1 OCTOBER 2021

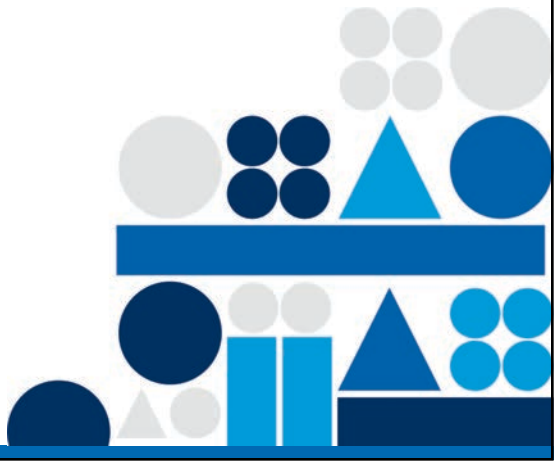
Fast, Slow, Small, and Tall

Otherwise NOT Normal ECGs

John S. Kim, MD MS
Assistant Professor of Pediatrics – Cardiology, CUSOM
Cardiologist and Intensivist, Cardiac Intensive Care Unit
Heart Institute, Children's Hospital Colorado

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus



1

Content Outline

1. Brief review of electrocardiography basics
2. Mostly normal things that look abnormal (PACs, PVCs, low-grade heart block)
3. When ECGs make the diagnosis (myocarditis, pericarditis, not-so-much MI)
4. HELP! (arrythmias and high-grade block)
5. Not so obvious things that are abnormal (long QT)

Children's Hospital Colorado
Here, it's different.™

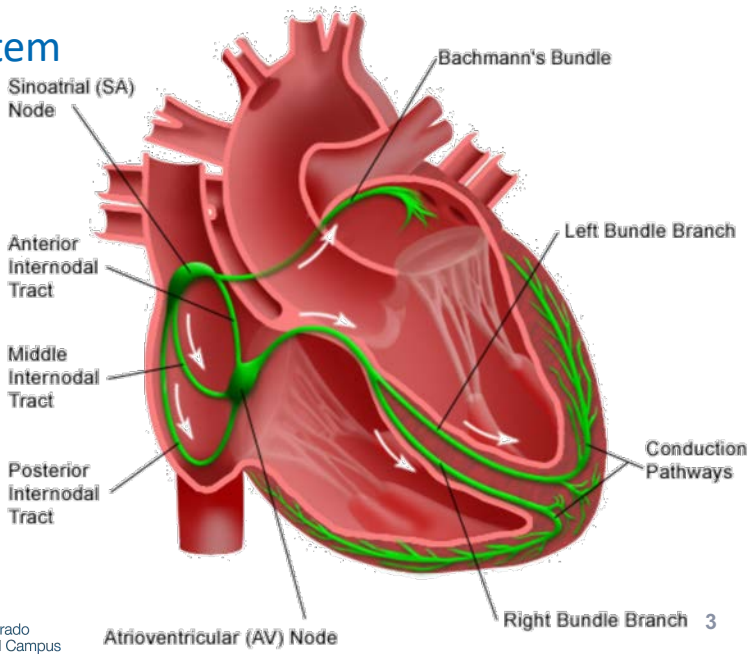
Affiliated with
University of Colorado
Anschutz Medical Campus

2

2

Cardiac Conduction System

- Electrical impulse initiated at the sinus (SA) node
- Spreads across both atria to the AV node
- AV nodes transmits to the ventricles via the Bundle of His
- Bundle Branches:
  - Transmits impulse throughout ventricles
  - Septum → apex → walls
  - Purkinje fibers – further propagate electrical activity to all ventricular cells



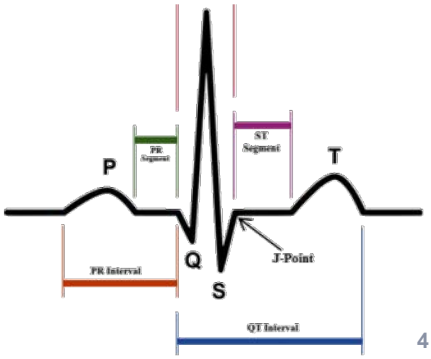
Children's Hospital Colorado Here, it's different.™ Affiliated with University of Colorado Anschutz Medical Campus

3

3

Electrocardiogram

- Tracing of the electrical activity of the heart
- Representation of vector forces that vary with time
  (Vector = a quantity indicated by a magnitude and direction)
- P wave = atrial depolarization
- QRS complex = ventricular depolarization
- T wave = ventricular repolarization



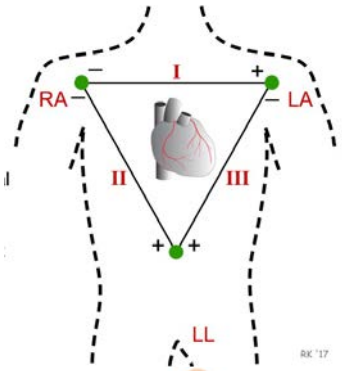
Children's Hospital Colorado Here, it's different.™ Affiliated with University of Colorado Anschutz Medical Campus

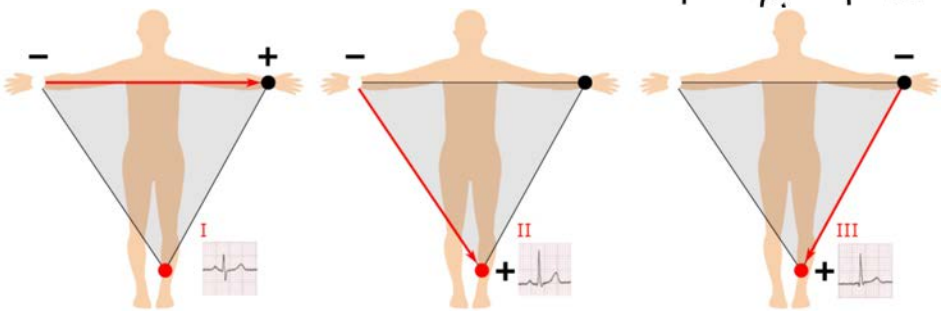
4

4

ECG Leads

- Electrodes are placed on:
  - Each arm and leg (limb leads) – RL is grounding lead
  - 6 leads across the anterolateral chest (precordial leads)
- Limb leads:
  - Standard limb leads (bipolar) – leads I, II, III



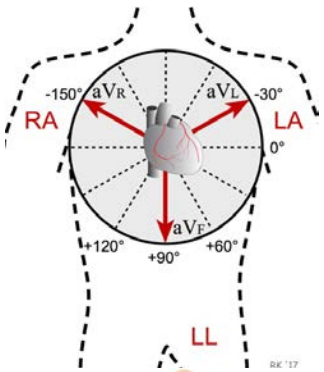


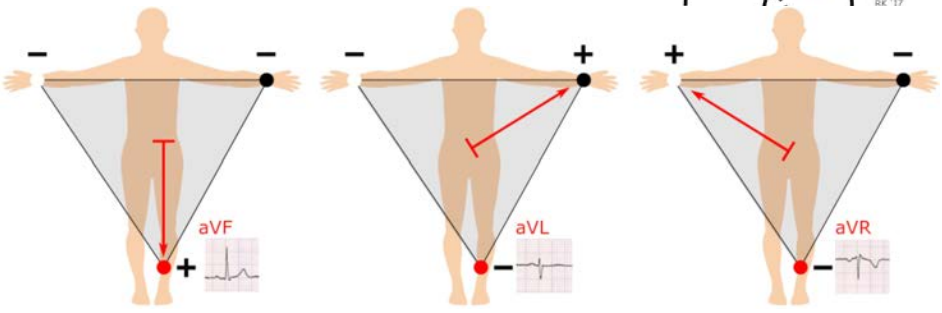
Children's Hospital Colorado
Here, it's different.

5

ECG Leads

- Electrodes are placed on:
  - Each arm and leg (limb leads) – RL is grounding lead
  - 6 leads across the anterolateral chest (precordial leads)
- Limb leads:
  - Standard limb leads (bipolar) – leads I, II, III
  - Augmented limb leads (unipolar) – aVR, aVL, aVF



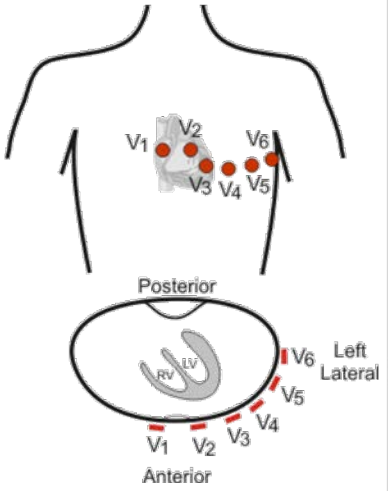


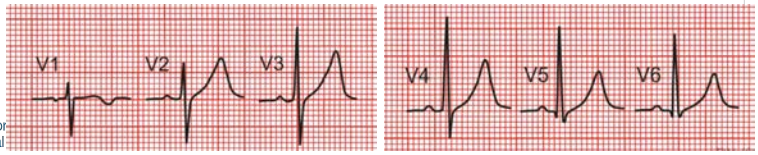
Children's Hospital Colorado
Here, it's different.

6

ECG Leads

- Electrodes are placed on:
  - Each arm and leg (limb leads) – RL is grounding lead
  - 6 leads across the anterolateral chest (precordial leads)
- Limb leads:
  - Standard limb leads (bipolar) – leads I, II, III
  - Augmented limb leads (unipolar) – aVR, aVL, aVF
- Precordial leads:
  - Positive unipolar leads placed on the surface of the chest (to record the electrical activity in the plane perpendicular to the frontal plan)
    - V1-V2 = anteroseptal
    - V3-V4 = anteroapical
    - V5-V6 = anterolateral





Children's Hospital Colorado
Here, it's different.

