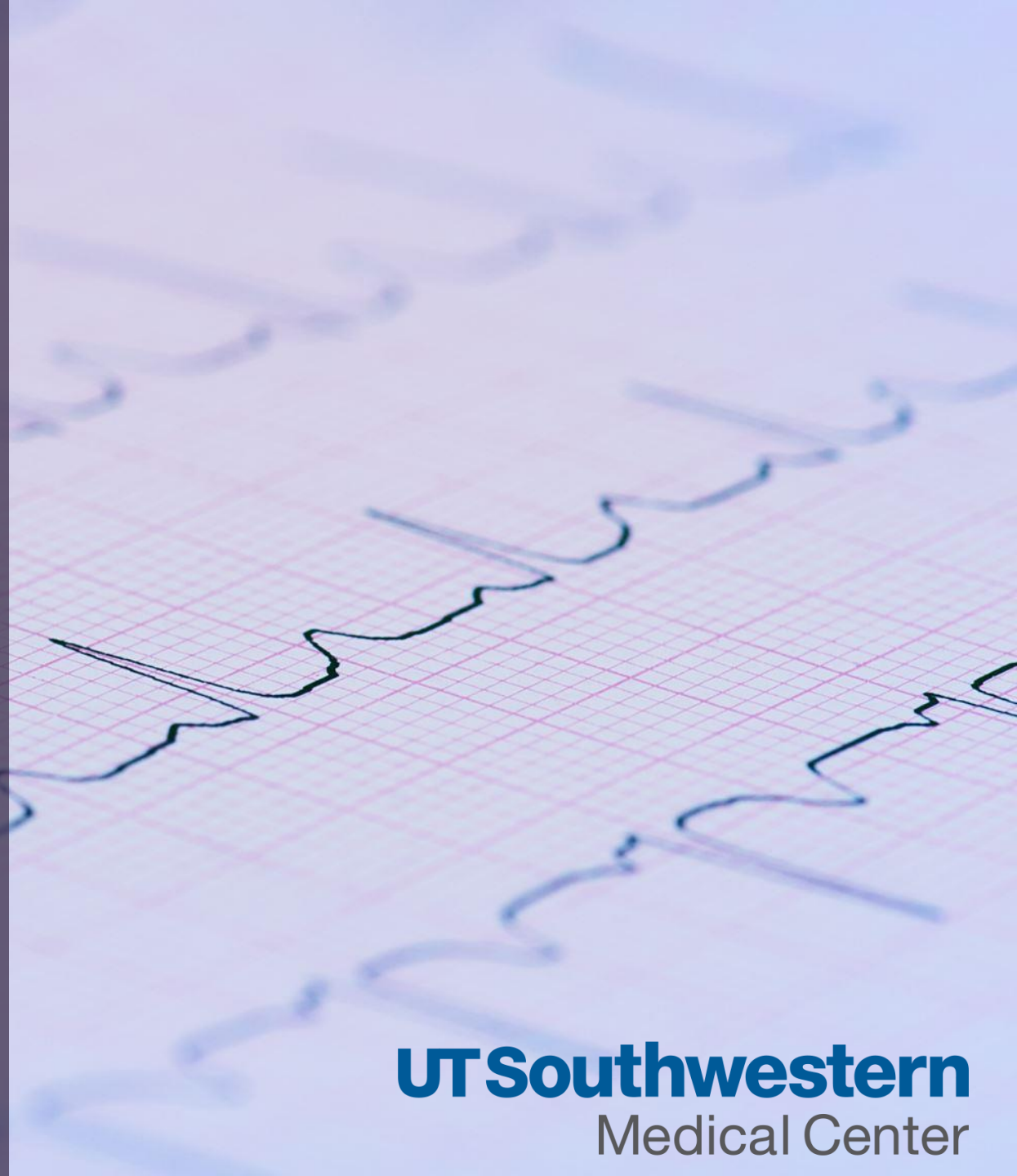
ECG BOOTCAMP

Children's Health – Dallas, TX USA

12.07.2024

Lauren Thai, MD

Pezad Doctor, MD



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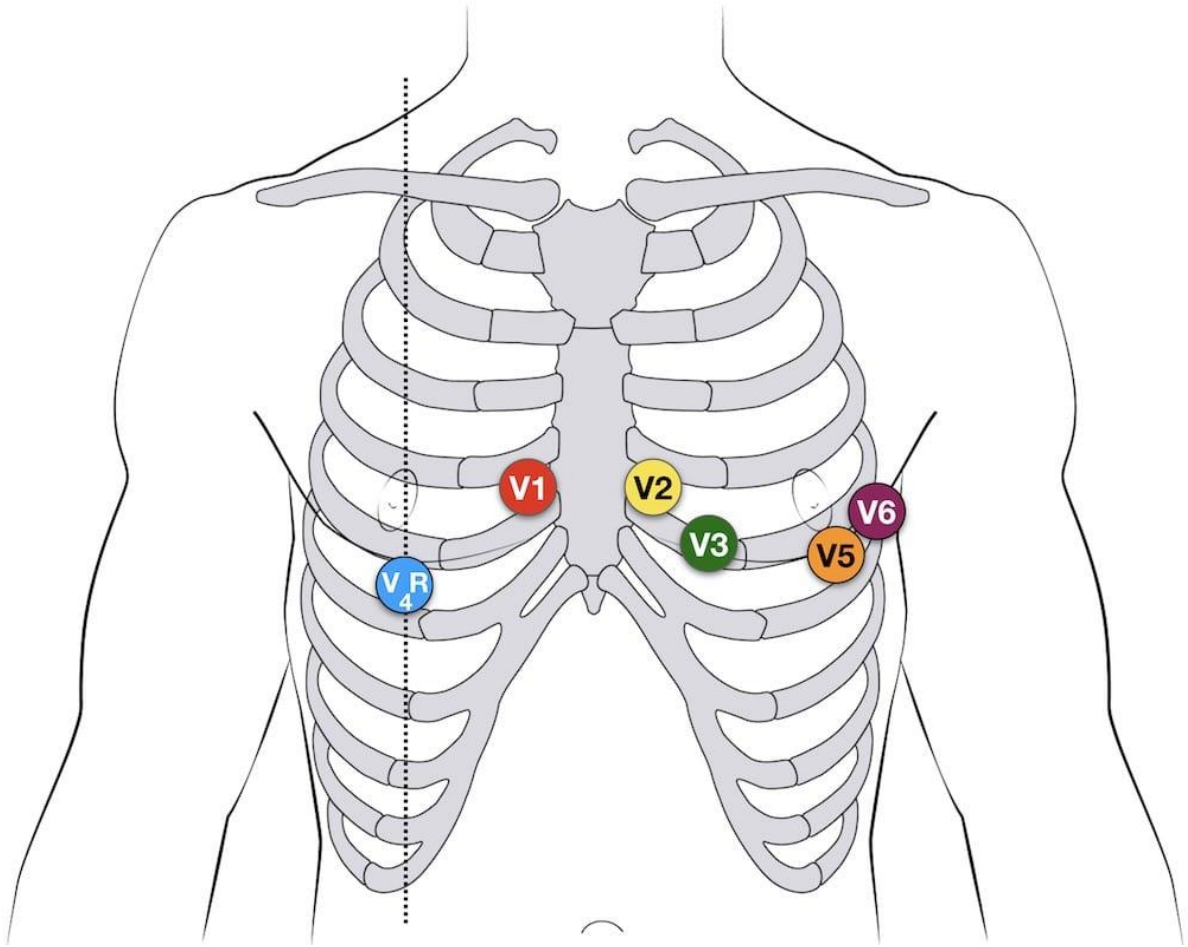
HOW TO OBTAIN AN ECG



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HOW TO OBTAIN AN ECG

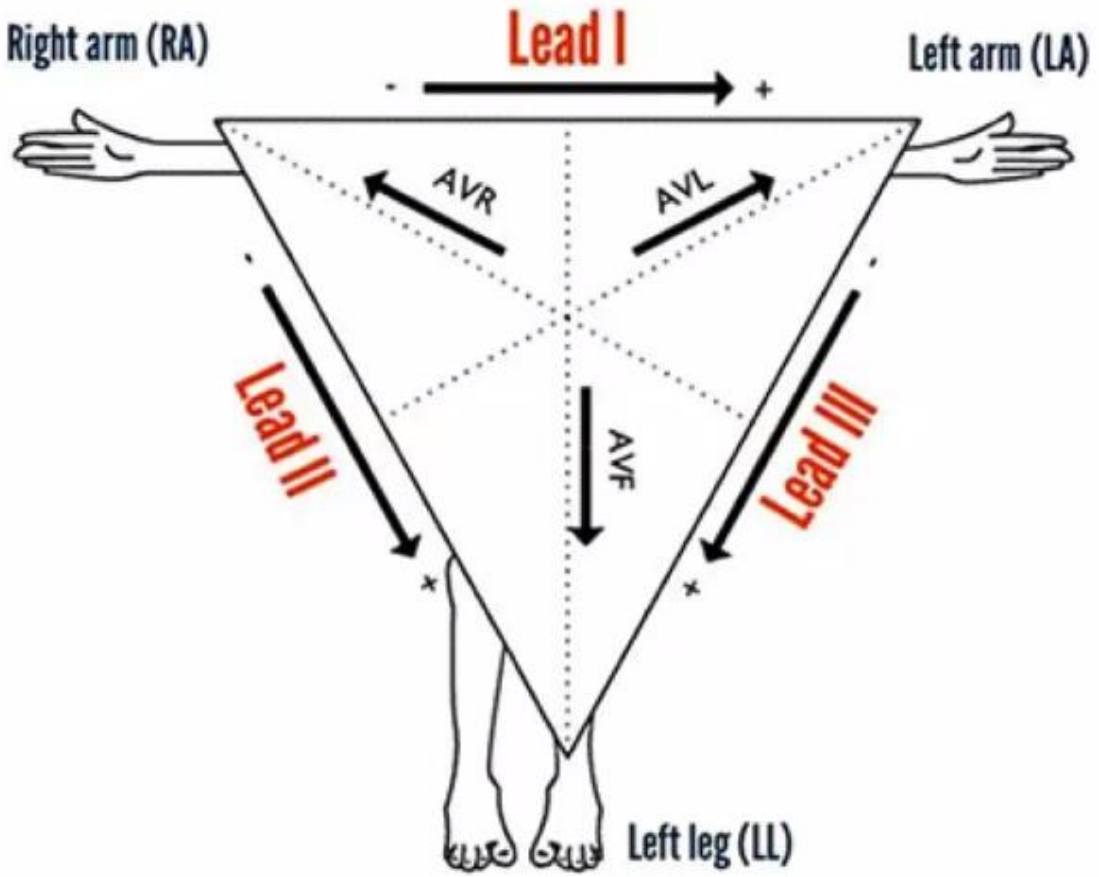
Precordial leads:

- V1: 4th intercostal space, right sternal border
- V2: 4th intercostal space, left sternal border
- V3: midway between V2 and the placement of V4 in adults (5th intercostal space, left mid-clavicular line)
- **V4R:** 5th intercostal space, right mid-clavicular line. *Use this lead for V4R, must label as such on ECG.*
- V5: anterior axillary line, same horizontal plane as V4
- V6: mid-axillary line, same horizontal line as V4

Limb leads:

- Place on top part of arm or leg (less muscle interference)

HOW TO OBTAIN AN ECG



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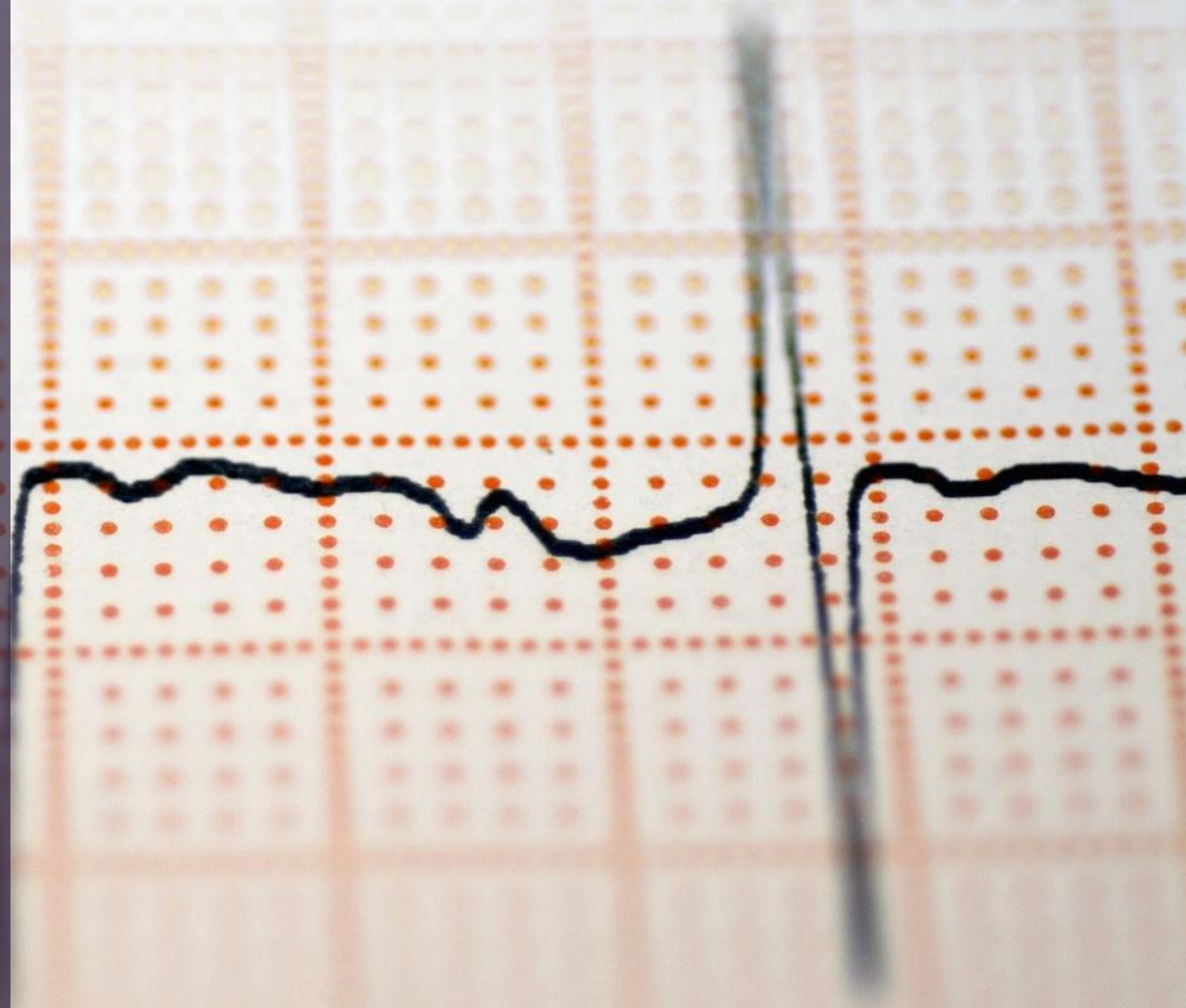
APPROACH TO READING PEDIATRIC ECGs



STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

→ Intervals and Shapes

→ Hypertrophy

→ Ischemia

→ Other

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DETERMINING THE HEART RATE

→ Rate

- How to calculate the heart rate:
  - Using large boxes (the fast way!)
  - Using small boxes
  - Using R waves

DETERMINING THE HEART RATE

- Each small box is equaled to 0.04 seconds (40 ms)
- Each big box (5 small boxes) is equaled to 1/5 of a second (0.2 seconds = 200 ms)

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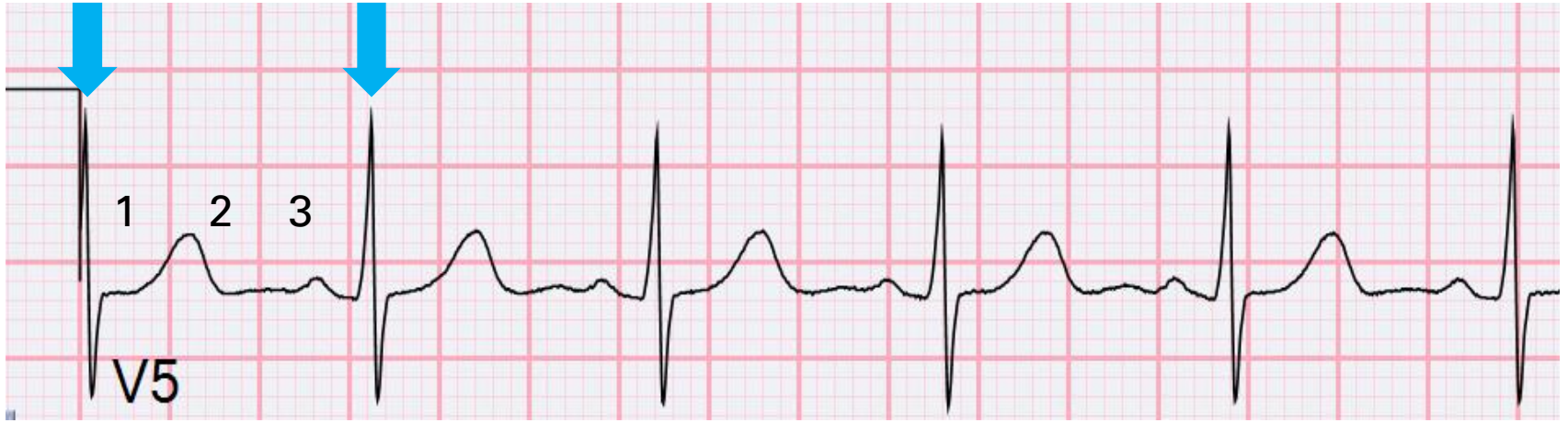
DETERMINING THE HEART RATE

→ Rate

- The fast way!!
  - Divide 300 by the # of big boxes in the R-R interval



300 / 3 =
~100 bpm

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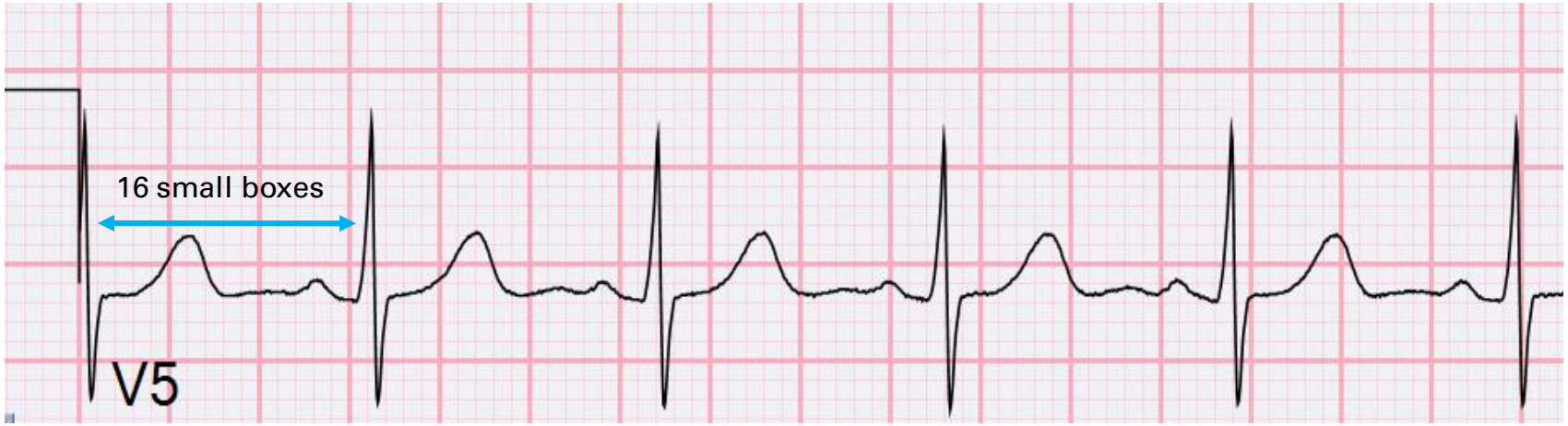
DETERMINING THE HEART RATE

