UNDERSTANDING AND INTERPRETATION OF THE PEDIATRIC ELECTROCARDIOGRAM
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Proper interpretation of the pediatric electrocardiogram and a careful cardiovascular examination form a powerful combination in the diagnosis of a normal heart or the presence of a cardiopathy.

Basic concepts

The electrical vector and the surface electrocardiogram: Standard and augmented limb leads.

Plotting the frontal axis of an electrical vector.

Interpretation of the electrocardiogram: step-by-step approach

1. - Rhythm – Sequence of the atrial depolarization (mean P axis)
   a- Sinus rhythm.
   b- Ectopic atrial rhythm.
   c- Recognition of situs solitus and right or left atrial isomerism.

2. - Atrial and ventricular rate
   a- Identify common arrhythmias.
      - Sinus arrhythmia
      - Premature atrial, junctional and ventricular contractions
      - Clinical significance
      - Sinus tachycardia vs supraventricular tachycardia (SVT)
      - Reentrant tachycardia: Wolff-Parkinson-White syndrome
      - Paroxysmal atrial tachycardia (PAT) - Acute treatment

3. - Intervals and clinical significance
   a- PR
   b- QRS
   c- QTc

4.- QRS axis
   a- Normal QRS axis.
   b- Right or left axis deviation.
   c- Superior (endocardial cushion defect) axis.
5. - Atrial enlargement (P waves)
   a- Right, left or bi-atrial enlargement

6. - Ventricular hypertrophy – Sequence of ventricular depolarization (QRS complexes) – Pediatric precordial leads (V3R-V7).
   a- Septal forces (q waves).
   b- Right ventricular hypertrophy - pressure and volume overload. Clinical correlations.
   c- Left ventricular hypertrophy – pressure and volume overload. Clinical correlations.
   d- Biventricular hypertrophy patterns – Clinical correlations.

7. - Ventricular repolarization (ST-T waves)
   a- Right ventricular “strain”.
   b- Left ventricular “strain”.

8. - Ventricular conduction defects.
   a- Right bundle branch block.
   b- Left bundle branch block.
   c- Interventricular conduction delay.

9. - Normal electrocardiogram in the newborn infant
   a- Septal forces (q waves)
   b- Criteria for right ventricular hypertrophy

10. - The electrocardiogram in the infant and child
    a- What makes a normal electrocardiogram to be normal!
Pediatric ECG Interpretation

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Pediatric ECG interpretation is fun (really) but you have to do it a lot!
Interpretation Approach

- Real
- Residents
- Always
- Harass
- Interns
- Regularly
- (incessantly)

Rate
Rhythm
Axis
Hypertrophy
Intervals (PR, QTc)
Repolarization
(ischemia/infarct)
Heart Rate

- Small box = .04 sec; large box = .2 sec.
A. count the number of small boxes between 2 QRS complexes and divide into 1500
B. count the number of R-R intervals in 6 large boxes (1.2 sec) and multiply by 50
C. memorize the intervals
3. When the tracing is unmouted, count the RR cycles between two markers (3 seconds) on the upper edge of the ECG paper and multiply them by 20 (Fig 1-3).

**Fig 1-3.**
Heart rate of 165 beats per minute. There are about 3.3 cardiac cycles (RR intervals) in 6 large divisions. Therefore, the heart rate is $3.3 \times 50 = 165$.

**Quick Method for Estimation of Heart Rate**
Rhythm

- Are P waves present and "married" to each QRS complex?
- Is there more than one P wave for each QRS
- What is the P wave axis? Is the P wave upright in leads I and aVF? (sinus rhythm)
- Is the P wave morphology constant?
Rhythm

- If the P wave is positive in lead I and negative in lead II and aVF, probable ectopic atrial pacemaker (usually benign)
- If the P wave is negative in lead I and positive in leads aVR, the arm leads are probably reversed (rarely situs inversus)

QRS Axis

- The QRS axis is the sum of the direction of the electrical activity of the heart
QRS Axis

- If the QRS complex is + in leads I and aVF, then the axis is between 0 and +90 (normal)
QRS axis

- If the QRS complex is negative in I and positive in aVF, this is RAD (or normal newborn)
- Think about:
  - RVH
  - RBBB
  - absence of left ventricular forces

QRS axis

- If the QRS is negative in aVF, this is a superior axis and is abnormal
- If the QRS is negative in aVF, look for q waves in leads I and aVL
- qR pattern in leads I and aVL signifies cushion axis or left ant. hemiblock pattern (think AV canal or tricuspid atresia and look at hypertrophy pattern)
QRS axis

