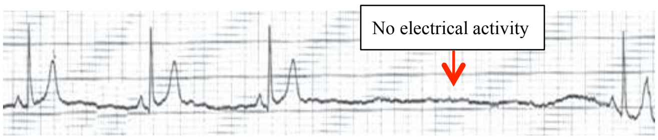


Figure: Sinus arrest.

Figure: Atrial escape. After a few milliseconds of sinus arrest, the atrial tissue fires to cause a beat, keeping the patient alive. Note the inverted (abnormal) P wave.

Examples of Premature and Escape beats.

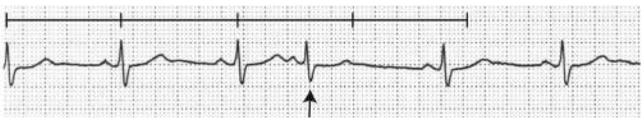


Figure: Premature atrial contraction. Note the shortened R-R interval. The beat appears earlier than expected.

Figure : Premature atrial contraction.

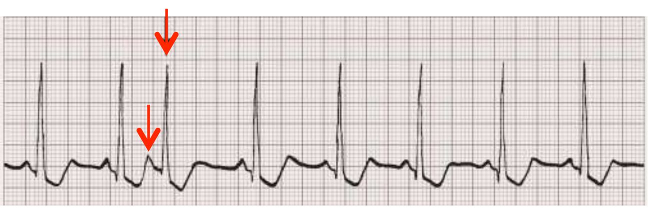


Figure : Premature atrial contraction. Note the abnormally shaped P wave as compared to the other normal P waves.

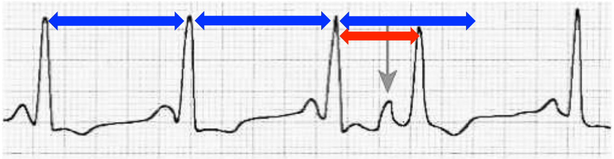


Figure: Premature Atrial Contraction (PAC). Note the early, abnormally shaped P wave (arrow), and the shorter R-R interval. The beat occurs ***earlier than expected***.

Figure: Atrial escape.

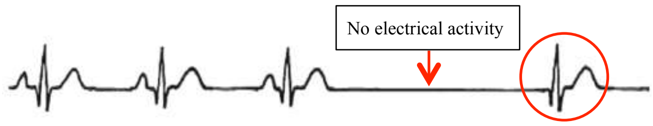


Figure: Nodal/ Junctional escape. After a few milliseconds of SA node not firing, the AV node fires spontaneously to keep the patient alive. Note that the ***QRS complex is narrow*** and there is no visible P wave.

Figure: Nodal/ junctional escape, with no visible P wave (red). Visible P waves are depicted in blue.

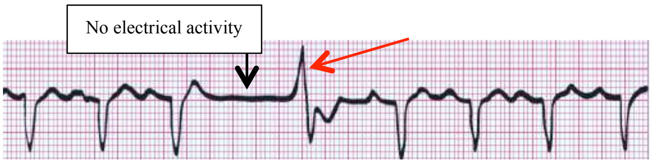


Figure: Ventricular escape. Note the singular abnormally shaped QRS complex.

Atrial Ectopics

Premature Atrial Contractions (PACs)

Just like the radiation of light from a light bulb, the current spreads in 360° (3 dimensionally speaking, it spreads radially in a spherical fashion). However, the radial spread is confined to the atria only. Once the current hits the AV node, it travels down the His bundle normally, and therefore a normal (Narrow) QRS complex. Figure 19.

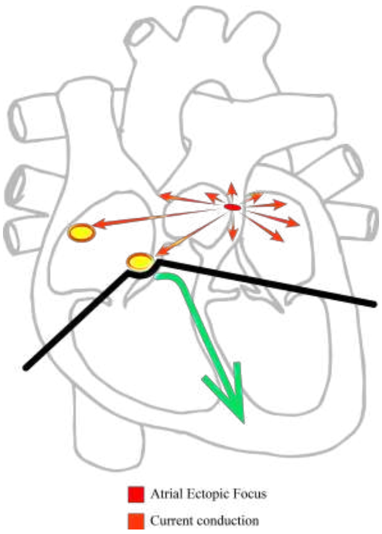


Figure: Atrial ectopic focus.
The current travels radially from the origin, but once at the AV node, it travels down the His bundle normally.