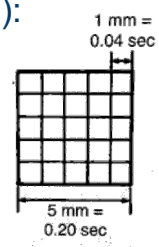
Affiliated with University of Colorado Anschutz Medical

7

Reading and ECG

*Start with: **Rate**, Rhythm, Axis*

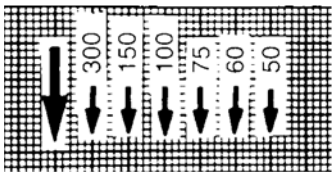
- Rate (measured in beats per minute):
  - Boxes:
    - Each little box = 1mm = 0.04 sec
    - Each big box = 5 mm = 0.20 sec
    - 6 big boxes = 30 mm = 1.2 sec
  - Length of ECG = 10 seconds

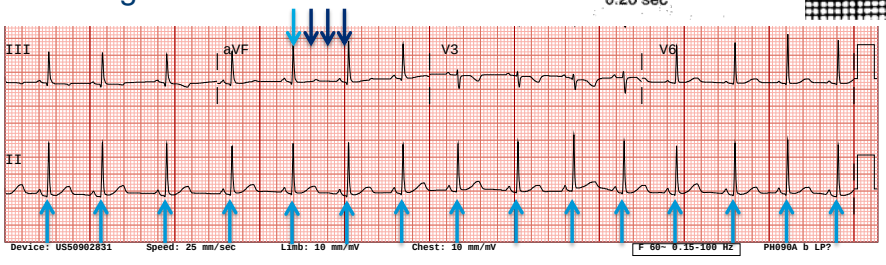


300-150-100-75-60-50 rule:

Rate (bpm) = 60/RR interval

- 60/0.2 = 300 bpm
- 60/0.4 = 150 bpm
- 60/0.6 = 100 bpm





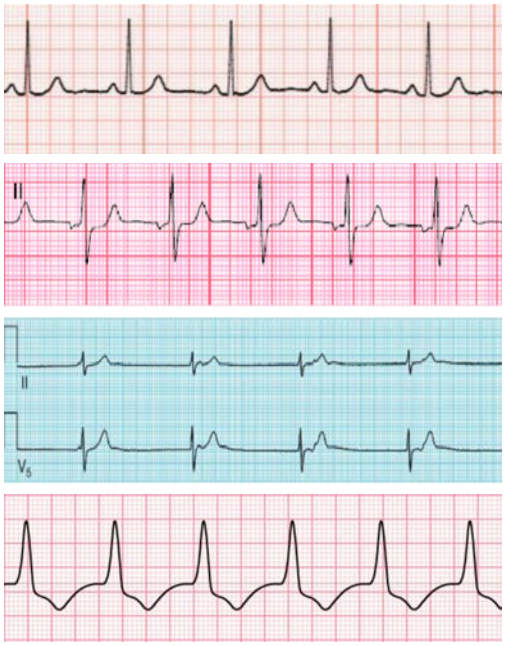
8

8

Reading and ECG

*Start with: Rate, **Rhythm**, Axis*

- Regular or irregular?
  - Regular/equal intervals between QRS complexes
- Sinus rhythm?
  - P wave before every QRS
  - QRS after every P wave
  - Regular P-P and R-R intervals

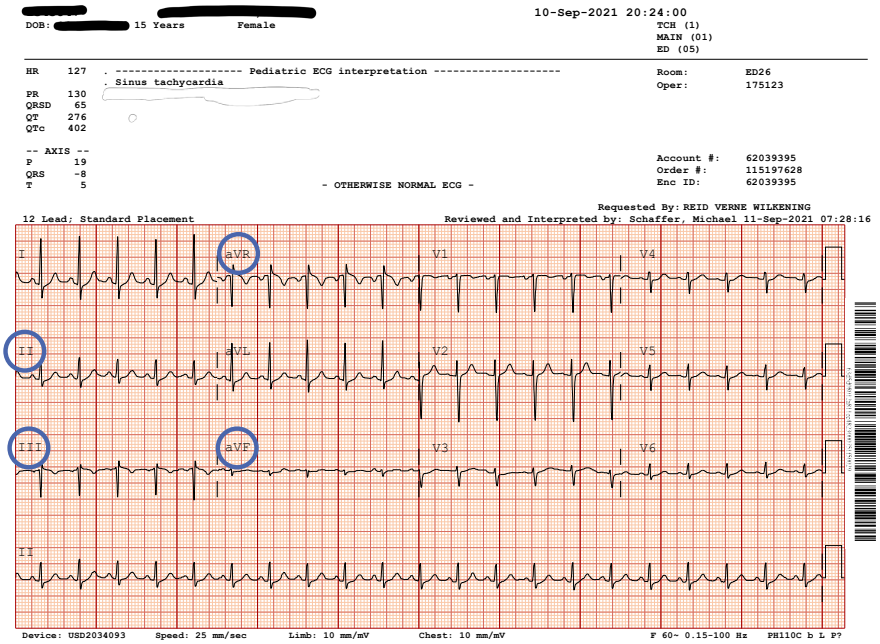


Children's Hospital Colorado
Here, it's different.

Affiliated with
University of Colorado
Anschutz Medical Campus

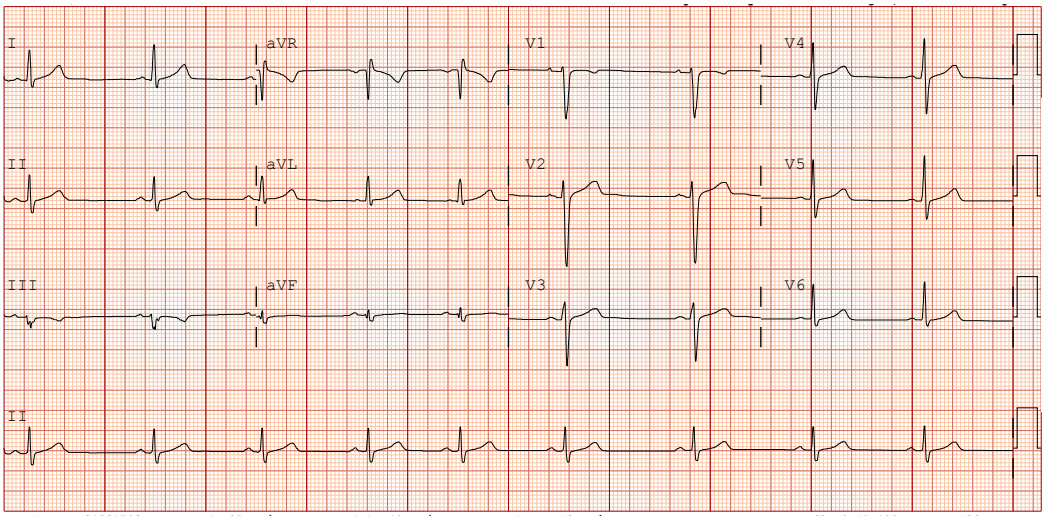
9

Look for P waves in: II, III, aVF (plus aVR)



10

Irregular?... Sinus arrhythmia



Children's Hospital Colorado
Here, it's different.™

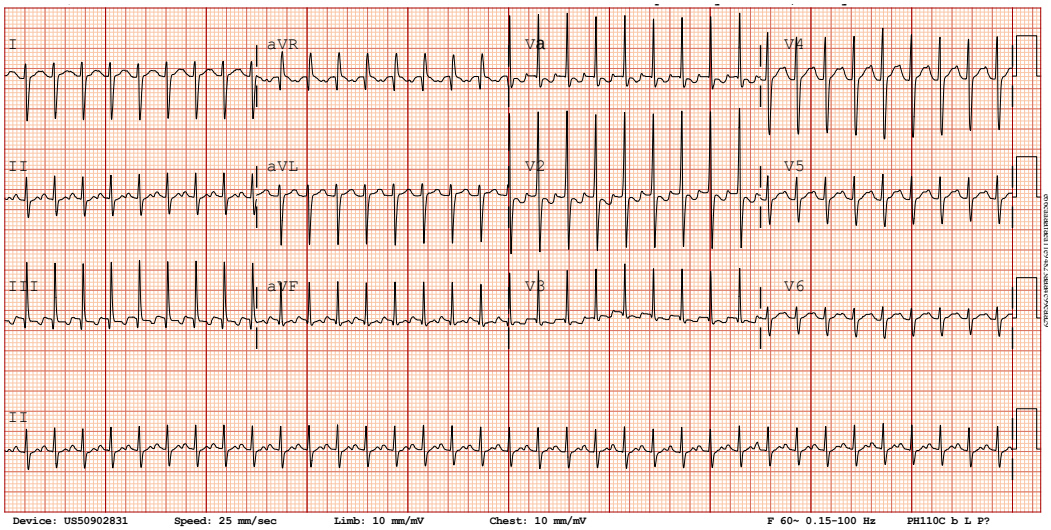
Affiliated with
University of Colorado
Anschutz Medical Campus

11

11

Can you see P waves?... I sure cannot

Will come back to this…



Children's Hospital Colorado
Here, it's different.™

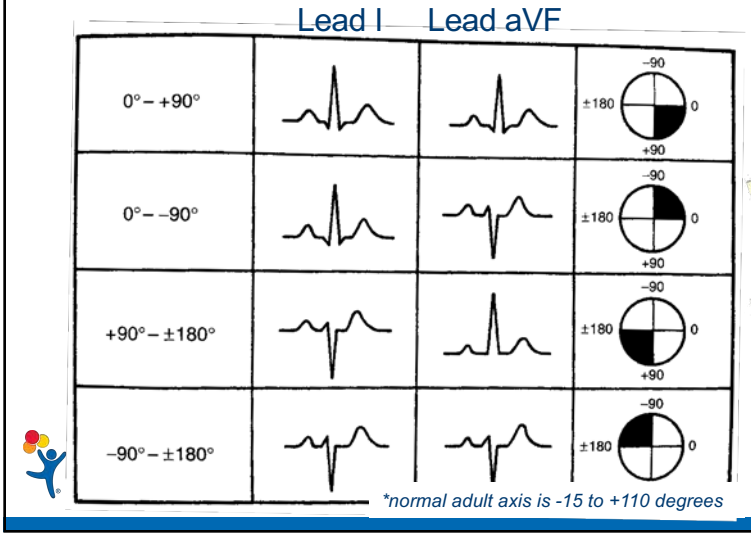
Affiliated with
University of Colorado
Anschutz Medical Campus

