Electrocardiography (ECG) Handout

Thanks to everyone who has looked at the EmergencyPedia page since we started in April 2013. Since the start we've been keen to include a FOAM ECG page to share our ECG collection and ideas. We have started by presenting an ECG checklist, OSCE station and more than 20 original ECG cases on this page (see below).

ECG interpretation is such an important skill for doctors, nurses and paramedics! There are already lots of Dedicated ECG 'FOAM' websites on the internet, all of which are excellent resources (we have listed our favourites on the front page). In combination with textbooks and real life cases, we think that FOAM sites are a great place to visit for up to date ECG education...

If you have cases your would like to share email andrewrcoggins@gmail.com

Please Read our Disclaimer @ http://emergencypedia.com/about

Introduction

Why is ECG interpretation an important clinical skill?

On a daily basis nurses, paramedics, cardiologists, GPs, physicians and many other practitioners routinely record and interpret ECGs. In the acute care setting a busy workload means that it can be challenging to accurately interpret all these tests in a short time. Core theoretical knowledge and practice of interpretation allow the learner to develop skills in ECG pattern recognition...

Furthermore, EmergencyPedia notes that in the Australasian Emergency Fellowship Examination ECGs constitute 25% of the Visual Aid Question (VAQ) component.

ECG interpretation is likely to remain a high yield topic in the future in many medical, nursing and paramedic exams. This is all for good reason, as the ECG is a commonly performed test in Acute Medicine and it is often poorly interpreted especially when a systematic approach is not applied.
ECG - Use of a System and Checklists

We have developed a **systematic approach** of interpreting ECGs that can be used as a learning tool or as a checklist. Learning this type of approach will probably be useful for both for ECG clinical cases and for passing exams (such as the FACEM Fellowship).

In both these situations (e.g. real life or an examination) ECGs need to be accurately interpreted under significant time pressure.

Our experience was that gradual study of an ECG textbook combined with using a systematic approach to ECGs encountered at the hospital quickly build up both theoretical knowledge about the ECG as well as an ability to recognise common problems...

If you are new to ECG interpretation, using a methodical approach at first helps develop the pattern recognition abilities that are common in experienced doctors and nurses... (i.e. *a good example of pattern recognition in clinical practice would be a nurse's "endofthebedogram" or "gestalt" suggesting that the patient is in hypovolaemic shock - she knew this was likely to be the problem because she had seen it many times before in her career*).

There are lots of examples of checklists in medicine (e.g. *Intensive Care*, *Theatre* and *Intubation*) and the experienced clinician can also make use of checklists and templates.

It is often said that the most commonly missed injury is said to be the "second injury". This second injury or problem often goes unnoticed due to a sense of 'relief' or 'satisfaction' which comes from the practitioner discovering the first abnormality... *Human errors (that we are all at risk of making)* are common and often predictable. Some of the common error producing pitfalls have been described as 'Search Satisfaction', 'Confirmation Bias', 'Anchoring' and 'Premature Closure'. These pitfalls are summarised in the following link and picture:

**Dr Chris Nickson’s Cognitive Pitfalls**
How is all this relevant to ECG interpretation? We believe that the same error producing pitfalls described above are also possible in the interpretation of ECGs. Jumping to a diagnosis without a checklist or systematic approach could be perilous as significant pathology could be missed.

**Look at the following ECG:**

You might notice that on the following ECG case example that the patient is in 'Rapid Atrial Fibrillation' just by a cursory glance.

However, it would be easy to miss the 'Inferior Myocardial Infarction' if you were distracted by the first (most obvious) abnormality...
The ECG Checklist

An ECG checklist or template, not only serves as a good learning tool for the novice ECG reader, but also should be useful for more experienced clinicians who are aware of 'human factors' and don’t want to miss significant abnormalities on the ECG.