→ Rate

- Using small boxes or R waves:
  - 1500 / # of small squares
  - Count the number R waves x 6 (entire rhythm strip)



1500/16 =
93.75 bpm

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NORMAL HEART RATES IN PEDIATRICS

Normal ECG Values by Age

Age	HR (bpm) 2nd-98th %ile	QRS axis (°) 2nd-98th %ile	PR (ms) 2nd-98th %ile	R, V1 (mm), 98th %ile	R, V6 (mm) 98th %ile
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1-3 mo	125-200	+40 to +140	80-130	>22	>26
3-6 mo	110-190	0 to +110	85-130	>22	>28
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1-3 yr	95-180	0 to +120	80-150	>21	>30
3-5 yr	75-125	0 to +110	100-150	>18	>30
5-8 yr	65-115	0 to +110	100-160	>15	>30
8-12 yr	55-110	0 to +110	105-170	>12	>30
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Note: For ease of use, this table of normal values was derived from resources such as:

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STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

→ Intervals and Shapes

→ Hypertrophy

→ Ischemia

→ Other

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STEPS TO READING PEDIATRIC ECGs

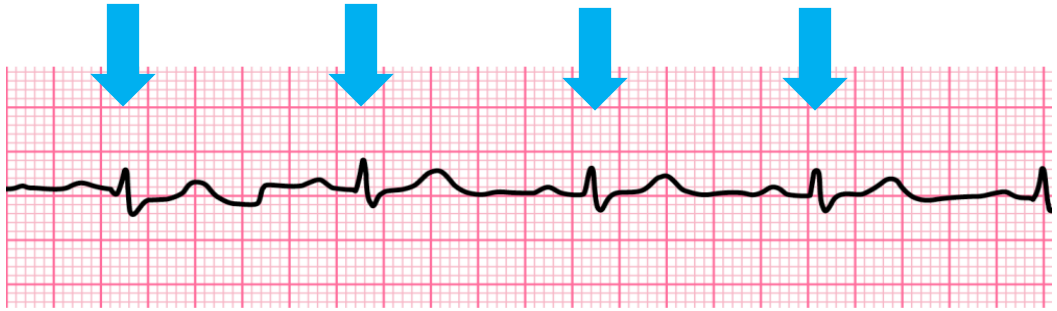
→ Rhythm

1. Is it regular or irregular?
2. Is it sinus?

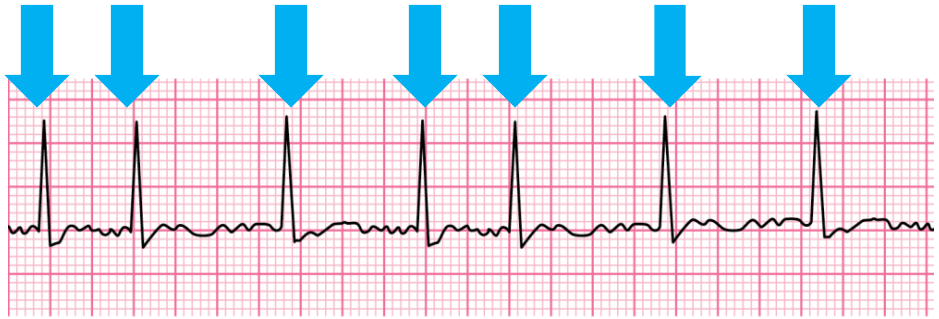
STEPS TO READING PEDIATRIC ECGs

→ Rhythm

1. **Is it regular or irregular?**



Regular



Irregular

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STEPS TO READING PEDIATRIC ECGs

→ Rhythm

2. Is it sinus?

- Is there a p wave before every QRS and a QRS after every p wave?

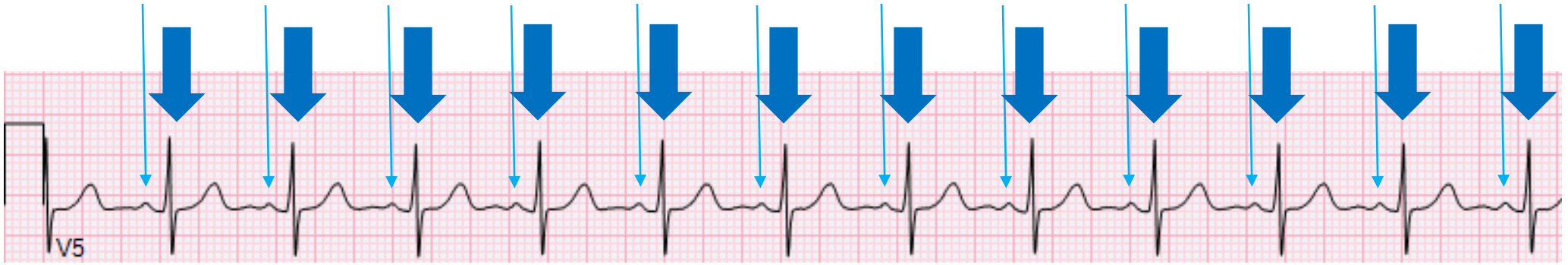
- Are the p waves upright in leads I and aVF?

STEPS TO READING PEDIATRIC ECGs

→ Rhythm

2. Is it sinus?

- Is there a p wave before every QRS and a QRS after every p wave?



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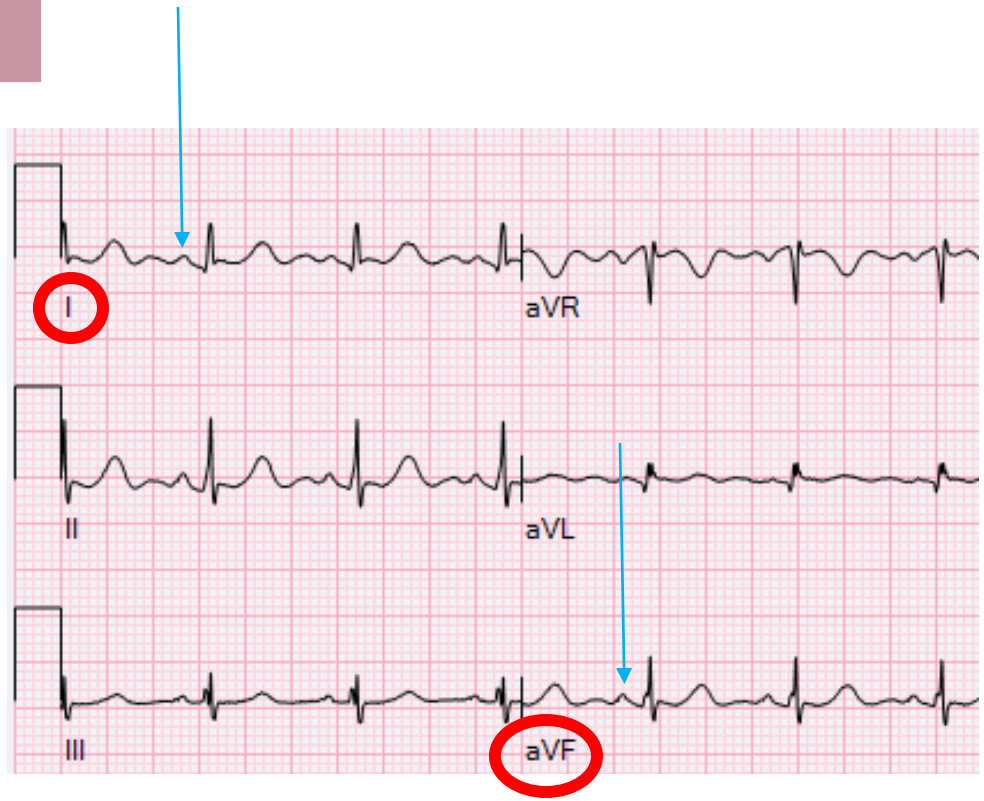
STEPS TO READING PEDIATRIC ECGs

→ Rhythm

2. Is it sinus?

- Are the p waves upright in leads I and aVF?