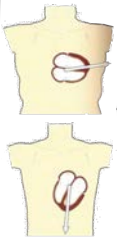
12

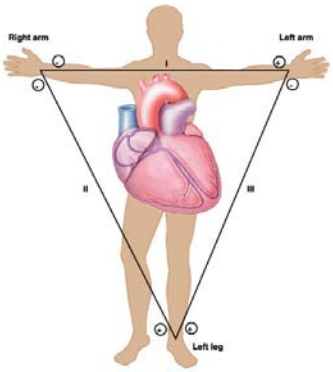
12

Reading and ECG

*Start with: Rate, Rhythm, **Axis*** 👉 *Sum of the QRS Vectors*





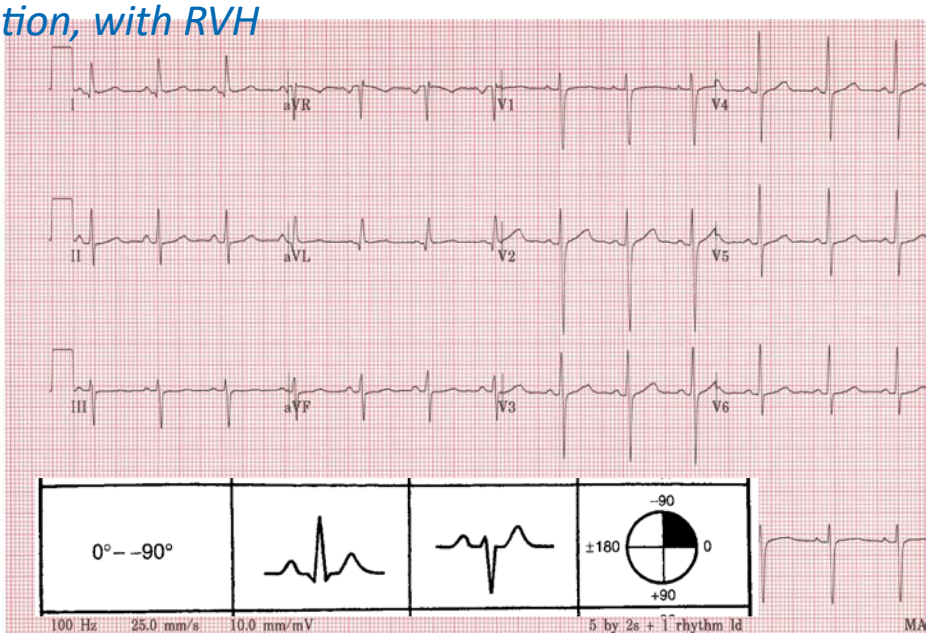


*normal adult axis is -15 to +110 degrees

13

13

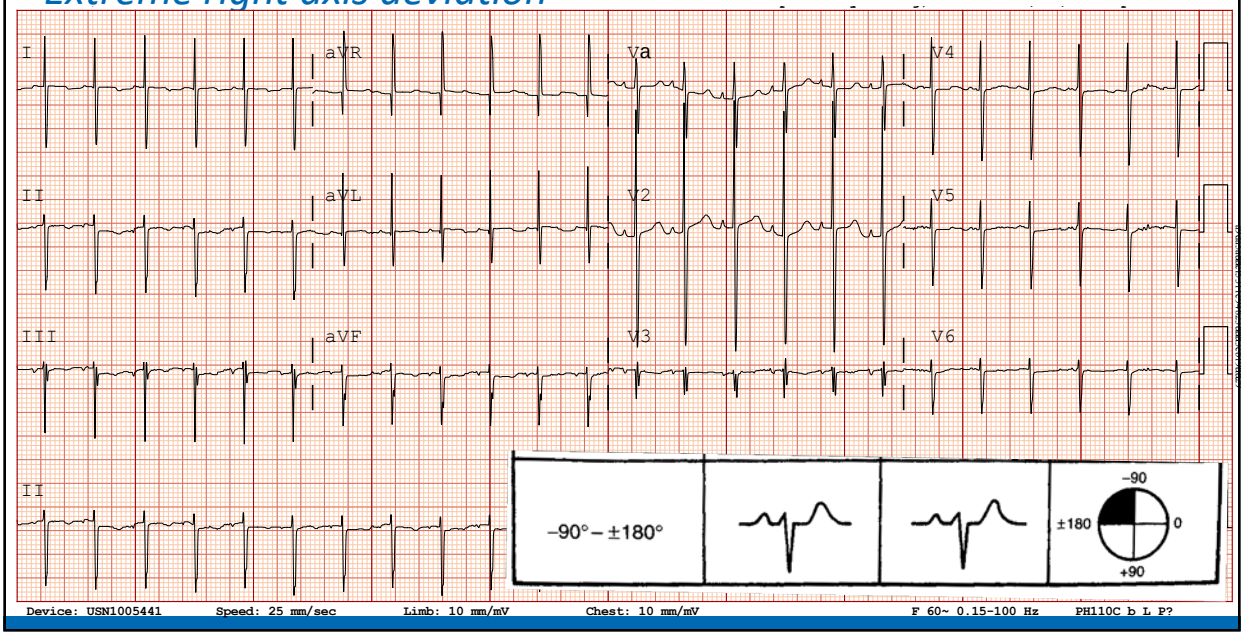
Left axis deviation, with RVH



Children's Hospital Colorado
Here, it's different.™

14

Extreme right axis deviation



15

Premature Atrial Contractions *(PACs)*

- Ectopic beats arising in the atria (but not from the sinus node)
- P wave morphology and PR interval is variable and different from normally generated sinus impulse
- Can be induced by stimulants (e.g., caffeine, smoking/vaping)
- Self-limiting, no treatment, can be reduced with correction of electrolyte disturbances

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

16

16

Premature Ventricular Contractions
(PVCs)

- Ectopic beats originating in the ventricles resulting in wide complexes
- Multiple PVCs:
  - Multiple PVCs that look alike = "monomorphic"
  - Multiple PVCs that look different = "polymorphic"
  - Alternating with sinus beat = ventricular bigeminy

- Can be induced by stimulants (e.g., caffeine, smoking/vaping)
- Self-limiting, no treatment, can be reduced with correction of electrolyte disturbances

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

17

17

Low-grade AV Block
First Degree Heart Block

creative commons source: litfl.com

- Simply defined as PR interval greater than 200 msec (one big box)
- Delay in AV conduction without interruption
- Usual causes:
  - Increased vagal tone
  - Athletic training
  - Can simply be a normal variation
- Pathologic causes:
  - Myocarditis
  - Electrolyte disturbances
  - AV node blocking drugs
  - Lyme disease
  - Myocardial ischemia #adults

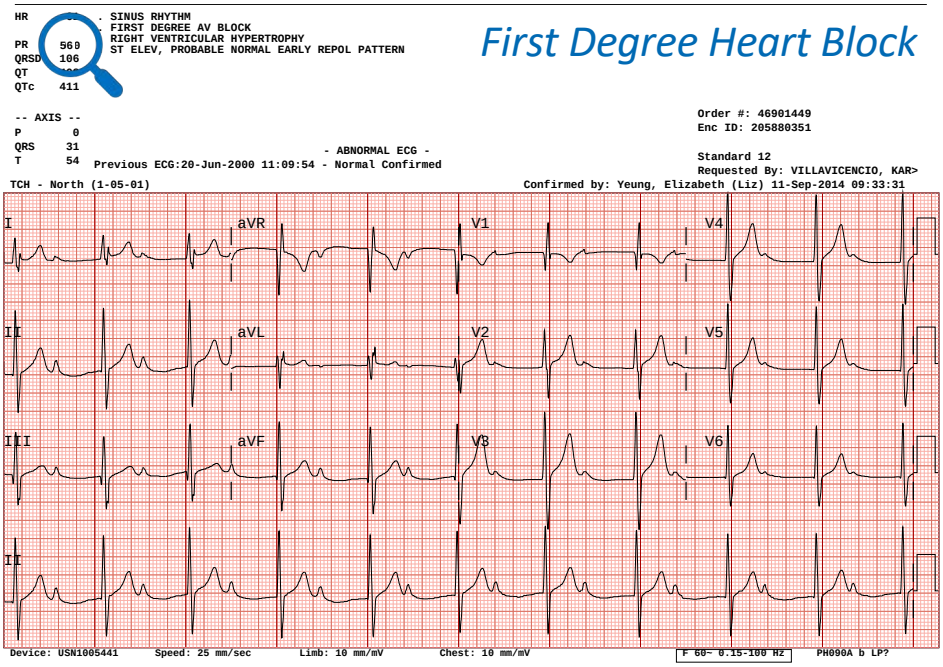
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

18

18

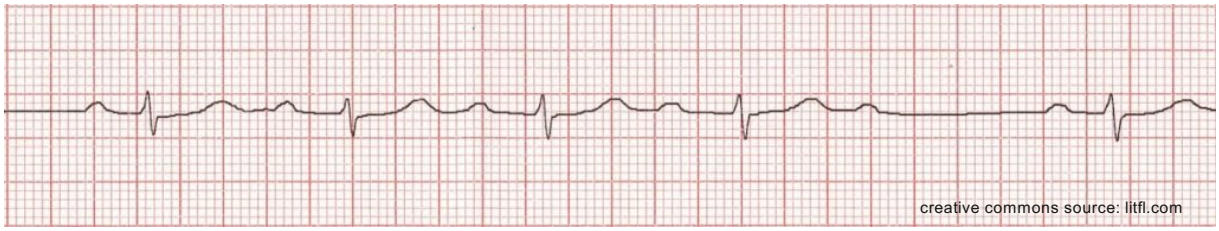
First Degree Heart Block



19

19

Low-grade AV Block
Second Degree, Mobitz I (Wenckebach)



- Progressive prolongation of PR interval… until non-conducting P wave
- Almost always benign (certainly in children)
- Usual cause – increased vagal tone