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<tr>
<th>ECG TEMPLATE</th>
<th>Findings: Description of The ECG</th>
<th>Interpretation (Conclusions, Implications and Differential Diagnosis) of Findings</th>
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<td>When Taken</td>
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<td>Axis</td>
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<td>T-P Segment (Baseline)</td>
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<td>P waves</td>
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<td>PR Interval</td>
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<td>Q waves</td>
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<td>QRS Complexes</td>
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<td>Any Bundle Branch Block?</td>
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<td>ST segments (J-point)</td>
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<td>T waves</td>
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<td>QT interval</td>
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<tr>
<td>Other (U, J or Epsilon Waves)</td>
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</tbody>
</table>
ECG Basics - Recording the ECG

- This is a common **OSCE STATION** in Medical Student Exams
- Start with washing your hands and making sure the ECG machine is clean...
- Take the ECG machine to the bedside (plug in as necessary)
- Introduce yourself to the patient
- Check the patient's name and I.D. wrist band
- Ensure privacy
  - Ask for a chaperone to assist you as appropriate
- Explain to the patient what the ECG involves and what it is looking for
  - Generally we need informed consent:
    - "This is a routine test looking at the electrical activity of the heart. To do the test we need 3-5 minutes of your time. We will place about 10 sticky labels on your legs, arms and chest and connect some wires to the sticky labels. The machine then detects the activity of the heart. The machine doesn't give you a shock and the test (shouldn't be painful). The requesting doctor will look at your ECG test once it has been printed on the paper... Do you have any questions or concerns about having this test done?"
- Input patient details into the ECG machine
- Place the ECG Dots on the chest, legs and arms
  - Arms (AVR (right) and AVL (left))
  - Legs (AVF)
  - Chest Leads
    - V1 at 4th Intercostal Place at right sternal border
    - V4 mid clavicular line at the 5th intercostal space
    - V6 mid axillary line at the level of V4
- Record the ECG (i.e. press the record button)
- Print and label the ECG
- Indicate if there was any chest pain when the ECG was taken
- Thank the patient, clean the machine's leads and wash your hands
Does every patient need an ECG?

- Not every patient needs an ECG. However, the ECG is a cheap and reproducible test which is a standard investigation in the work up of many undifferentiated presentations in the Emergency Department (ED).

- Most advocate the liberal use of ECGs for Chest Pain patients but it is also useful in most medical and toxicological patients in the ED.

- An early review of any ECG taken is important because conditions readily diagnosed on the ECG such as Acute Myocardial Infarction are time dependent emergencies that are ideally recognised and treated as soon as possible. Therefore, viewing of ECGs by a senior doctor early is mandatory in many Emergency Departments.

- More about the efficient and safe work-up of chest pain patients can be found in the following NSW health document published in 2011 - Chest Pain Quality Improvement

ECG Basics
An Interpretation System

We found the process of learning ECGs frustrating at times. Despite many books and apps reassuringly titled along the lines of 'the ECGs made Easy' there is, in fact, often a significant degree of difficulty when starting learning about ECGs.

Rest assured, time and patience will get you to your goals eventually...

We suggest you practice as many ECGs as you can both from books and on the wards.

Dr Ken Grauer's 'Pocket Brain' resource is an up to date adjunct for learning at the bedside.

Find a copy by Clicking Here.
**The EmergencyPedia ‘ECG System’**

- **Identify Demographics** (name of patient, time take, old ECG for comparison)

- **Identify as a Complete 12 lead ECG** (e.g. not a derived ECG from a monitoring system)

- **Check Paper speed (25mm/s)**
- **Standard Calibration is 5mm by 10mm**

- **On the ECG look at the bottom centre (paper speed) and bottom right (calibration 'vertical block' of 10mm) for these details**

  We have circled the key areas to check in the following ECG portion:

  ![ECG Image]

  - At a paper speed of 25mm/s:
    - A 'BIG' square is 0.2 seconds in duration and a 'SMALL' square is 0.04 seconds

  **Click Here** for more on ECG Basics

- **RATE, RHYTHM and AXIS**
  - Rate (Big Squares are 0.2 seconds at a paper speed of 25mm/s) = 300/R-R interval squares
  - Rhythm (Card Method)
  - Axis
    - Lies at 90 degrees to Isoelectric Lead
    - This AXIS is Normal if I and II have a positive deflection and AVR is negative