- If the QRS is negative in aVF (superior axis) and negative in lead I with rS pattern in aVL, this is severe RAD
- Think of severe RVH or weird stuff (single ventricles, etc)

Hypertrophy - Atrial

- RAE = tall/peaked P waves in any lead (look in lead II and right precordial leads)
  - P wave greater than 2.5 mm in height
- LAE = widened P waves (> 0.08 sec if less than 1y; > 0.10 sec if more than 1 y)
  - also look for notched or bi-phasic p waves
- Combined atrial enlargement must meet both criteria
Right Ventricular hypertrophy

- CRITERIA:
  - pure R or RR’ in V3R/V1 (pressure overload, i.e. pulmonary stenosis)
  - qR in V3R/V1 (can not have q also in left precordial leads) is severe RVH
  - RSR’ with R’>R wave in V3R/V1 (volume overload pattern, i.e. ASD)
  - tall R in V3R/V1, deep S in V6/V7 (look at the R:S ratio)
  - upright T waves in V3R/V1 between 3d-8y

Left Ventricular hypertrophy

- CRITERIA
  - Tall R wave (>25mm) in V6 (large voltages in left precordial leads)
  - deep S wave in V3R/V1
  - deep (>3mm) Q waves in V6/V7 with tall R waves suggests volume overload (i.e. PDA)
  - also look at T-waves with LVH- if flat/inverted in left leads signifies LVH with strain
Bi-ventricular hypertrophy

- This is a "relative" phenomenon
- If criteria for RVH exist, are the LV forces still prominent?
- If criteria for LVH exist, are the RV forces still prominent?
- Large mid-precordial voltages (>50mm) suggests BVH

Intervals

- Check the PR interval, QRS duration, and QTc
PR interval

- Measure from onset of P-wave to beginning of QRS complex (usually look in lead II)
- represents conduction time through the atria and AV node
- varies with age and HR- but usually
  - infant < .12 sec
  - child < .14 - .16 sec
  - adolescent < .16-.18 sec

The long & the short of it:

**DDX long PR**
- idiopathic 1st heart block
- myocarditis
- digoxin toxicity
- hyperkalemia
- RAE

**DDX short PR**
- Pre-excitation (like Wolff-Parkinson-White or Long-Ganong-Levine)
- ectopic atrial pacemaker
PR Interval

- If PR interval is variable- look for evidence of 2\(^\circ\) heart block (Wenkeback) with progressive prolongation of PR followed by dropped beat
- Also make sure the P is actually associated with the QRS (if not- this is complete heart block)

QRS duration

- represents ventricular conduction time
- should be less than .10 sec (usually .08)
- DDX long QRS:
  - right or left bundle branch block patterns (especially post-op patients)
  - ventricular arrhythmias (PVC's, V-tach, ventricular pacing)
  - interventricular block (high K\(^+\), ischemia, etc.)
  - WPW
QRS amplitude

- Look at overall amplitude of QRS complex
- Be concerned about "low voltage" tracing
  - myocarditis
  - pericardial effusion
  - transplant rejection

QT interval

- Represents ventricular depolarization and repolarization
- measure from onset of QRS to end of T wave
- use longest QT interval on tracing
- must correct for heart rate
QTc

\[
QTc \text{ (sec)} = \frac{QT \text{ interval (sec)}}{\sqrt{\text{Previous RR interval (sec)}}}
\]

... Normal < 0.45 sec (newborns up to 0.49 but must be repeated/followed if prolonged)

Prolonged QTc

- Long QT syndromes (Romano-Ward or Jervell-Lange-Nielsen)
- myocarditis
- head injuries
- hypocalcemia
- drugs/meds (procainamide, quinidine)
- significance of long QT: at risk for ventricular arrhythmias/sudden death
Repolarization

- T-waves represent ventricular repolarization
  - if inverted in inferior (II, III, aVF) or lateral leads (I, V5, V6) this represents strain
  - If T waves flat, represents overall repolarization changes

Repolarization

- Look at ST segments- if abnormal worry about myocarditis, pericarditis, ischemia, infarction

Normal J-depression
Abnormal ST segment changes
Q waves

- Represent septal forces and should be present in inferior (II, III, aVF) and left precordial leads (V5, V6)
- If Q waves are deep in left leads- think about LVH with volume overload
- If Q waves are deep and wide- think about infarction
- If Q waves are present in right precordial leads, this is severe RVH (or ventricular inversion)

Newborn ECG

- Usually show RAD (90-180°) and right ventricular predominance
- T waves usually low voltage and may be upright in right precordial leads in 1st 3 days of life
- Q waves should be present in left precordial leads
- RVH difficult to call: Pure R>10mm V3R/V1, qR right leads