ECG interpretation fundamentals and arrhythmia recognition principles

Robert M Gow
Department of Paediatrics
University of Ottawa
Faculty of Medicine
ECG fundamentals

Review

Lead theory and wavefront activation
Unipolar and bipolar leads
Determination of frontal plane axis
Determination of horizontal plane axis
ECG recognition of electrolyte imbalance
Systematic approach to arrhythmia recognition
ECG fundamentals

History

Augustus Waller (1856-1922)
First ECG 1887
Labelled V1 V2 then ABCD

Willem Einthoven (1860-1927)
PQRST
Einthoven’s triangle

Frank Wilson (1890-1952)
Unipolar leads
ECG fundamentals

Electrical field passes through lungs, muscle, blood, fat
Detected at skin
Spreads out from source (heart)
ECG fundamentals

• Skin resistance is critical to recording of electrical activity

• Resistance due to dry, dead, horny layer of epidermis

• MegaOhm resistance at surface (1 million Ohms)

• Simple abrading of skin reduces resistance to 5000 Ohms

• Good electrodes reduce to 100 Ohms
ECG fundamentals

Bipolar

Records difference between -ve and +ve terminals
-ve is subtracted from +ve
difference is recorded

Unipolar

Records difference between +ve electrode and remote zero
Impulse travelling towards electrode causes a positive deflection
ECG fundamentals

<table>
<thead>
<tr>
<th>Lead</th>
<th>+ve</th>
<th>-ve</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>LA</td>
<td>RA</td>
</tr>
<tr>
<td>II</td>
<td>LL</td>
<td>RA</td>
</tr>
<tr>
<td>III</td>
<td>LL</td>
<td>LA</td>
</tr>
</tbody>
</table>

True bipolar leads
Actual voltage not known
ECG fundamentals

Einthoven’s Law

\[ l + lll = ll \]

Simple check for lead misplacement
ECG fundamentals

Chest lead exploring electrode - unipolar

RA  LA

LL

ECG amplifier

+ve

- ve

5000 Ohm

Wilson central terminal
ECG fundamentals

Augmented limb leads

unipolar limb leads
compares one limb with the average of the other 2

For example lead aVR
unipolar RA is positive
average of LA and LL is negative
aVR equals the potential of right arm minus the mean of the potentials of left arm and left foot
ECG fundamentals

Lead theory

Vector: electrical forces have direction and magnitude
Heart vector - from activation and propagation
Lead vector - orientation of leads to heart vector

3 vector concept
is an extreme simplification
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- Frontal Plane

+ aVR -150°

+ aVL -30°

+ V1 0°

+ II 60°

+ III 120°

+aVF 90°

Hexaxial lead system
ECG fundamentals

Horizontal Plane Lead Vectors

Posterior

V1, V2, V3, V4, V5, V6

+ 90°
ECG fundamentals

vector away = negative
vector towards = positive
equiphasic = 90°

1 = septum
2 = dominant LV
3 = basal RV/LV
ECG fundamentals

QRS axis estimation

actually estimating a “mean” or average electrical forces
mean force estimated by area under QRS complex

then these are plotted as vectors on the hexaxial graph
ECG fundamentals

QRS axis estimation

Thankfully, measuring the area is not necessary.

The net amplitude of the QRS complexes can be used instead.

Resultant = (+10) + (-4) = +6
ECG fundamentals

Different methods for frontal plane QRS axis

• Can take any 2 leads, or all six

• Leads 1, aVF commonly used

• Lead with smallest or equiphasic complex identified, and axis is approximately 90° to this lead
ECG fundamentals

Not perfect, but good enough
ECG fundamentals

Horizontal Plane

- V1
- V2
- V3
- V4
- V5
- V6

right posterior
right anterior
left posterior
left anterior
ECG fundamentals

QRS axis

• affected by anatomic position of the heart

• properties of the cardiac conduction system

• developmental changes in RV/LV mass relationships

• conduction system most influential in mature heart
ECG fundamentals

Electrolyte abnormalities

Hypokalaemia
- ST depression
- lowering of T wave
- increase in U wave height
- $U > T$ suggests $K < 2.7$ mEq/l

Hyperkalemia
- Tall thin T waves
- PR prolonged
- QRS widens
- P waves disappear
ECG fundamentals

Electrolyte abnormalities

Hypokalemia

Hyperkalemia
ECG fundamentals

Electrolyte abnormalities

Hypocalcaemia
Prolongs QT interval (ST segment)