- *Not infrequent call to cardiology from hospital medicine service*

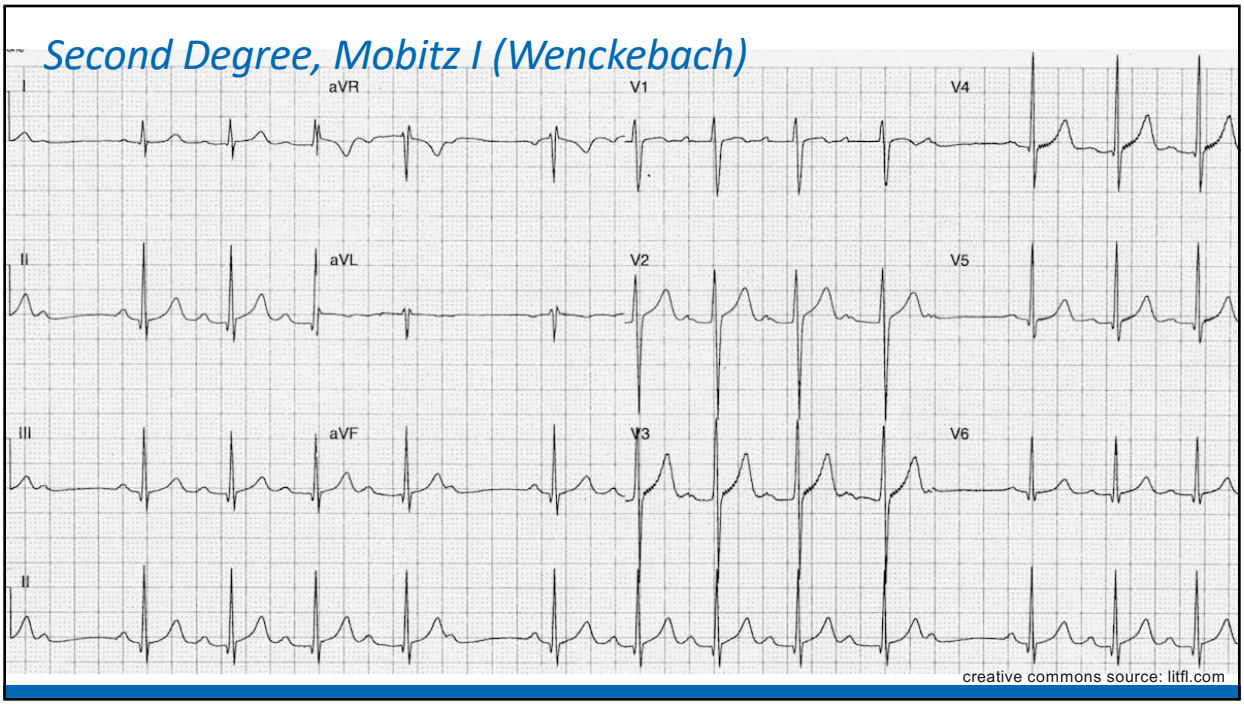
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

20

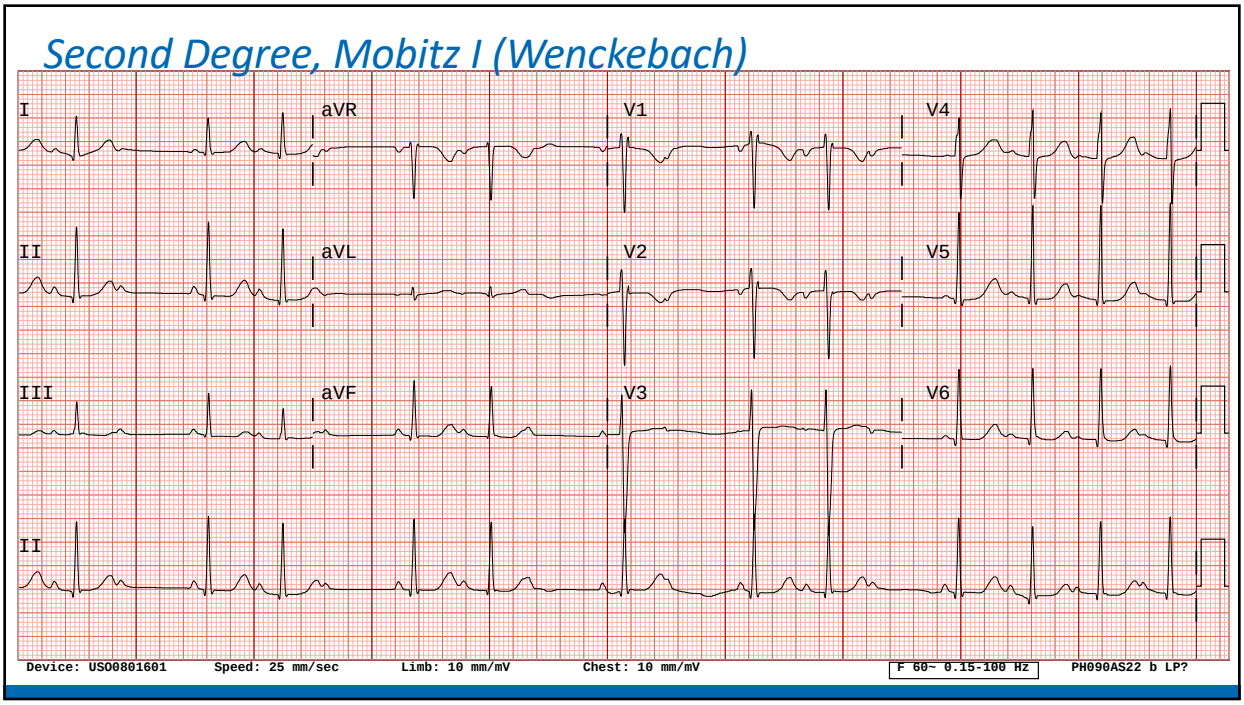
20

Second Degree, Mobitz I (Wenckebach)



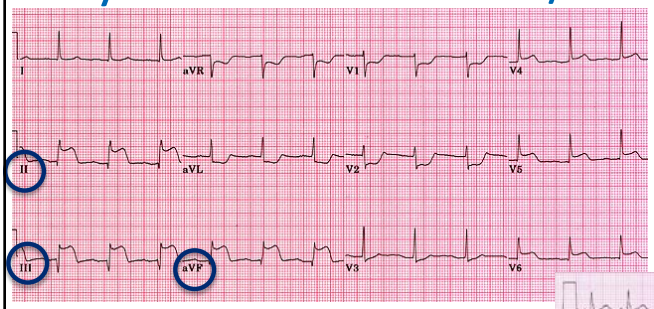
21

Second Degree, Mobitz I (Wenckebach)

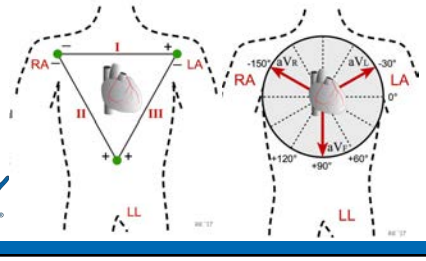


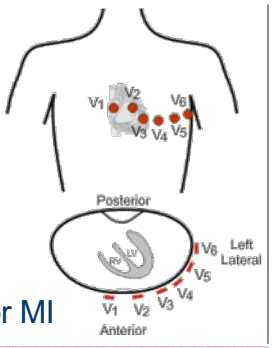
22

Myocardial Infarction/Ischemia

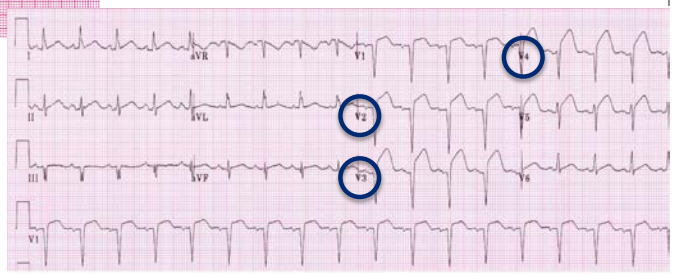


Inferior MI





Anterior MI



23

23

Myocardial Infarction/Ischemia

PEDIATRICS

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Case Report

ST-Elevation Myocardial Infarction due to Acute Thrombosis in an Adolescent With COVID-19

Jessica Persson, Michael Shorofsky, Ryan Leahy, Richard Friesen, Amber Khanna, Lyndsey Cole and John S. Kim

Pediatrics August 2021, 148 (2) e2020049793; DOI: https://doi.org/10.1542/peds.2020-049793

#shamelessplug
#butidohaveshame
#butihadtomentionit

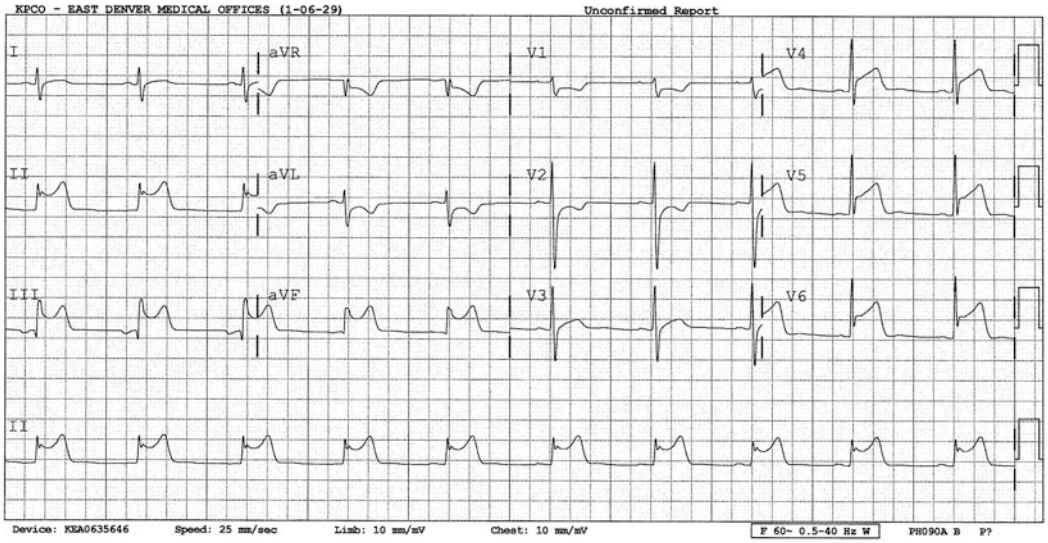
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