In the ECG, the 'P' wave appears '*abnormal*' ('different'), as the current arose from a part different from the SA node. Figure 20. .(atrial ectopic beat➔appears earlier than expected)

Figure: Atrial extrasystole (arrow and circle) The '***P***' wave appears abnormally shaped. It appears different than the other ***'sinus' P*** waves and the beat appears prematurely (shorter R-R interval).(atrial ectopic beat➔appears earlier than expected)

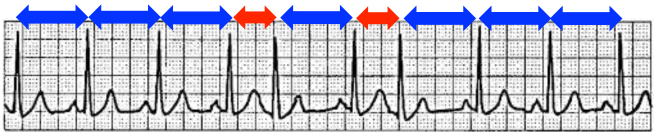


Figure: Multiple premature atrial ectopics. QRS appears earlier than expected.

"It is wise to compare the 'P' and QRS complexes to determine if one is abnormal"

'Low' Atrial Ectopics (PACs)
(*As seen by Lead II - and also III, aVF*)

"It is NOT a low atrial ectopic if the P wave is upright; It is a low atrial ectopic if the P wave is inverted."

(As seen in leads II, III, aVF*)*
In low atrial ectopics, the current commences from a region low in the atria near the AV node. Once fired, the *time taken for the current to reach the SA node is shorter than the time taken to reach the ventricles*. (current ***goes 'back'*** into atria = ***-ve P***) Figure 22.

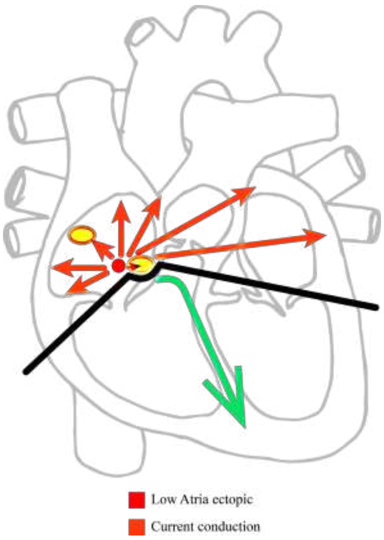


Figure: 'Low' atrial ectopics.
The current arise from a region near the AV node.
('P' is -ve *as seen by Leads II, III, aVF*)

The ECG would appear as follows (Figure 22):

- Narrow QRS complex.
- Inverted P wave (retrograde conduction of current in the atria, therefore P is inverted. Can be found in Leads II, III, aVF.)

Figure: 'Low' atrial ectopics. Inverted P wave.

Nodal / Junctional rhythm

"In a normal person, the SA node controls the AV node. The AV node builds up current, but is suppressed by the SA node; The SA node is always suppressing the AV node, unless the SA node stops firing…"
Then … a current from Atrial Ectopic will suppress the SA node for 1 beat; Similar event will occur for AV nodal beat"

In view of the beat suppression, the AV node will now fire spontaneously (and in all directions.) The current travels down the His bundle normally
(g narrow QRS complex). Figure 24.

It should be noted that:
Time for current going to Atria = Time for current going to ventricles.

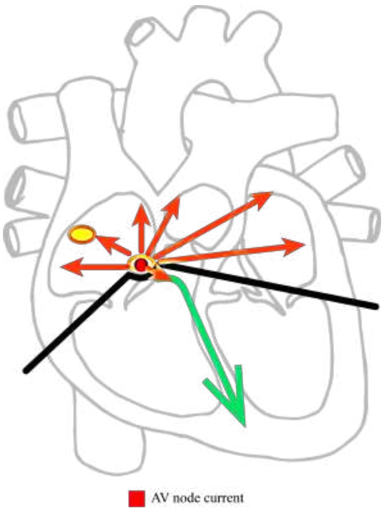


Figure: AV node/ Junction fires spontaneously in all directions. Time for impulse to reach atrium is equal to time for impulse to reach ventricles.