- **Define the Baseline**
  - Look at the 'TP' Segment – use this to define ‘ST segment elevation’ and ‘PR depression’
    - The importance of this is described by Brady and Mattu in the following figure:
- **P waves**
  - P waves correlate with Atrial electrical activity arising in the Sino-atrial (SA) Node
  - The P wave is marked with the Red Arrow:

  ![P wave marked with Red Arrow](image)

  - Ask yourself:
    - Does each QRS complex have an associated P wave?
    - Is the rhythm Nodal in origin (Narrow Complex, No P Waves) or Ventricular in origin (wide complex and No P wave)

  - Types of P wave:
    - **A Bifid P wave** - May suggest Left Atrial Enlargement
    - **Peaked P wave** = P-pulmonale

      This can represent Right Atrial Hypertrophy or represent ‘a pseudo peak’ (Hypokalaemia)
Absent P Waves - Think of AF (most common), sinoatrial blocks, junctional and ventricular rhythms

- **PR interval**
  - What is the PR interval?
    - It should be 0.12 to 0.2 seconds
    - It is measured from the start of the P wave to the start of the QRS complex
  - Is the interval constant?
  - Is there a QRS complex for every P wave?

**Specific PR Interval Problems**

Is there a 1st degree heart block? (See ECG 14 below)

Wolf-Parkinson- White Syndrome (WPW) type I is Upright Delta Wave in V1

WPW type II is Down-going Delta Wave in V1
If increasing PR interval – Consider Wenkebach’s Phenomenon (AKA Mobitz I) - See ECG 13

Wenckebach Phenomenon (Mobitz Type I)

If constant but a QRS is dropped regularly – Consider Mobitz Type 2 Heart Block

Mobitz 2

P waves seen but NO association – this may be 3rd degree (complete) Heart Block

Complete Heart Block

- **PR Segments**
  - Depression in most leads or elevation of the PR segment in AVR is suggestive of Pericarditis when associated with concave up ST elevations globally

- **Q waves**
  - Non pathological waves are common
    - These represent normal L-R depolarization in the septum
  - Pathological is likely with the following:
    - Q waves more than 40ms (1mm) wide
    - Q waves more than 25% of R wave or Q waves more than 2mm deep
- **QRS Complex**
  - The QRS Complex (marked with the Red Arrow) should be less than 0.12 seconds or 3 small boxes
  - When prolonged suggests a conduction delay as depolarization occurs across the Myocardium. There is the bundle of His which becomes a right bundle, a left bundle with 2 fascicles (anterior and posterior) – these can become ‘blocked’ as a result of conduction delay due to Myocardial Ischaemia, Drugs or Electrolyte Abnormalities
  - Look at the Chest leads V1 – V6
    - If shaped as an ‘M’ in V1 (that is mostly positive RSR pattern in lead V1) and ‘W’ in lead V6 think MARROW – [Right Bundle Branch Block](#)
    - If shaped as W in V1 and M in V6 thing WILLIAM – [Left Bundle Branch Block](#)
  - You can have Unifascicular Block (that is an isolated BBB), Bifascicular Block (classically RBBB with Left Axis Deviation) and Trifascicular (RBBB, LAD, Heart block)

- **ST segments** (depression or elevation)
  - Elevation or depression of the ST segments classically represents Ischaemic Heart Disease and/or Myocardial Ischaemia. The elevation or depression is measured from the J point
  - **J Point** (the junction of the QRS complex and beginning of the ST segment)
  - How much is too much? This depends on the lead – in the Chest lead 2mm of elevation in 2 leads if significant, in the limb leads (further away) 1mm is significant
• QT interval
  o Represents Potassium channels – i.e. a marker of repolarisation
    ▪ Drugs or disease that cause QT interval prolongation can lead to sudden syncope or sudden death due to an arrhythmia called Torsades de Pointes (Twisting around the point). This is also known as Polymorphic Ventricular Tachycardia.
    ▪ While rare QT prolongation is a concern. Treatment includes Magnesium and Potassium infusions.
  o Consider using the QT nomogram to estimate risk of Torsades:

![QT Interval Nomogram](image)

• T waves
  o If peaked think about Hyperkalaemia. If Inverted (outside of III and AVR) think about Paediatrics (T wave inversions are normal in Kids) and young females (also normal variant). Pathological Causes of T wave inversion include Myocardial Ischaemia, Pulmonary Embolism, Cardiomyopathy, Electrolytes Disturbances and Stroke (especially Haemorrhagic)

• U waves (and T-U fusion)
  o Can be seen when the K is low – an ‘extra’ wave ‘blip’ after the T wave

• J waves (Osborn)
  o When seen are suggestive of Hypothermia

• Epsilon Wave
  o Rare finding that suggests Arrhythmogenic Right Ventricular Dysplasia

• Check for Pacemaker
  o Various problems and presence of a pacemaker are detected on the ECG

ECG interpretation is about pattern recognition. However, so as not to miss subtle abnormalities, and to gradually build up to an adequate level of expertise we need to practice.

In doing this it is best to use a systematic approach such as the approach outlined above. The best way to learn is to go through lots of sample ECGs (the textbooks below are good resources for this) and take a problem based approach to learning the theory...

We recommend various websites and books (not paid by them) including the following:
ECG Books

ECGs for the Emergency Physician
Amal Mattu and William Brady

150 ECG Problems
John R. Hampton

ECG Blogs

DR SMITH’S – ECGs (Minnesota, USA)

KEN GRAUER – ECGs (Florida, USA)

AMAL MATTU – ECGs (Baltimore, Maryland)

ECG WAVE MAVEN (Harvard, Massachusetts)
www.emergencypedia.com

EmergencyPedia's ECG Cases

ECG 1 - A 60 year old male patient presenting with Syncope pre-dialysis:

[ECG image with annotations]

ECG 10

Finding:

<table>
<thead>
<tr>
<th>Description of the ECG</th>
<th>Diagnostic of Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Patient</td>
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</tr>
<tr>
<td>Taken</td>
<td>ST depression 0.25mm s</td>
</tr>
<tr>
<td>Rate</td>
<td>Regular</td>
</tr>
<tr>
<td>Rhythm</td>
<td>T-wave, Extreme Left Axis deviation</td>
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<tr>
<td>Atria</td>
<td>Conduction, Depression</td>
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<tr>
<td>PR interval</td>
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<td>QT interval</td>
<td>0.36 s</td>
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<td>Complete</td>
<td>Yes</td>
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<tr>
<td>QRS duration</td>
<td>0.10 s</td>
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<td>ST segment</td>
<td>Depression</td>
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<tr>
<td>T wave</td>
<td>Depression</td>
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<td>LVH</td>
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<tr>
<td>LVH</td>
<td>Yes</td>
</tr>
<tr>
<td>RVH</td>
<td>Yes</td>
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<tr>
<td>Bundle Branch Block</td>
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<td>P waves</td>
<td>Normal</td>
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<tr>
<td>Atrial Fibrillation</td>
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</tr>
<tr>
<td>Pulmonary Atelectasis</td>
<td>No</td>
</tr>
<tr>
<td>Pmitral echo</td>
<td>No</td>
</tr>
<tr>
<td>ECG</td>
<td>N.D.</td>
</tr>
</tbody>
</table>

Conclusion: Some waves suggest Empiric RVH, but no LVH indicated.
ECG 2 - A 30 year old female patient presenting with recurrent palpitations.

Her heart rate is recorded at 190 on arrival:
ECG 3 - A middle aged smoker presents to the Emergency Department following a Cardiac Arrest

His ECG is taken on arrival following Return of Spontaneous Circulation (ROSC):
ECG 4 - An elderly man presents with light headedness and lethargy.

He is found to be bradycardic at triage with a blood pressure of 90/55:
ECG 5 - A man with a history of hypertension presents chest pain and palpitations.

This is his 12 lead ECG:
ECG 6 - a young male presents to the ED with flu like symptoms and a runny nose. He has a cough and mild chest pain associated with coughing paroxysms.