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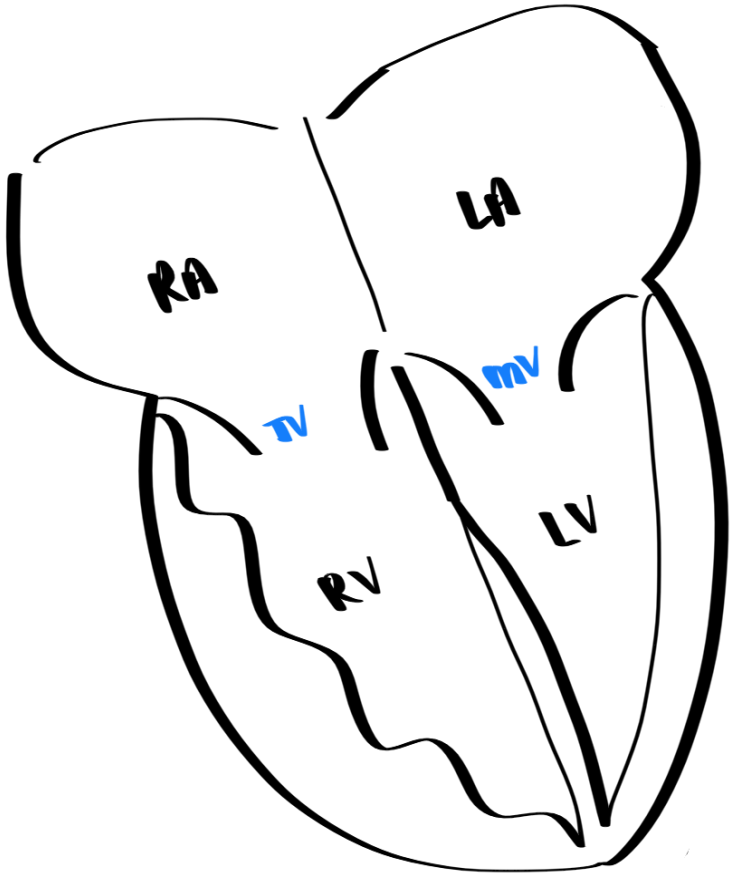
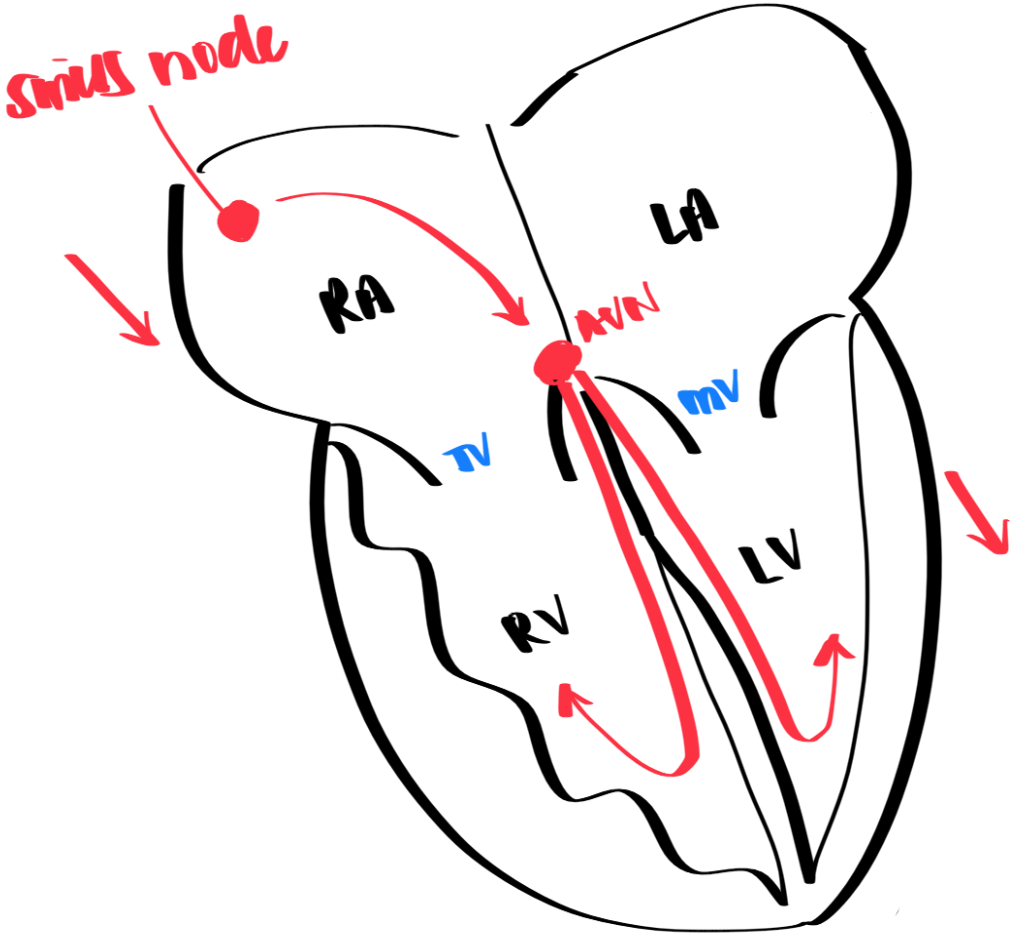
STEPS TO READING PEDIATRIC ECGs





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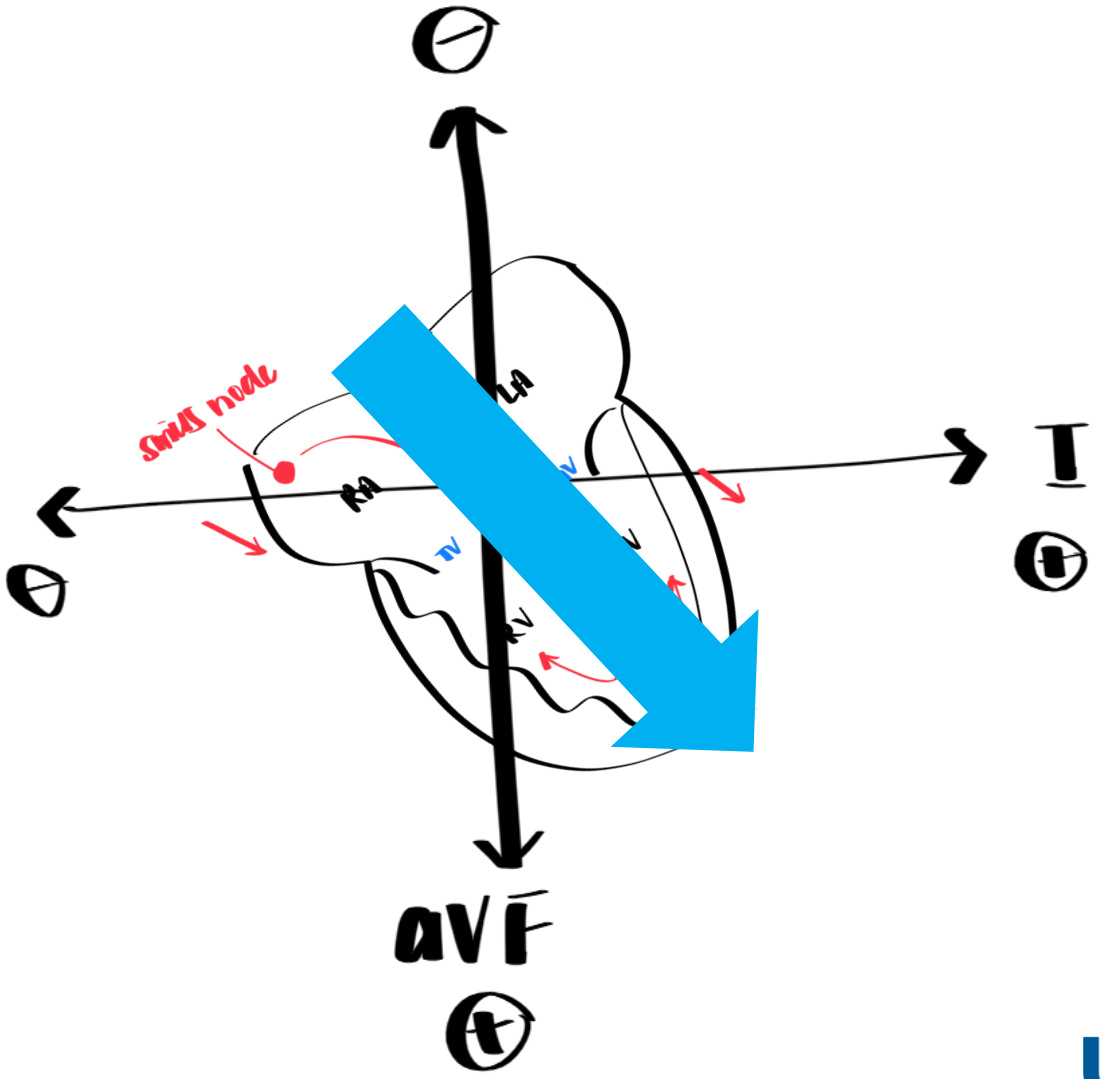
STEPS TO READING PEDIATRIC ECGs



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STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

→ Intervals and Shapes

→ Hypertrophy

→ Ischemia

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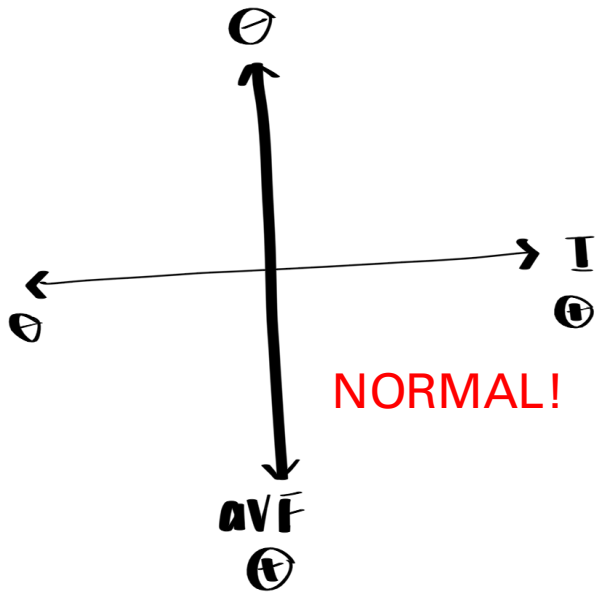
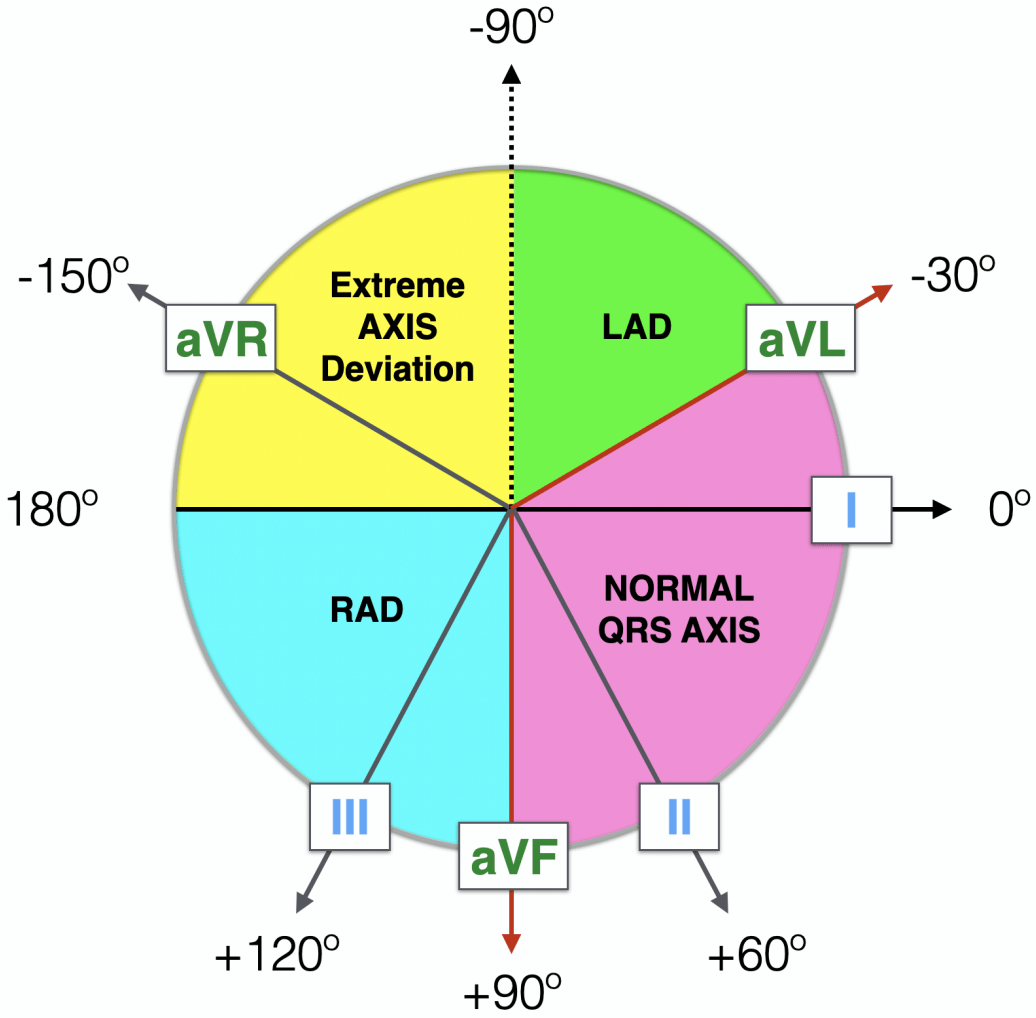
STEPS TO READING PEDIATRIC ECGs