Hypercalcaemia
Shortening of QT interval (QTa – apex of T)
Systematic approach to arrhythmia recognition

Tachyarrhythmias
  Supraventricular
  Ventricular

Narrow complex
Wide complex

Regular, narrow complex/supraventricular principles behind the components of the algorithm
Regular narrow QRS tachycardia

visible P waves

Yes

atrial rate greater than ventricular rate

No

atrial tachycardia
atrial flutter

identify RP interval

Yes

RP < PR

RP < 70 msec

AVNRT
AT with 1º AVB

RP > 70 msec

AVNRT
AVRT, AT

RP > PR

atrial tachycardia
atypical AVRT/AVNRT
Systematic approach to arrhythmia recognition

Narrow complex/supraventricular (normal QRS duration, appearance)
QRS normal for age <120 msec (adults)

Classification schemes
Mechanistic
- automaticity/ectopic
- reentry
- triggered
Anatomical
- atrial, junctional, accessory pathway
AV relationship
- independent, dependent
Systematic approach to arrhythmia recognition

Narrow complex/supraventricular

Combined anatomical/AV relationship

Dependent
the arrhythmia requires both atrium and ventricle
to continue

Independent
the arrhythmia continues regardless of the involvement
of the other chamber
Systematic approach to arrhythmia recognition

Narrow complex/supraventricular

Direction of activation
arrhythmia arises in the atrium
the atrial activity drives the ventricle

the atrium is activated by impulses that arise lower down (AV node, ventricle)
Sinus node atrial ectopic focus

Reentry circuit Atrial Flutter

Atrium

P=QRS
P>QRS

Ventricle

JET

P=QRS
P<QRS

Independent arrhythmias
Can have different rates in 2 chambers
Atrium may be faster in one, may be slower in other
More (or less) P waves than QRS complexes on ECG
Arrhythmia dependent on both chambers expect a 1:1 relationship one P for each QRS on ECG
Systematic approach to arrhythmia recognition

Narrow complex/supraventricular

<table>
<thead>
<tr>
<th>Condition</th>
<th>Anatomical</th>
<th>Indep/dependent</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNRT</td>
<td>atrium</td>
<td>independent</td>
</tr>
<tr>
<td>Atrial tach</td>
<td>atrium</td>
<td>independent</td>
</tr>
<tr>
<td>Atrial flutter</td>
<td>atrium</td>
<td>independent</td>
</tr>
<tr>
<td>Atrial fib</td>
<td>atrium</td>
<td>independent</td>
</tr>
<tr>
<td>AVNRT</td>
<td>Atr/AV node</td>
<td>dependent</td>
</tr>
<tr>
<td>AVRT</td>
<td>Atr/Cond/vent</td>
<td>dependent</td>
</tr>
<tr>
<td>JET</td>
<td>AV node</td>
<td>independent</td>
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</table>
Systematic approach to arrhythmia recognition

Locate P wave
Calculate RP and PR intervals

- $\text{RP/PR} < 1$
- $\text{RP/PR} = 1$
- $\text{RP/PR} > 1$

Long RP tachycardia
Systematic approach to arrhythmia recognition

2 explanations for same ECG

1° AV block

A (or P)

V (or R)

slow

fast
Systematic approach to arrhythmia recognition

Regular, narrow complex tachycardia with no visible P waves

Could be simple, uncomplicated AVNRT
Systematic approach to arrhythmia recognition

Concealed atrial activity

adenosine
carotid sinus massage
Regular narrow QRS tachycardia

visible P waves

Yes

atrial rate greater than ventricular rate

No

Yes

atrial tachycardia
atrial flutter

identify RP interval

RP<PR

RP < 70 msec

AVNRT
AT with 1° AVB

RP>PR

RP> 70 msec

AVNRT
AVRT, AT

atypical AVRT/AVNRT
In general the common forms of SVT are short RP tachycardias (RP/PR<1), because the atrial activation is from rapid retrograde conduction to, and then activation of, the atrium.

Long RP tachycardias (those with a normal looking PR interval) are either tachycardias arising in the atrium, or unusual forms of SVT.

Sometimes it may be difficult to differentiate whether the atrium has been activated from the top or retrograde.
Systematic approach to arrhythmia recognition

The analysis of the electrocardiogram in narrow complex SVT requires an understanding of the possible mechanisms, anatomical substrates and atrioventricular dependence.

Being aware of all these features will usually enable an accurate diagnosis to be made on the electrocardiogram.