In the minors area of the ED the nursing staff perform a routine 12 lead ECG which is presented to you:

This ECG shows atrial to ventricular conduction via an accessory pathway (note the inverted P waves and very short PR interval with 'delta' waves). This ECG finding is highly suggestive of Wolf Parkinson White Syndrome (WPW), a relatively common condition affecting about 1 in 500 people. In WPW an accessory bundle ("bundle of kent") can allow for conduction from atria to ventricle bypassing the normal AV node pathway. The resting ECG shows a short PR interval (<0.12 seconds), delta wave (i.e. slurred upstroke into the QRS complex) as well as broadening of the QRS complex. There are two main sub-types of WPW: Type A (+ve delta wave in V1) and Type B -(ve delta wave in V1).

Emergencies associated with WPW include arrhythmia (e.g. SVT and AF) as well as a small increased risk of sudden death. Treatment of acute rhythm disturbances is generally best achieved with DC cardioversion rather than chemical (medication) cardioversion. In WPW with associated Atrial Fibrillation (AF) there is a specific risk of precipitating malignant arrhythmia by using AV node blocking drugs such as Verapamil and Metoprolol because the AF is transmitted rapidly to the ventricles increasing the risk of VF. Follow up with a cardiologist sub-specialising in electrophysiology studies and radio frequency ablation is appropriate.

More on Wolf Parkinson White Syndrome in Emergency Medicine can be found at the following tutorial:

www.youtube.com/watch?v=qrhWH2_KKOY&feature=youtu.be
ECG 7 - Following review by the local heart specialist a further ECG was taken showing a normal sinus rhythm and the patient was discharged home with outpatient follow up:
ECG 8 - A different patient presents with palpitations and a history of WPW:

WPW with Palpitations - a broad complex tachycardia is seen with pre-excitation complexes in Leads I and II

ECG 9 - The patient from ECG Case 8 has a further ECG taken after resolution of his symptoms:

Underlying WPW seen on Repeat 12 Lead ECG
ECG 10 - A 64 year old man with Acute Onset of Chest Pain

Faxed ECG from and Ambulance - Their patient has Severe Chest Pain and a history of smoking

ECG 10 (above) shows inferior ST elevation (III, II and aVF) with reciprocal ST depression in aVL. There are no specific features of a **Right Ventricular Infarction**.

The patient is sent to the Cardiac Catheter Lab and has the following findings (see next page):
Angiogram Findings for Patient from ECG 10
ECG 11 - The patient from ECG 10 has a repeat ECG on the Ward - he is asymptomatic and happy his chest pain has gone away. The nurses are very concerned about the patient having 'VT' and have drawn the broad complexes on the ECG to you attention:
Similar cases have been described by Amal Mattu on several occasions:

"Post-MI reperfusion arrhythmias often take the form of a regular, wide-QRS complex dysrhythmia with a rate of 90-120. The rhythm is often mistaken for VT. Treatment with “standard” VT medications is well-known to induce asystole."

In Summary, in the post MI patient who looks well and has a broad complex arrhythmia be careful not to make a premature diagnosis of 'VT' unless the rate is at least 120/minute. A reperfusion arrhythmia if present is likely to be transient and resolve on its own (this was the case with our patient and his follow up ECG is shown in 'ECG 12')

**ECG 12** - The patient from ECG 10 and ECG 11 has a repeat ECG taken which shows 'resolution of the arrhythmia'
ECG 13 - A 13 year old boy has a routine ECG in the Emergency Department

Mobitz Type I (Wenckebach Phenomenon)
The medical officer reviews the above ECG and diagnosed Type I Mobitz Heart Block (also known Wenckebach Phenomenon). In this case the patient is completely asymptomatic (there is no history of any cardiac symptoms or any family history of heart disease). The case is discussed with the specialist team who asked for a repeat ECG (shown below). After discussion it was decided to reassure the patient and family that Mobitz Type I on an ECG is likely to be a benign finding in children. However, it should be noted that in patients over the age of 45 that Mobitz I is associated with worsening heart blocks.