→ Axis





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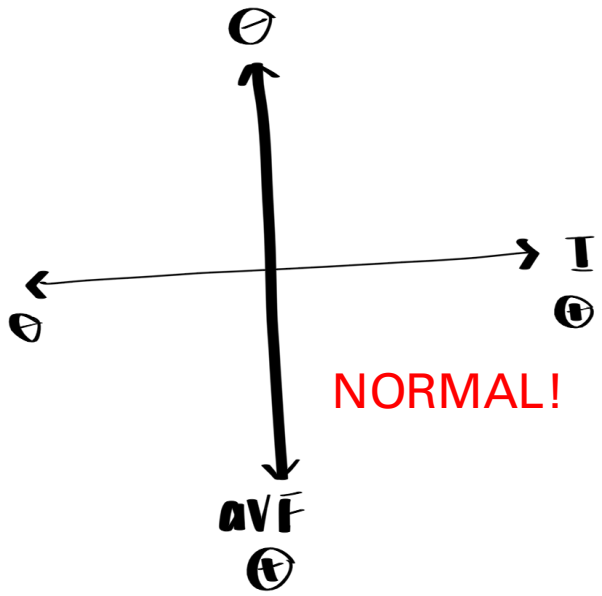
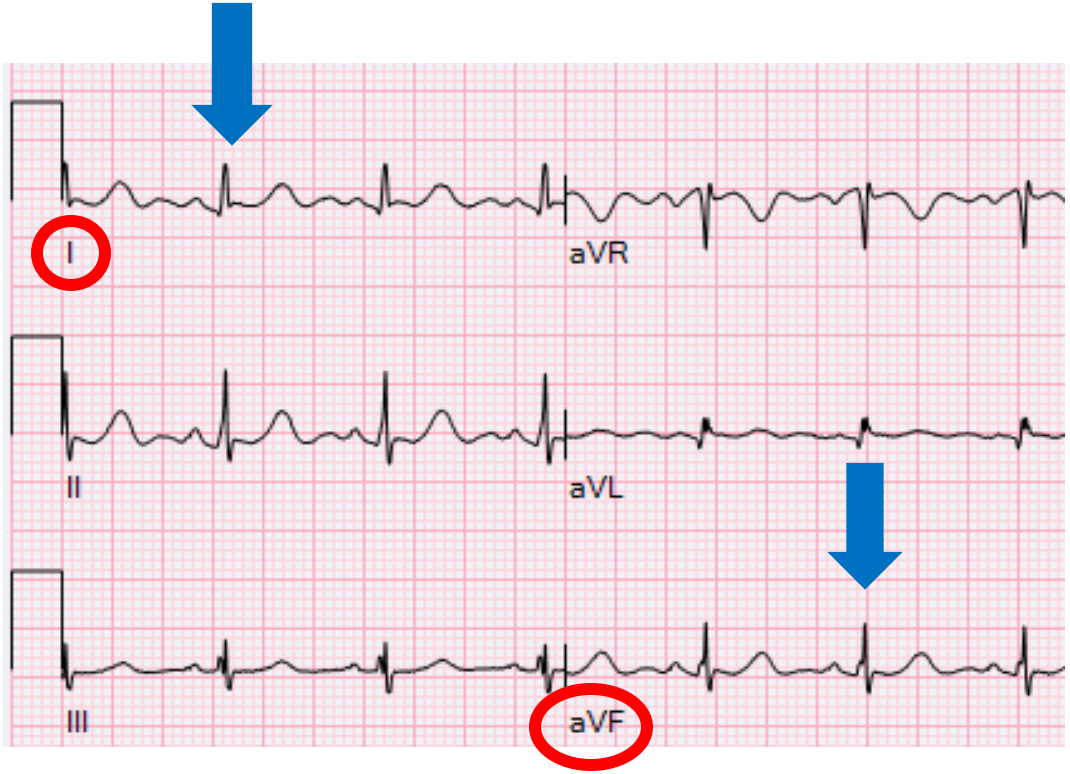
STEPS TO READING PEDIATRIC ECGs

→ Axis



What is the axis of your R waves in leads I and aVF?



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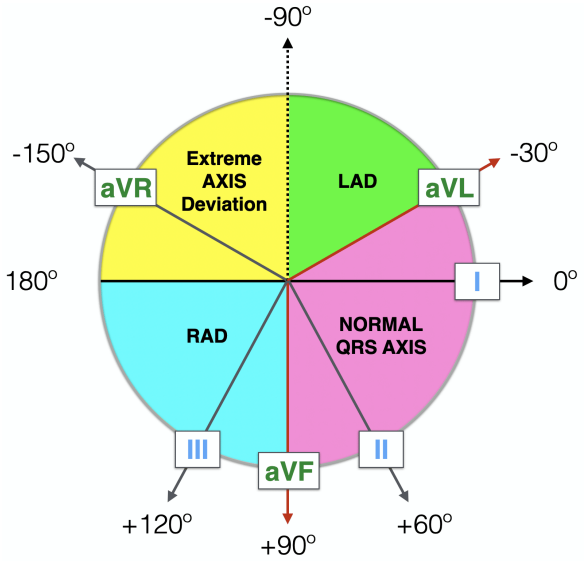
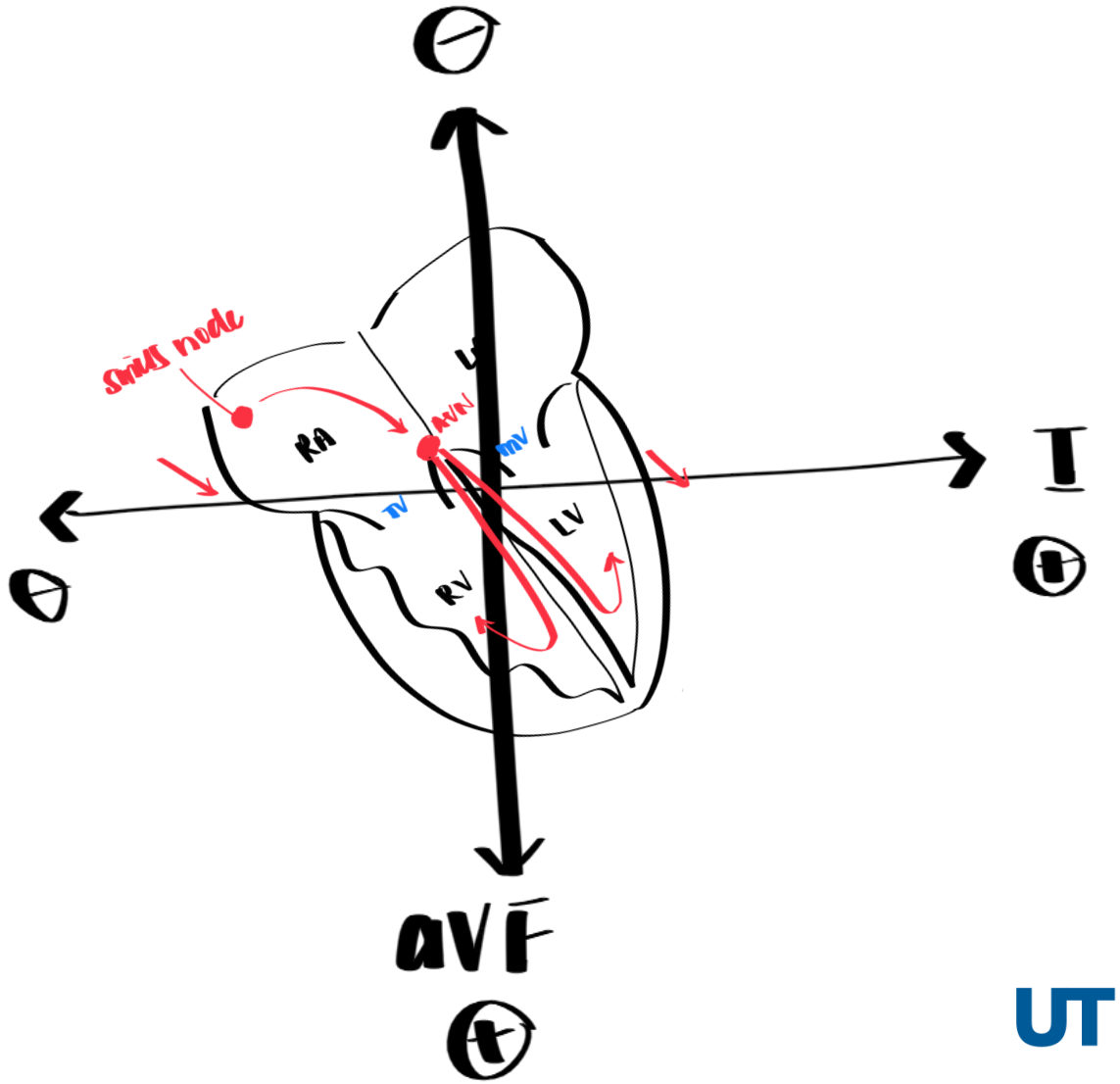
STEPS TO READING PEDIATRIC ECGs





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STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

LET'S PRACTICE JUST THESE 3 THINGS!