Thus, the ECG will show (Figure 25):

- Narrow QRS complex
- No ***visible*** P wave. (The P wave is hidden in the QRS complex (As both atria and ventricle receive current at the same time)

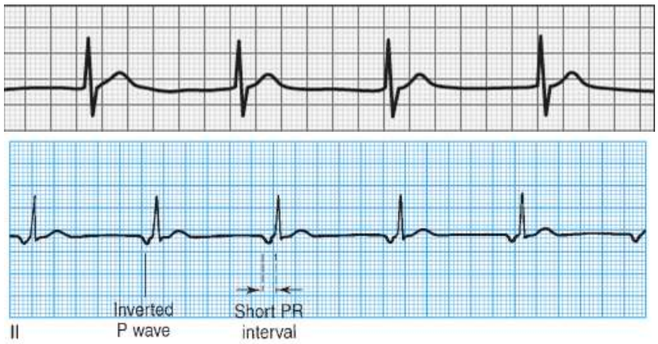


Figure: Nodal/ Junctional rhythm.
"Nodal/ Junctional rhythm ***usually has no visible P wave.****"*
If there are visible P waves, it is
i) Inverted   ii) shorter PR interval

"In a case of inferior myocardial infarction, the vagus nerve often suppresses the SA node; and then a ***Nodal / AV Nodal rhythm*** *can take over heart contraction."*

Figure: A short sinus pause, followed by an escape beat.(escape beat➔appearss later than expected) arising from the AV node; Note that the QRS complex is narrow (normal) despite spontaneous depolarization occurring at the AV node. The subsequent current travels normally down the ventricles.

Sinus Arrest

"Sinus arrest is very common in your working life."

The condition whereby the SA node fails to work is termed '*sinus arrest*'. An atrial ectopic usually follows a sinus arrest, appearing in the ECG as an abnormally shaped P wave.

Figure: A short sinus pause, followed by an atrial escape beat.(escape beat➔appearss later than expected) Note the abnormally shaped P wave and that the beat appears later than expected.

Figure: Atrial escape. After a few milliseconds of sinus arrest, the atrial tissue fires to cause a beat, keeping the patient alive.
Note the inverted (abnormal) P wave

Figure: A short sinus pause followed by sinus rhythm. The SA node first fails to fire on time, but later fires before AV node fires.

ECG will show (Figure 27 and 28):

- **Absence of predicted P wave.**
- **Subsequent (possibly abnormally shaped) P wave appears delayed,** followed by normal QRS complex.
- **Narrow QRS.**

Non-conducted atrial ectopics

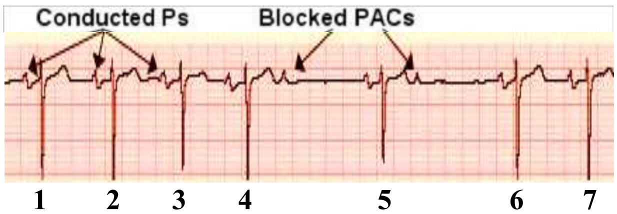


Figure: The above ECG showing conducted beats (1-7) and non-conducted (blocked) premature atrial contractions
(***P wave seen without a QRS after them***).