24

Pericarditis

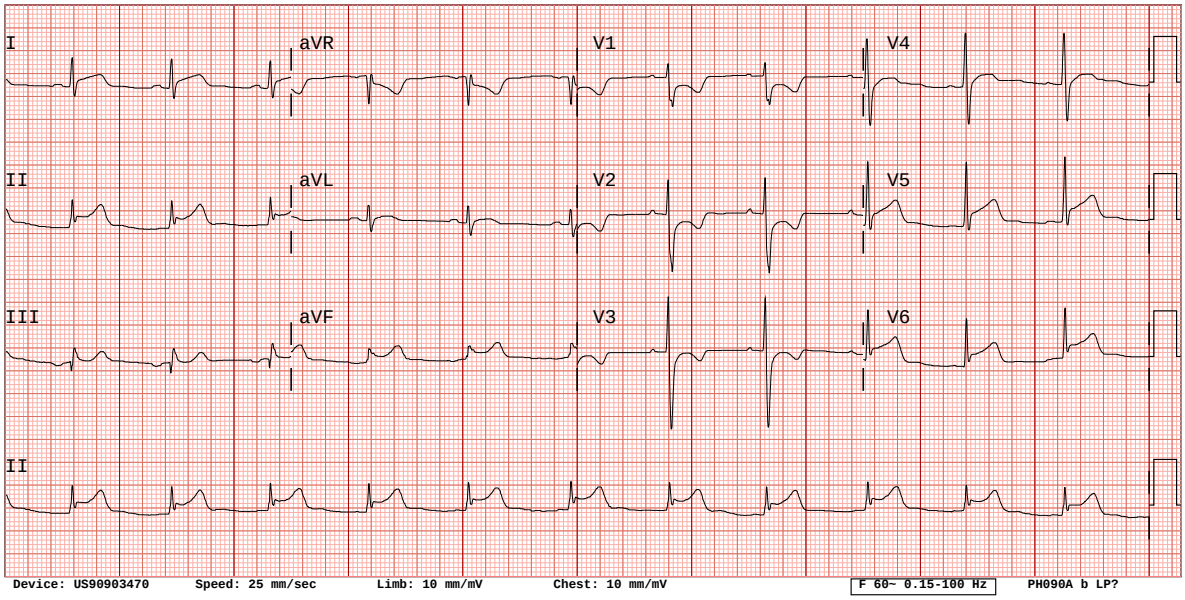
- Seen with viral or inflammatory illnesses
- *Frequently self-limited with supportive care (including NSAIDs)*



25

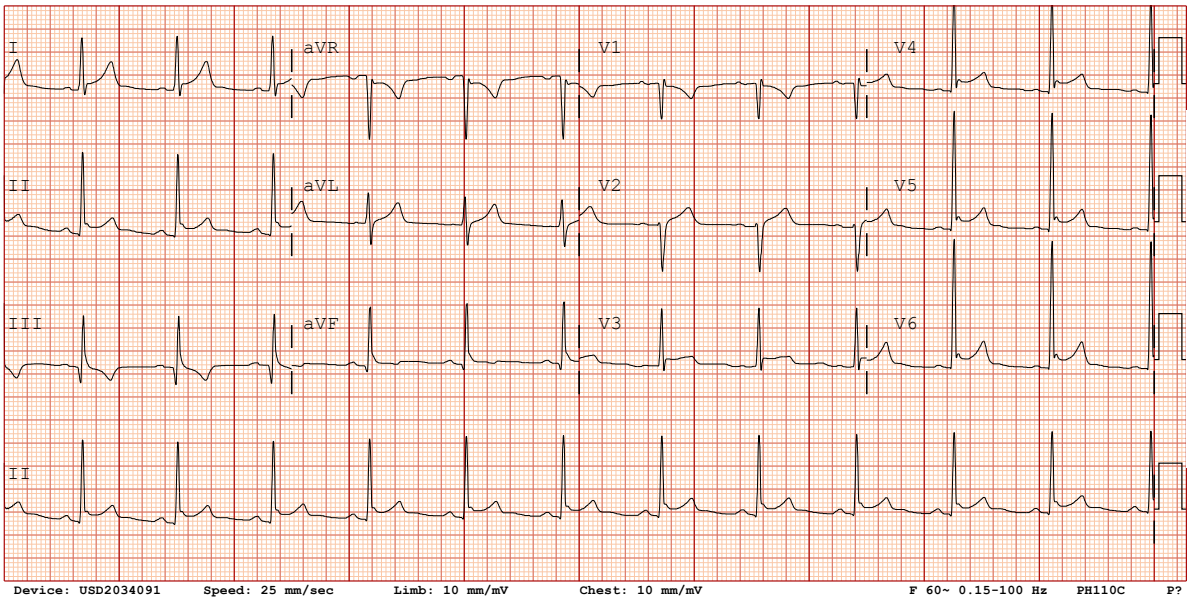
25

Pericarditis



26

Pericarditis



27

Myocarditis

Circulation
Volume 129, Issue 1, 7 January 2014; Pages 115-128
https://doi.org/10.1161/CIRCULATIONAHA.113.001372

CHALLENGES AND OPPORTUNITIES IN PEDIATRIC HEART FAILURE AND TRANSPLANTATION

Diagnosis and Treatment of Myocarditis in Children in the Current Era

Charles E. Canter, MD and Kathleen E. Simpson, MD

- Inflammatory disease of the myocardium (often myopericarditis, in conjunction)
- Causes:
  - Numerous infections (viruses, bacteria, fungal infections, helminths, protozoa, spirochetes) #allthethings
  - Autoimmune diseases
  - Hypersensitivity reactions to drugs
  - Toxins
- ECGs always abnormal (low QRS voltage, ST changes, conduction delays, PACs/PVCs)

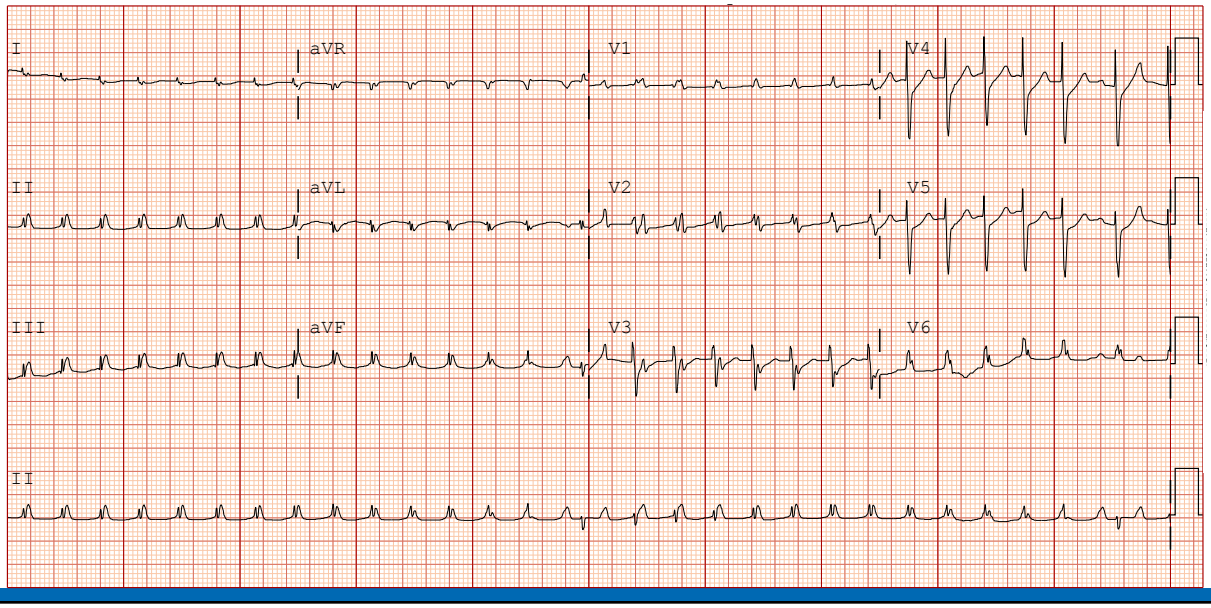
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

28

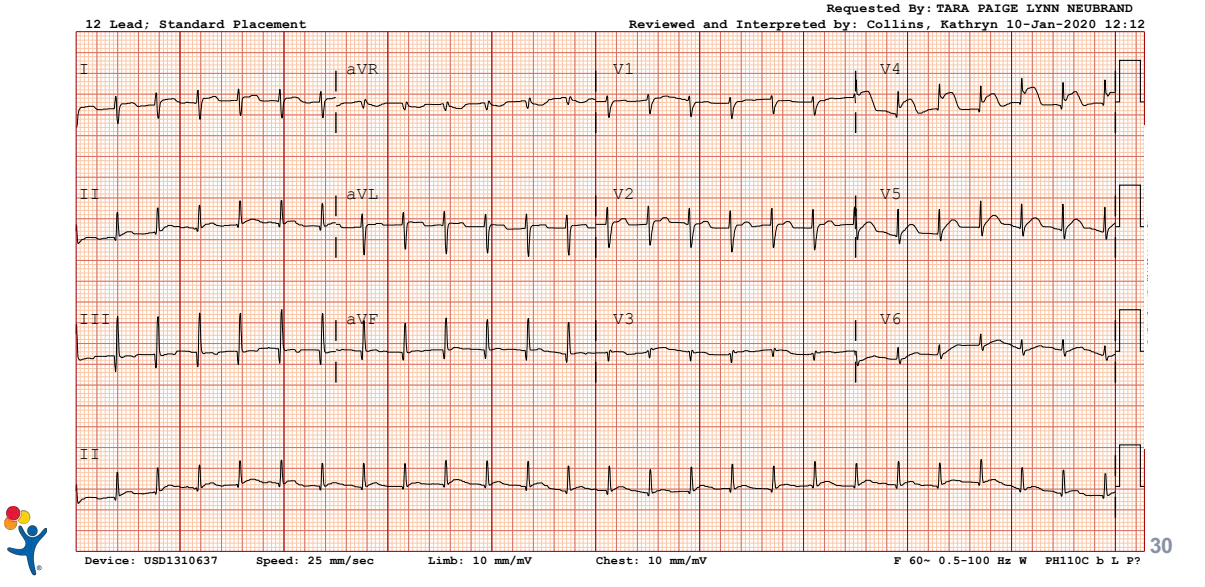
28

Myocarditis – diffusely low QRS voltage



29

Myocarditis – diffusely low QRS voltage



30

High-grade AV Block
Second Degree, Mobitz II

- Potential pediatric causes:
  - Inflammatory diseases
  - Autoimmune diseases
  - Hyperkalemia