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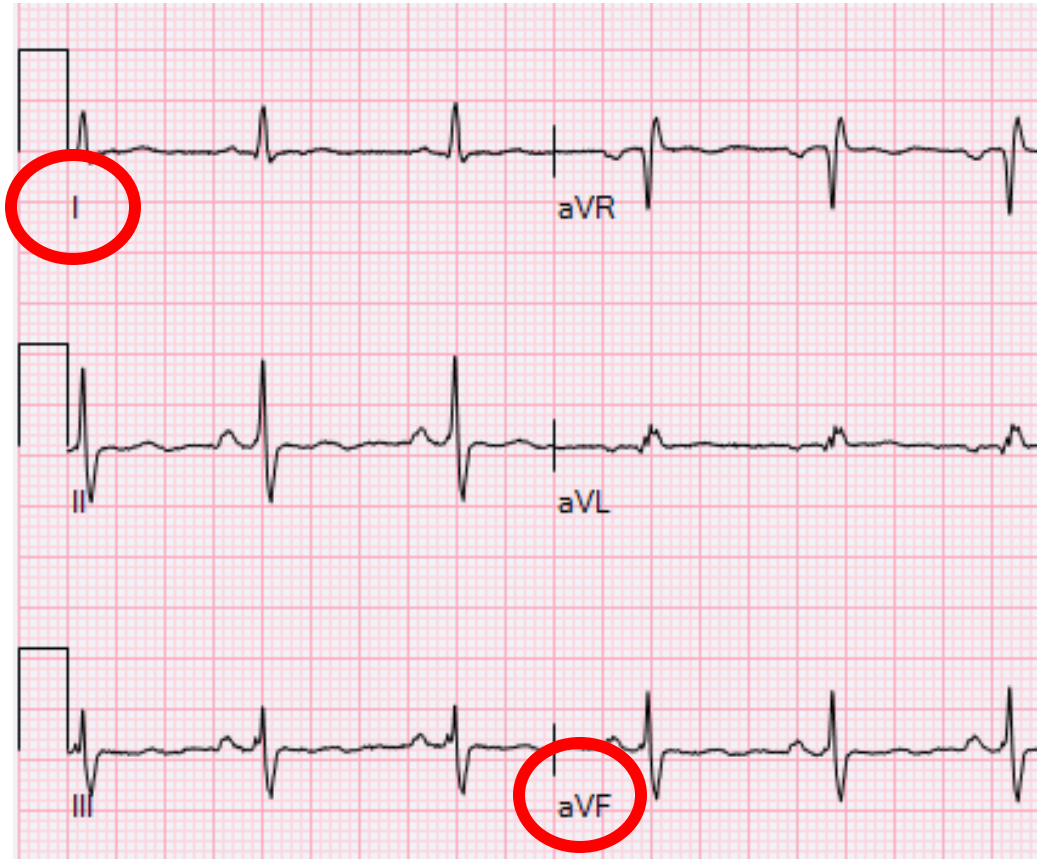

Ventricular, atrial rate:	78	78	bpm
PR, QRS:	142	108	ms
QT, QTc:	374	426	ms
PRT Axis:	76	14	-6

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NORMAL QRS AXIS IN PEDIATRICS

Normal ECG Values by Age

Age	HR (bpm) 2nd-98th %ile	QRS axis (°) 2nd-98th %ile	PR (ms) 2nd-98th %ile	R, V1 (mm), 98th %ile	R, V6 (mm) 98th %ile
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STEPS TO READING PEDIATRIC ECGs

→ Rate

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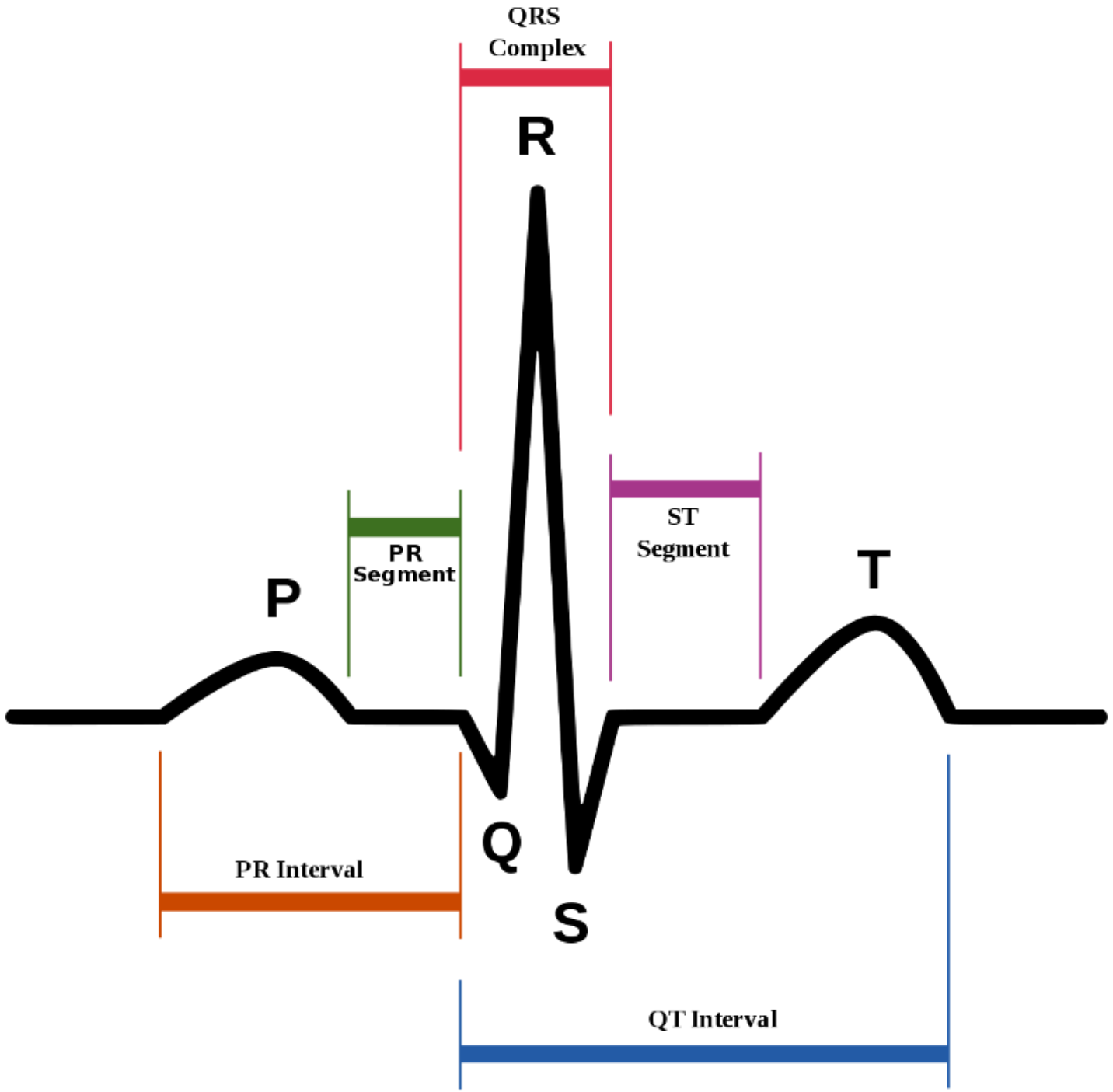
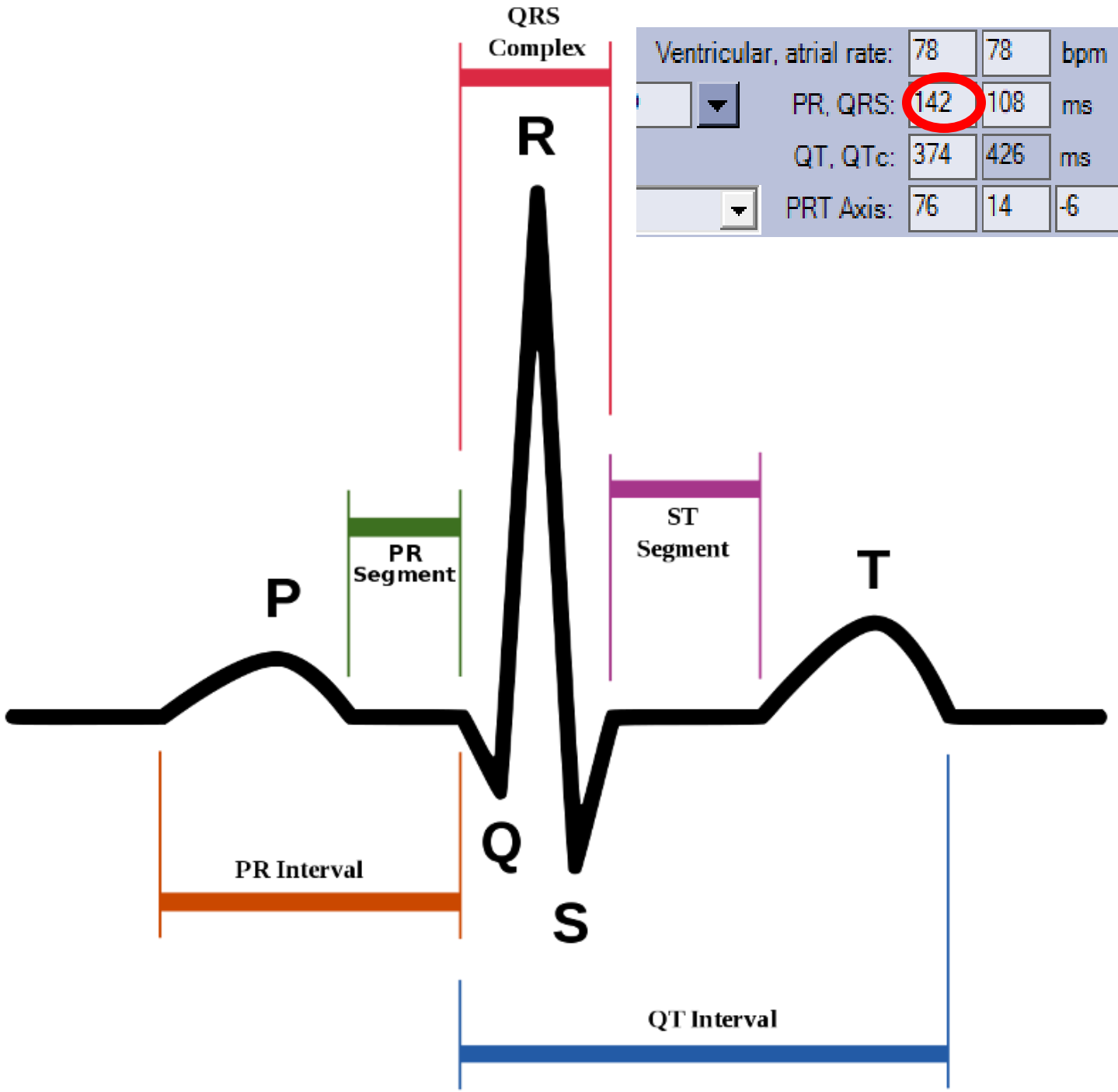
→ Intervals