**ECG 14** - The patient from ECG 13 has a repeat ECG which is shown to the cardiologist.

The repeat ECG taken shows a first degree heart block. In teenage boys (this is the ECG of a 13 year old boy) first and second degree heart blocks are more common in athletically trained individuals (found in up to 20% of the population).
ECG 15 - a 20 year old female presents with lethargy and neck swelling. This is her 12 lead ECG:

ECG showing Sinus Tachycardia, QT prolongation and T wave inversions - The serum K was 2.3
Blood results (shown below) were obtained and she was treated for severe hypokalaemia with potassium and magnesium infusions via a central line placed with USS guidance.

<table>
<thead>
<tr>
<th>Group</th>
<th>Detail</th>
<th>Date</th>
<th>Value w/Units</th>
<th>Flags</th>
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Blood Results ECG 16

**ECG 16** - A patient presents to the ED with Shortness of Breath.

The nursing staff are concerned about his abnormal ECG:

Striking T Wave Inversion suggestive of Wellen's Syndrome
We were concerned following review of ‘ECG 16’ that the patient may have a cardiac lesion and he was monitored in the ED and referred to the Cardiology team. The patient’s angiogram (done within 24 hours) showed a >90% LAD occlusion similar to cases first described by Wellen’s et al with this ECG abnormality.

Angiogram and Echocardiogram

These findings and mimics of Wellen's Syndrome are summarised in the following videos:

www.youtube.com/watch?v=4Op76WcN7AA

www.youtube.com/watch?v=RdnwIWu5Hhg

The last two cases have had significant Anterior T wave inversions.

What is the differential diagnosis of Anterior T wave Inversion?

Causes of T wave inversion in the anterior leads (V1-V4)

- Anterior ischemia, LAD obstruction ex. Wellens syndrome
- Posterior infarction
- Pulmonary embolism (secondary to right ventricular strain)
- Cerebral T waves
- Yamaguchi syndrome: an apical hypertrophic cardiomyopathy
ECG 17 - 21 year old male patient with a week of 'flu like' symptoms. A 12 lead ECG is taken:

A further example of T wave inversion (this time it is widespread): This ECG was thought to be due to resolving Pericarditis
ECG 18 - An 80 year old man presents with Syncope. This is his 12 lead ECG:
A middle aged patient presents with light-headedness and a heart rate of 50. This is his 12 lead ECG:

<table>
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<th>Interpretation (Conclusions, Implications and Differential Diagnosis) of Findings</th>
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<td>Axis</td>
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<td>QRS Complexes</td>
<td>Bizarre QRS complexes</td>
<td></td>
</tr>
<tr>
<td>Any Bundle Branch Block?</td>
<td>Atypical LBBB</td>
<td>(current regarding Hypokalaemia)</td>
</tr>
<tr>
<td>ST Segments (T-point)</td>
<td>No changes</td>
<td></td>
</tr>
<tr>
<td>T waves</td>
<td>Peaked T waves</td>
<td></td>
</tr>
<tr>
<td>QT interval</td>
<td>450ms (Hard to delineate T wave)</td>
<td></td>
</tr>
<tr>
<td>Differential - Hyperkalaemia, MI, Sodium Channel Disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implications - High Risk of VF/Asystole</td>
<td></td>
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<tr>
<td>Conclusions - Hyperkalaemia - Urgent tx needed</td>
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</tr>
</tbody>
</table>
ECG 20 - A 70 year old man presents with fever and hypotension. The patient's 12 lead ECG is shown:
ECG 21 - A middle aged patient taking 'heart medications' presents with palpitations. This is his 12 lead ECG:

A similar ECG was seen in the 2012 FACEM fellowship exam:

Click Here - http://lifeinthefastlane.com/2013/01/ecq-quiz-037

In high grade blocks (e.g. flutter with 4:1 block) always think of drug toxicity, in particular digoxin toxicity.
ECG 22 - A middle aged smoker presents with palpitations. They have a heart rate of >160 unresponsive to vagal manoeuvres.

The patient's 12 lead ECG is shown:
ECG 23 - A 64 year old male with history of Coronary Artery Disease, Cardiac Stents and Pacemaker Insertion presents with chest pain whilst riding a bicycle.