- More-severe form of second-degree heart block:
  - Intermittent non-conducted P waves
  - Without progressive prolongation of the PR interval, as in Wenckebach
    - PR interval is constant
    - P-P intervals are constant
- Caused by failure of the His-Purkinje system (Wenckebach is suppression of AV node function)

Children's Hospital Colorado
Here, it's different.™

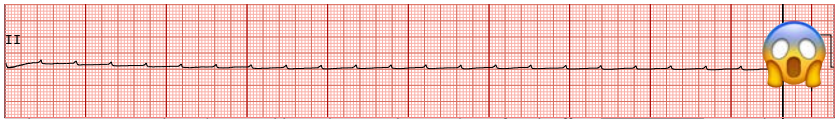
Affiliated with
University of Colorado
Anschutz Medical Campus

31

31

High-grade AV Block
Third Degree – Complete Heart Block

- Complete dissociation of the atria and ventricles
- Most likely cause for finding CHB in a child is congenital (YES! congenital!)
  - Can otherwise be seen with congenital heart disease or heart surgery



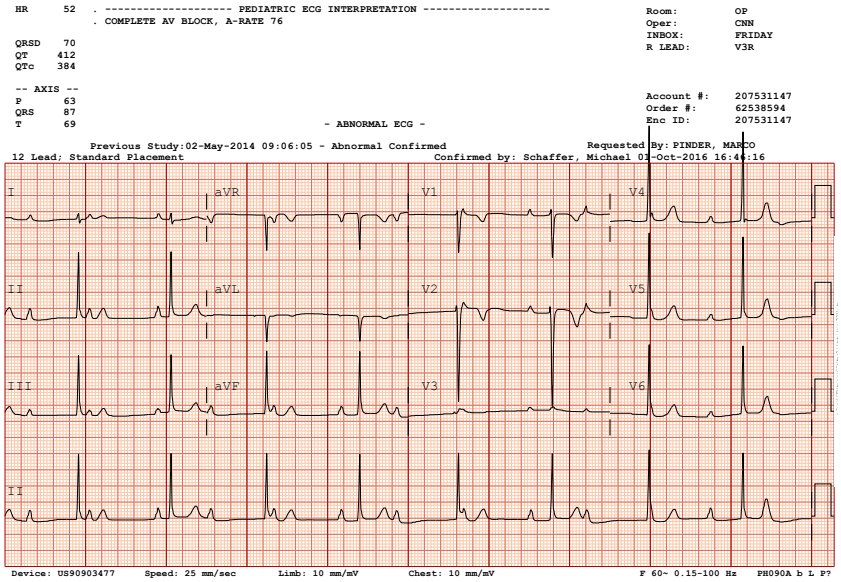
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

32

32

Third Degree – Complete Heart Block



Children's Hospital Colorado
Here, it's different.™

33

33

Heart Block – Summarized

- Benign:

  - First Degree – simply, PR interval >200

  - Second Degree, Mobitz I (aka. Wenckebach) – progressively prolonged PR, until dropped QRS

- Pathologic heart block (requires pacemaker):

  - Second Degree, Mobitz II – constant PR, randomly dropped QRS
  - Third Degree – complete AV block

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

34

34

Rhythm Differential Diagnosis

Slow:
- Sinus bradycardia
- Junctional rhythm (sinus node dysfunction)
- Degrees of heart block

Fast:
- Narrow QRS:
  - SVT
  - Atrial flutter
  - Atrial fibrillation
  - Junctional or ectopic atrial tachycardia
- Wide QRS:
  - Ventricular tachycardia/fibrillation
  - BBB (SVT with "aberrancy")

Irregular:
- Degrees of heart block
- Ectopy (PACs and PVCs)
- Sinus arrhythmia

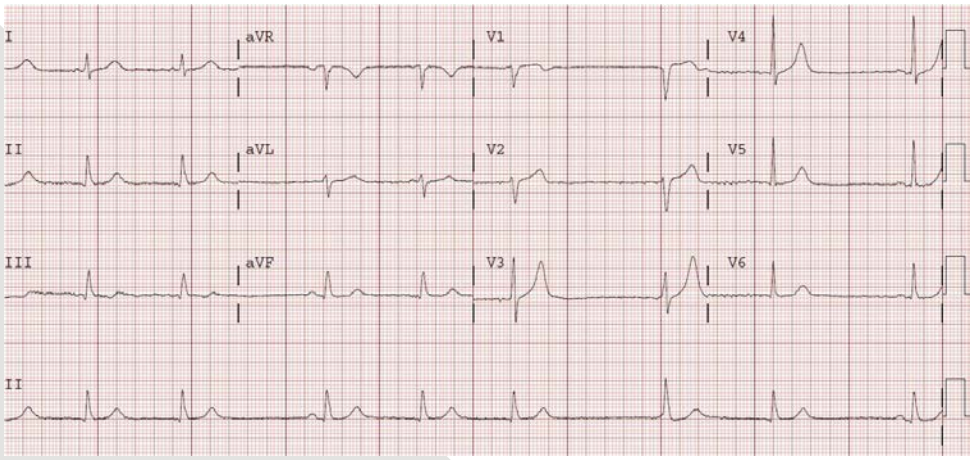
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

35

35

Slow:
- Sinus bradycardia
- Junctional rhythm (sinus node dysfunction)
- Degrees of heart block



Children's Hospital Colorado
Here, it's different.™

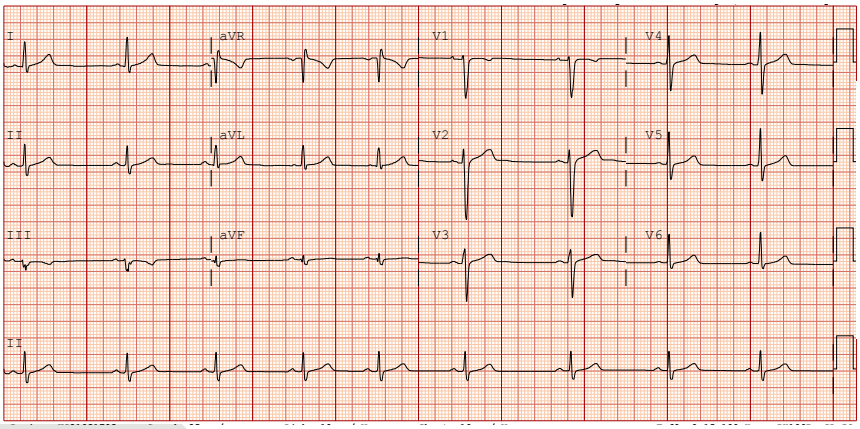
Affiliated with
University of Colorado
Anschutz Medical Campus

36

36

Rhythm Differential Diagnosis

Slow:
- Sinus bradycardia
- Junctional rhythm (sinus node dysfunction)



Irregular:
- Sinus arrhythmia
- Ectopy (PACs and PVCs)
- Degrees of heart block

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

37

37

Rhythm Differential Diagnosis

Irregular:
- Sinus arrhythmia
- Ectopy (PACs and PVCs)
- Degrees of heart block

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

38

38

Slow:

- Sinus bradycardia
- Junctional rhythm (sinus node dysfunction)
- Degrees of heart block (e.g., third)

Rhythm Differential Diagnosis

Irregular:

- Sinus arrhythmia
- Ectopy (PACs and PVCs)
- Degrees of heart block (e.g., second)

Children's Hospital Colorado
Here, it's different.™

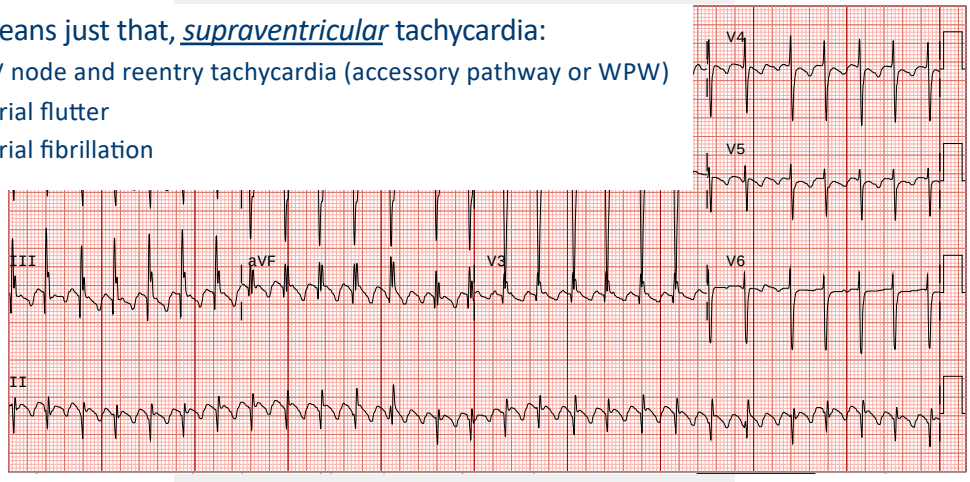
Affiliated with University of Colorado Anschutz Medical Campus

39

39

SVT, right?