QRS
Complex
R
PR
Segment
ST
Segment
P
T
PR Interval
Q
S
QT Interval

→ Intervals

PR Interval

- Indicates the time between atrial and ventricular depolarization
- Measure from the start of the P wave (start of atrial contraction) to the beginning of the Q wave (start of ventricular contraction)
- Normally ~3-5 small boxes



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PRT Axis:	76	14	-6

NORMAL INTERVALS IN PEDIATRICS

Normal ECG Values by Age

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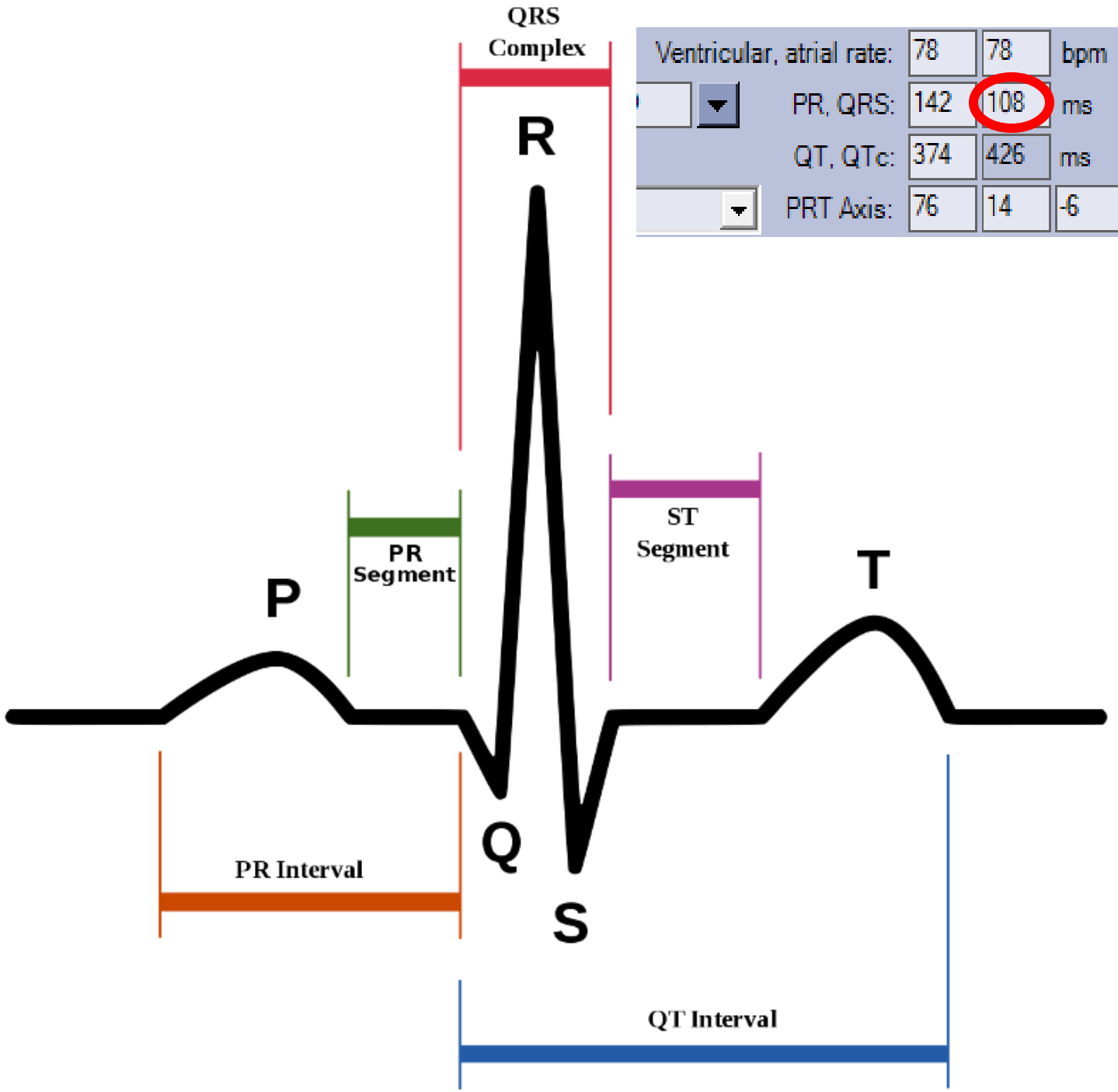
→ Intervals

QRS Interval

- Represents ventricular depolarization
- Measure from the beginning of the Q wave to the end of the S wave
- Normally <100 ms (<2.5 small boxes)



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PRT Axis:	76	14	-6

NORMAL INTERVALS IN PEDIATRICS

QTc interval: Borderline = 450-460, prolonged >460	
Bundle branch blocks: a. 0-5 yr = >90 ms b. 5-12 yr = >100 ms d. >13 yr = 120 ms	**Incomplete bundle branch block** **(or nonspecific intraventricular conduction delay):** Wide QRS or RSR' without meeting BBB criteria

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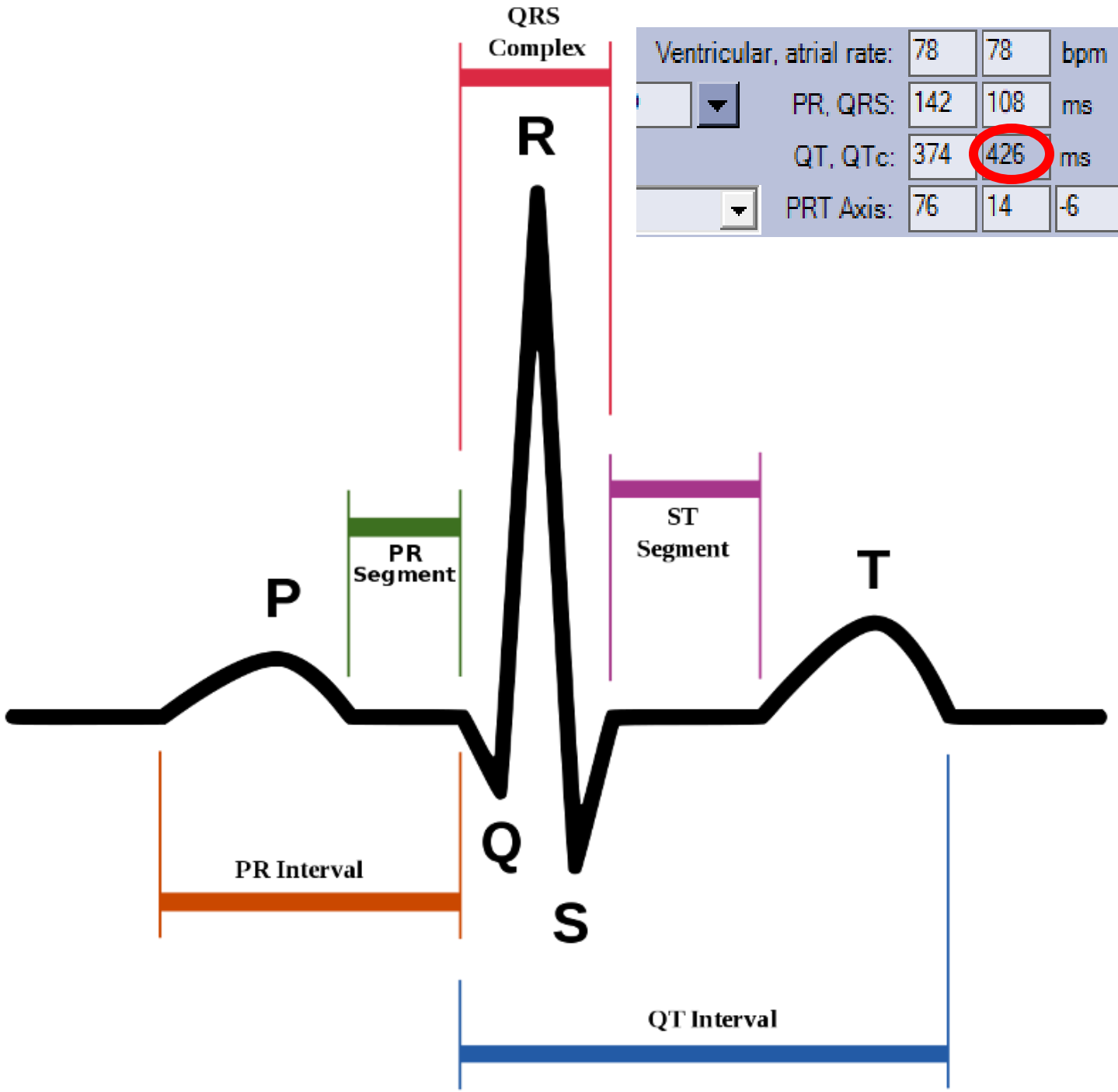
→ Intervals

QT Interval***

- Measure from the beginning of the Q wave to the end of the T wave
- Corrected QT interval (QTc) is normally 340-440ms
- ALWAYS MEASURE YOURSELF!!