Premature Atrial Contractions (PACs) ***Further explained…***

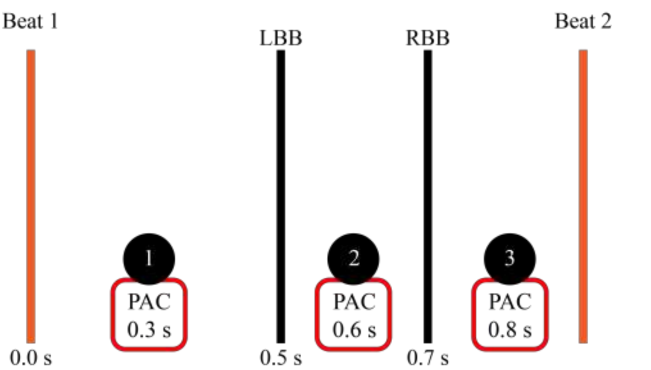


Figure: Schematic diagram illustrating beats and depolarization timing. *PAC = Premature Atrial Contraction, *LBB = left bundle branch, *RBB = right bundle branch.

3 above PAC at 0.8s – P wave with ***narrow QRS complex.***

Both left bundle and right bundles conduct the ectopic current (*Both repolarized after **LAST** sinus beat*)

PAC at 0.8s – P wave with narrow QRS complex

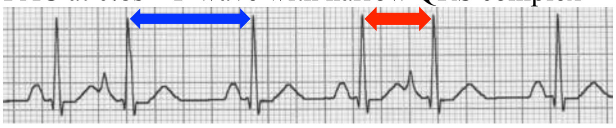


Figure: Note narrow QRS complexes. PAC with shortened R-R interval (arrow in red) (earlier than expected), and abnormally shaped P waves preceding PACs.

***Note: ALL BEATS HAVE P WAVES**

PAC at 0.6s – P wave with a wide QRS comples (its atrial P wave can be seen)
RBB still refractory (not repolarized) and does NOT carry the current.

Figure: PAC(Atrial Ectopic) with RBBB aberration.
1 Note the P wave (so its ATRIAL) and
2 wide QRS complex
Explanation: If there is a DELAY in ventricular current in LV ***or*** RV, ➔the QRS ***widens*** and

a) its called an ***"aberrant" beat or***
b) ***"atrial ectopic with aberrant conduction"***

PAC at 0.3s – P wave with no QRS complex
LBB and RBB still refractory.
(Not repolarized after the PREVIOUS sinus beat)

Figure: Non-conducted atrial ectopics (non-conducted PACs). Conducted and non-conducted P waves shown. Note that in the 'blocked PACs' the P wave is NOT followed by a QRS comlex.

T-P complexes

Appears when the P wave falls concurrently on the T wave of the ECG. The resultant T-P complex is (abnormally shaped) taller than the other normal T waves. BOTH the T wave (from previous beat) and P wave (from the next beat) have 'merged' (ONLY on the ECG paper).

Figure: T-P complexes

Multifocal atrial tachycardia

Figure: Multifocal Atrial Tachycardia. (MAT)

ECG of Multifocal Atrial Tachycardia (MAT) shows:

1. **Sinus beats (not in this strip)**
2. **At least 3 differently shaped P waves.**
3. **Irregularly irregular rhythm.**

Explanation: There are different sites of electrical foci in the atria which fire PACs. Often found in patients with underlying COPD.

Summary

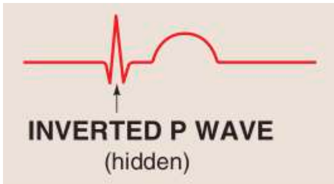
Premature contracture	Escape
Earlier than expected	Later than expected

Different appearances of P waves

"Abnormally inverted P wave appearing before QRS complex."

Inverted P because: Retrograde current conduction back into atria.

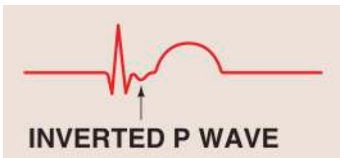
P appearing before QRS means: Atrial depolarized first, then the ventricles.



"Abnormally inverted P wave not visible. (Buried within QRS complex)"

Inverted P because: Retrograde current conduction back into atria.

P buried in QRS means: atria and ventricles depolarize at the same time.



"Abnormally inverted P appearing after QRS complex."

Inverted P because: Retrograde current conduction back into atria.

P appearing after QRS means: Ventricles depolarized first, then the atria.

______________ END ______________

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