- SVT means just that, *supraventricular* tachycardia:
  - AV node and reentry tachycardia (accessory pathway or WPW)
  - Atrial flutter
  - Atrial fibrillation



Children's Hospital Colorado
Here, it's different.™

Affiliated with University of Colorado Anschutz Medical Campus

40

40

- Atrial fibrillation:
  - No organized or regular atrial impulses (no normal/regular P waves)
  - Atrial impulses are not originating at the sinus node
  - Atrial activity is chaotic (and, thus, ventricular conduction is chaotic)

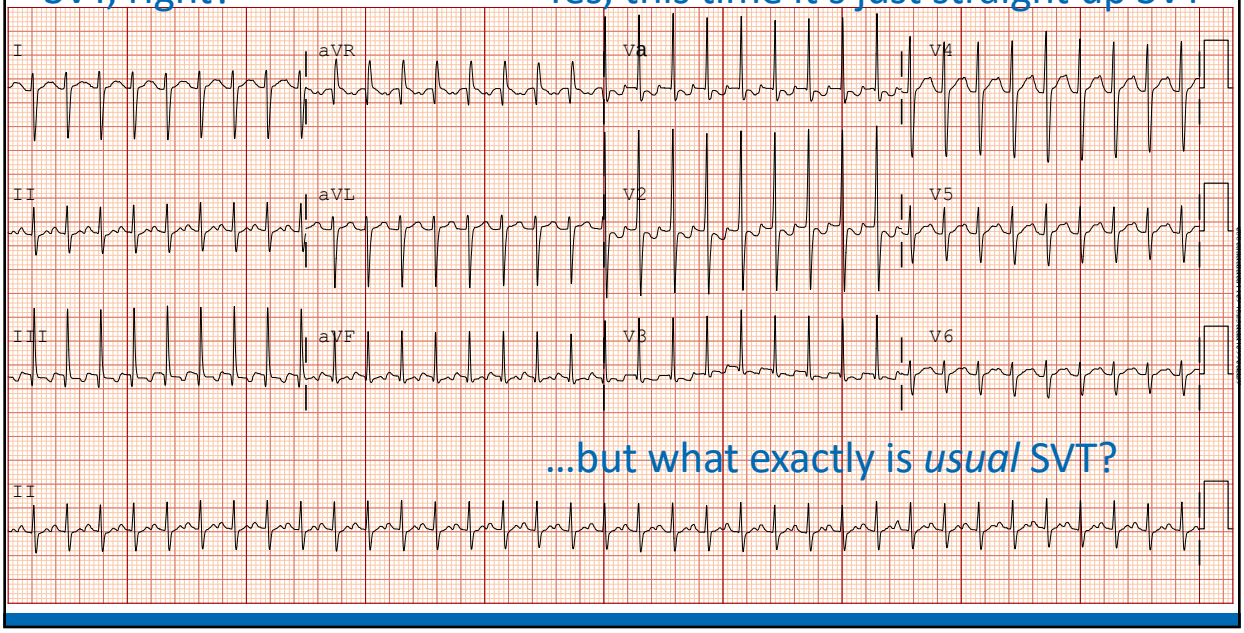
- Atrial flutter:
  - "Flutter" waves rather than P waves (characteristic "sawtooth" pattern)
  - Regular rate of 250-320 bpm (yea, that's right… that fast)
  - Only some impulses conduct through AV node (usually at regular interval)

41

41

SVT, right?

Yes, this time it's just straight up SVT



…but what exactly is *usual* SVT?

42

SVT Supra-Ventricular Tachycardia

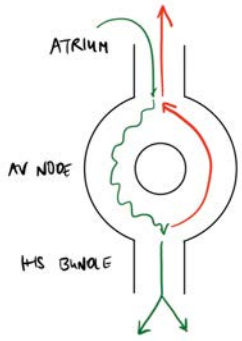
- Most common rhythm disturbance in children (and young adults)
- Majority of SVT occurs in structurally normal hearts (CHD is a risk factor)
- Occurs primarily by the presence of an **accessory pathway**:
  - Results in re-entry of the electrical impulse from the atrium
  - Creates a circuit in which the electrical impulse can cycle repetitively and result in rapid/regular ventricular contraction
- Two primary locations for accessory pathways:

Children's Hospital Colorado Here, it's different.™ Affiliated with University of Colorado Anschutz Medical Campus

43

43

SVT Supra-Ventricular Tachycardia



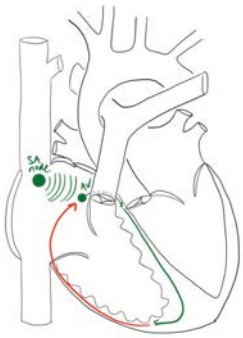
- Two primary locations for accessory pathways:
  - At the AV node – aka. Dual AV node physiology

Children's Hospital Colorado Here, it's different.™ Affiliated with University of Colorado Anschutz Medical Campus

44

44

SVT Supra-Ventricular Tachycardia



- Two primary locations for accessory pathways:
  - At the AV node – aka. Dual AV node physiology
  - Somewhere else along the AV valve annuli
    - SVT due to accessory pathways is common in neonates (1 in 250 neonates)… usually resolves by 12 mo

Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

45

45

- SVT occurs in 2.25 per 1000 people in the general population
- You probably know someone walking around who gets SVT from time to time!

SVT Supra-Ventricular Tachycardia

- SVT can be treated with beta blockers
- Some people choose to break their tachycardia with vagal maneuvers (and live without meds!)

- SVT can be ablated via a catheter procedure
- (…those crazy electricians burn the pathway from inside the heart and… BAM! No more SVT!)
  - Here, at Children's, we do on-average 3 ablations for SVT every week!

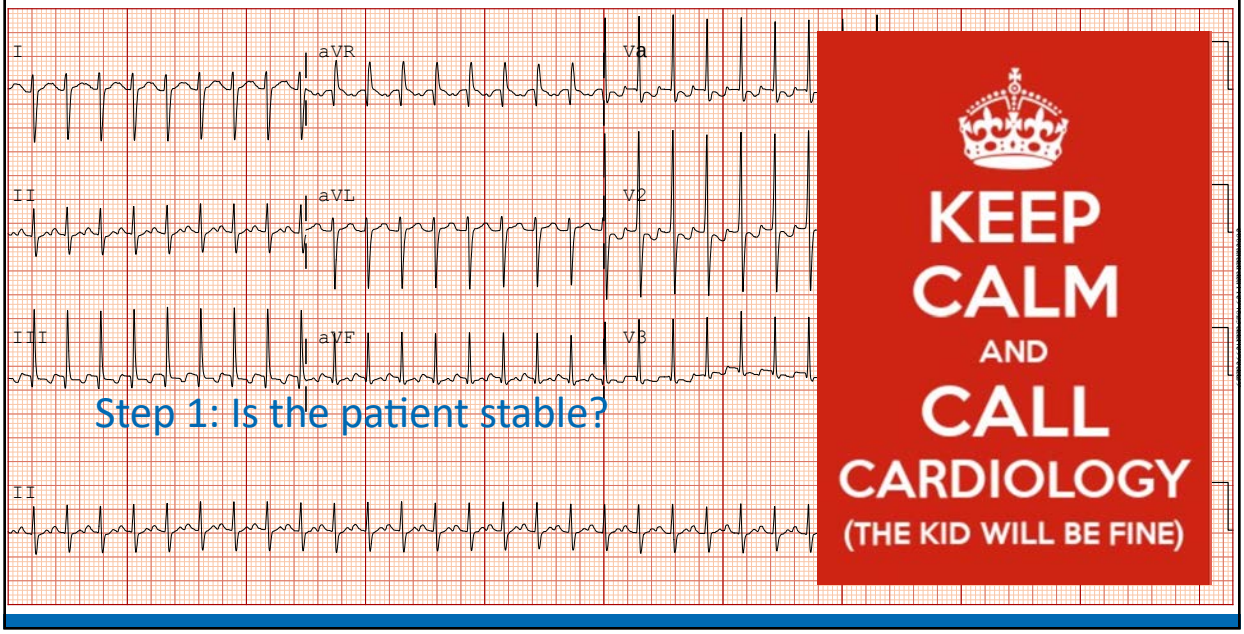
Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

46

46

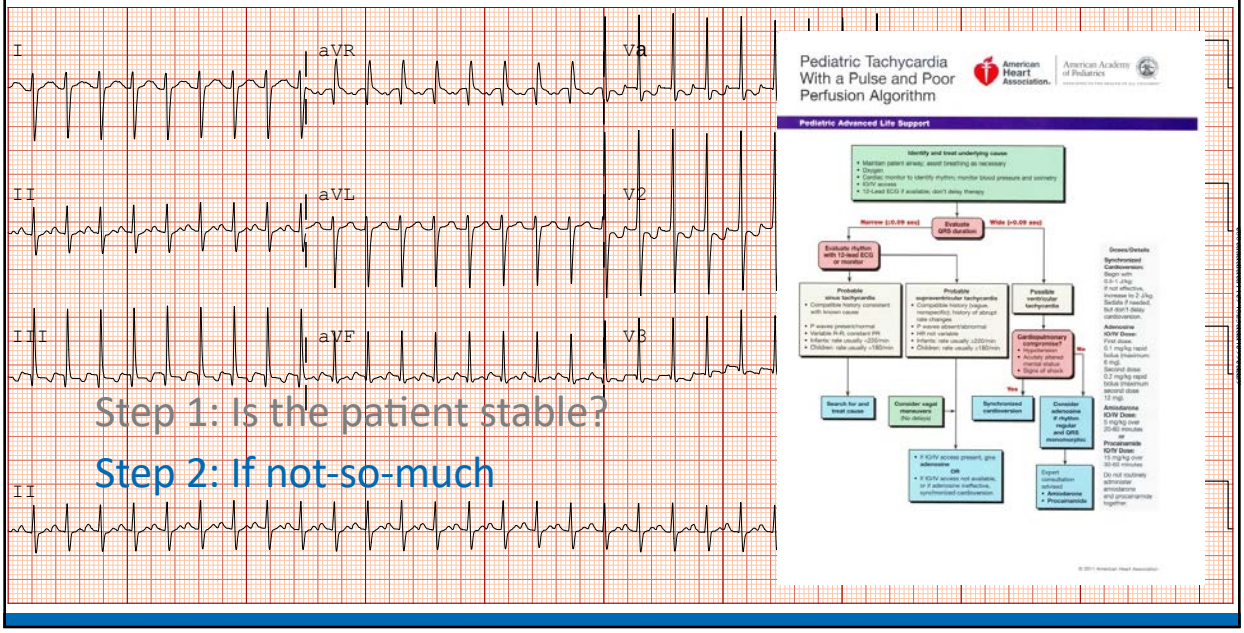
So… Next time you see this…



Step 1: Is the patient stable?

47

So… Next time you see this…



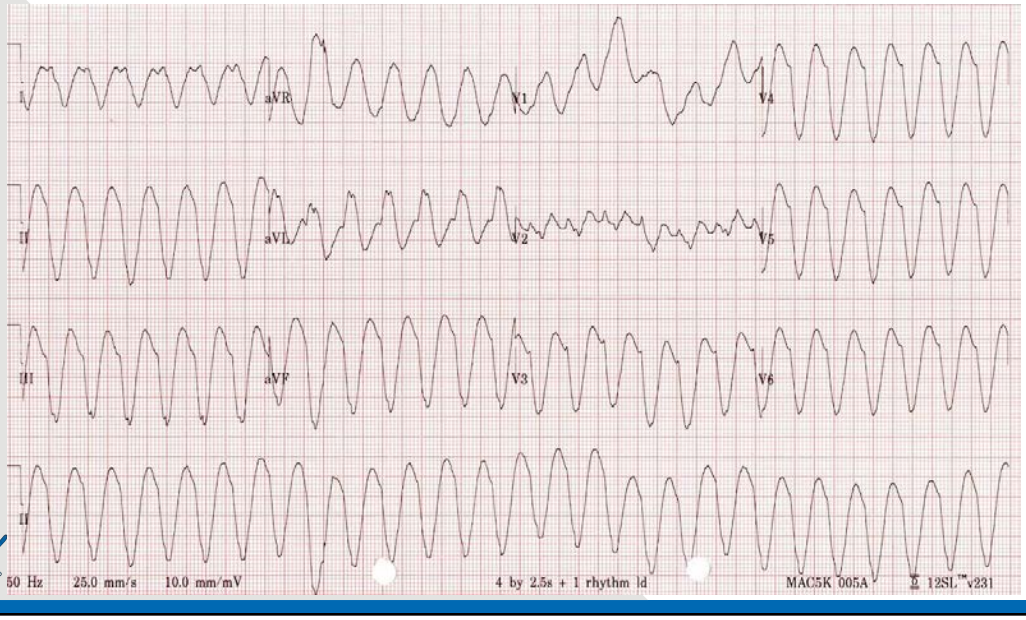
Step 1: Is the patient stable?

Step 2: If not-so-much

48

This could also be SVT!

For reals! I'm not kidding!



SVT with "aberrancy"
(aka. SVT with BBB)

49

Long QT

- List of QT prolonging drugs:
  - Antimicrobials – Levofloxacin, Ciprofloxacin, Clarithromycin, Erythromycin, Ketoconazole, Itraconazole
  - Antidepressants – Amitriptyline, Fluoxetine, Sertaline, Citalopram, Venlafaxine
  - Antipsychotics – Haloperidol, Quetiapine
  - Antihistamines – diphenhydramine, loratadine
  - Others – Sumatriptan, Methadone
  - Antiarrhythmics
- Other causes of QT prolongation:
  - Electrolyte abnormalities
  - Hepatic dysfunction
  - Hypothyroidism
- So, what is a normal QT interval?
  - 100% agreement on this definition does not exist
  - In general, 440-460 msec is borderline prolonged (only considered significant if symptomatic)
  - QT interval >460 is generally accepted as long
  - However! Do not be alarmed if a cardiologist says not to worry about a QT interval >460

Children's Hospital Colorado
Here, it's different.™

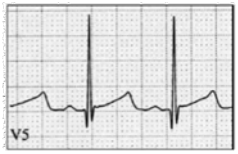
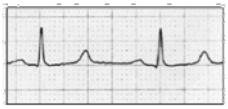
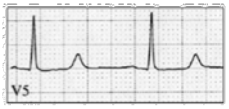
Affiliated with
University of Colorado
Anschutz Medical Campus

50

50

Congenital Long QT Syndrome

10 genetically distinct types of long QT syndrome (LQTS), first 3 types are most-common

Type	QT Morphology			Clinical Phenotype	Incidence
LQT1 (KCNQ1)	Broad-based, symmetrical T wave			Adrenergic triggers (swimming, emotion, exercise)	30-35%
LQT2 (KCNH2/ HERG)	Bifid T wave			Commonly drug-induced, auditory stimuli	25-30%
LQT3 (SCN5A)	Delayed-onset/ asymmetrical T wave			Rest/sleep	5-10%

Children's Hospital Colorado
Here, it's different.

Affiliated with
University of Colorado
Anschutz Medical Campus

51

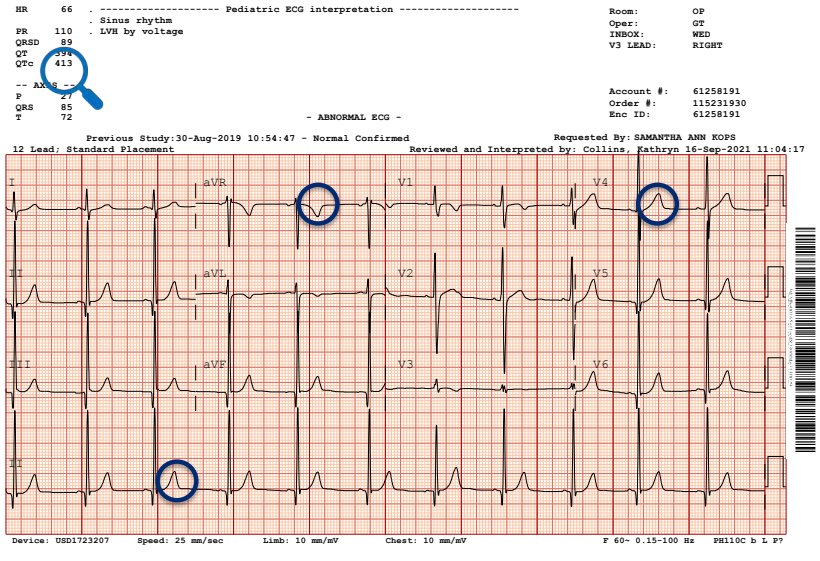
51

How to consider the QT interval on an ECG?

Why go to the trouble of calculating it?

Can you easily see the beginning and the end of the T wave?

If so, then just trust the machine read.



Children's Hospital Colorado
Here, it's different.

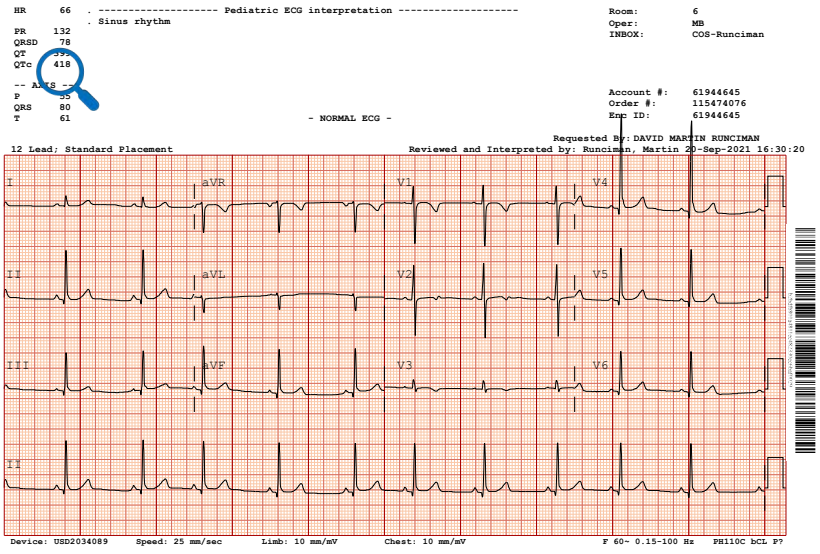
52

52

How to consider the QT interval on an ECG?

Why go to the trouble of calculating it?

Can you easily see the beginning and the end of the T wave?



Children's Hospital Colorado
Here, it's different.™

53

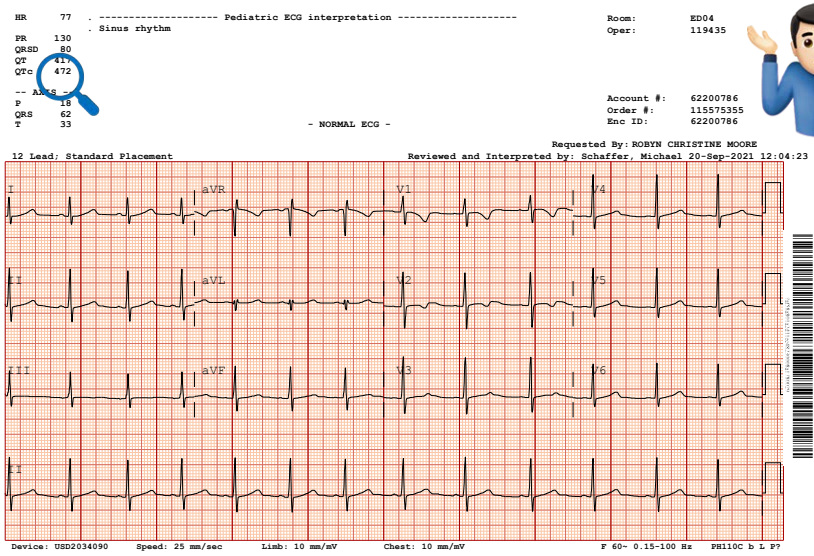
53

How to consider the QT interval on an ECG?

Why go to the trouble of calculating it?

Can you easily see the beginning and the end of the T wave?

If you're worried, have a cardiologist take a look



Children's Hospital Colorado
Here, it's different.™

54

54

Content Outline – Summary

1. ECG is generated by vectors formed by the leads
2. PACs, PVCs, and low-grade block are usually benign
3. Diffuse ST = pericarditis, low voltage = myocarditis
4. Keep calm, SVT happens!
5. Many things cause QT prolongation… but you can read the ECG!

Children's Hospital Colorado
Here, it's different.™

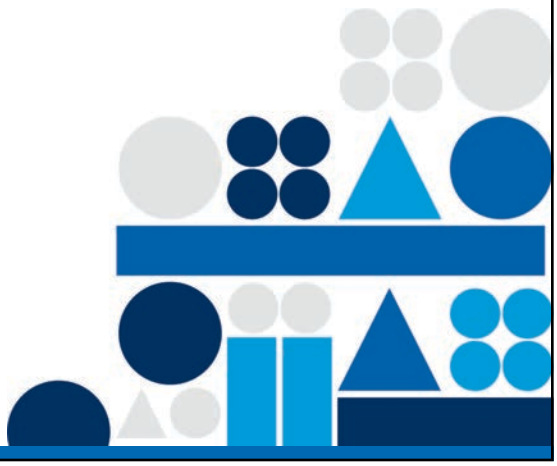
Affiliated with
University of Colorado
Anschutz Medical Campus

55

55

Thank you

John.Kim@childrenscolorado.org



Children's Hospital Colorado
Here, it's different.™

Affiliated with
University of Colorado
Anschutz Medical Campus

56