Ventricular, atrial rate:	78	78	bpm
PR, QRS:	142	108	ms
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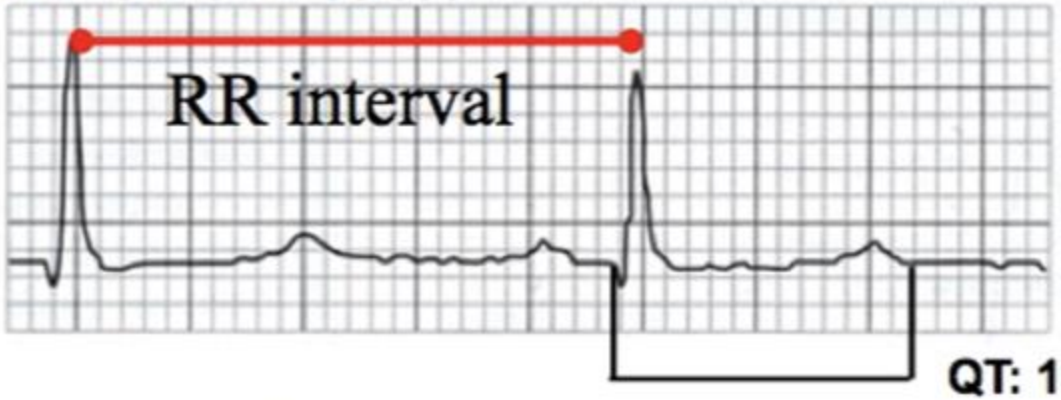
NORMAL INTERVALS IN PEDIATRICS

RR: 24.5 x .04 = .98 sec



QT: 13 x .04 = .52 sec

$$QTc = \frac{QT}{\sqrt{RR}} = \frac{.52}{\sqrt{.98}} = \frac{.52}{.989} = .525 \text{ or } .53 \text{ sec}$$

Or just plug into any calculator :)

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NORMAL INTERVALS IN PEDIATRICS

QTc interval: Borderline = 450-460, prolonged >460	
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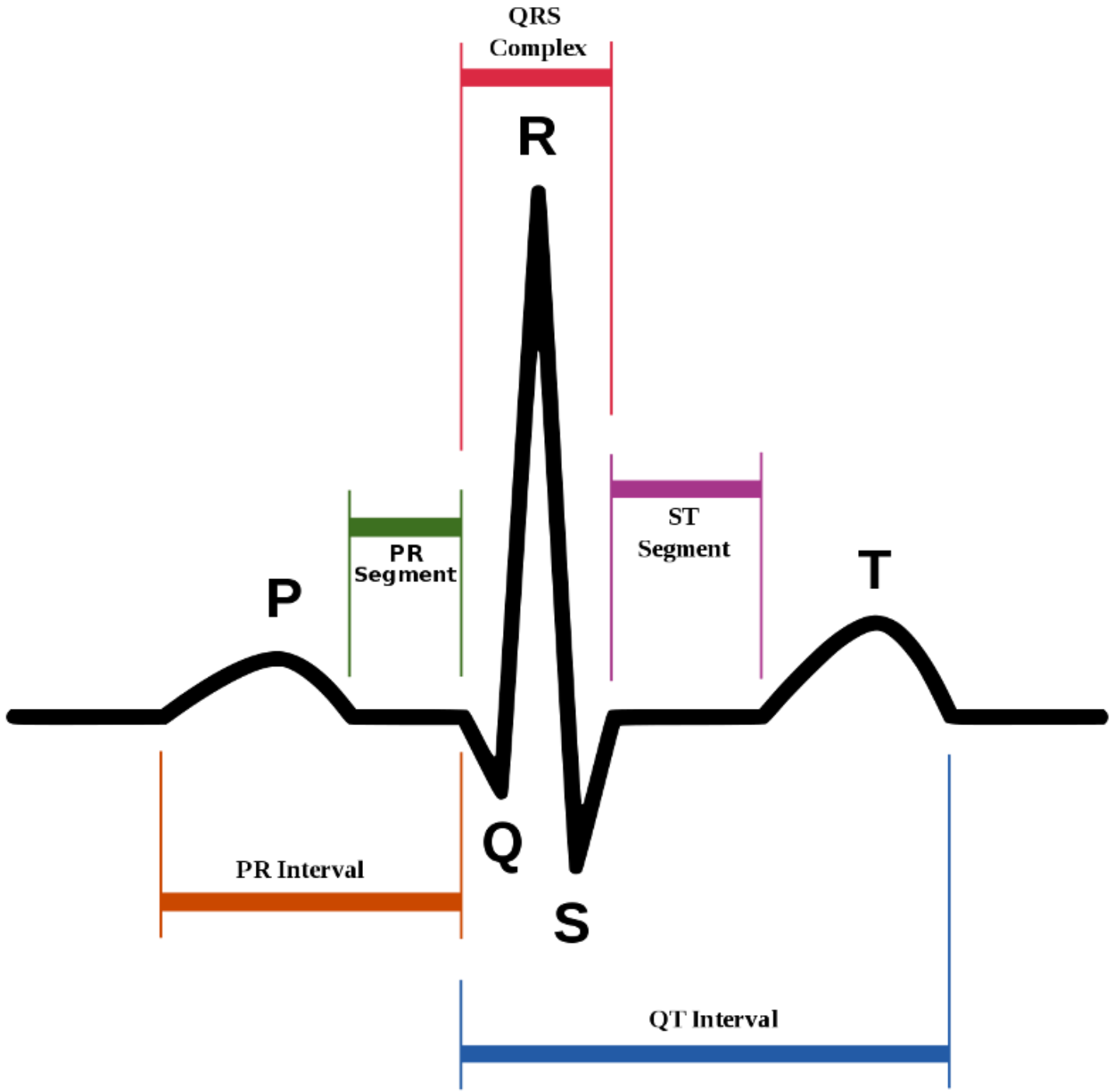
→ Shapes

P Wave

- Atrial depolarization
- Normal P wave is < 2mm in height and <120 ms (3 small boxes)



→ Shapes

P Wave

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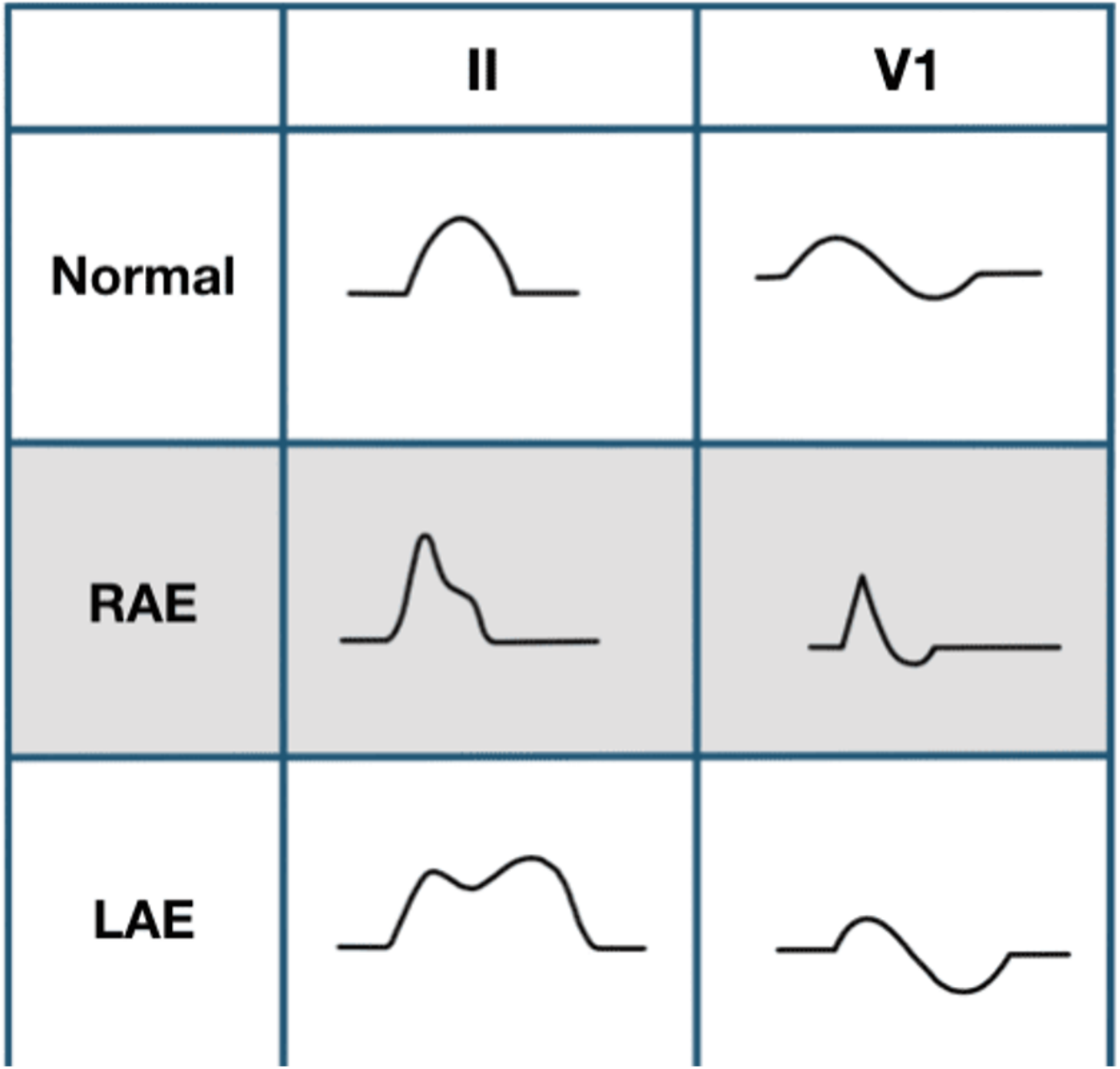
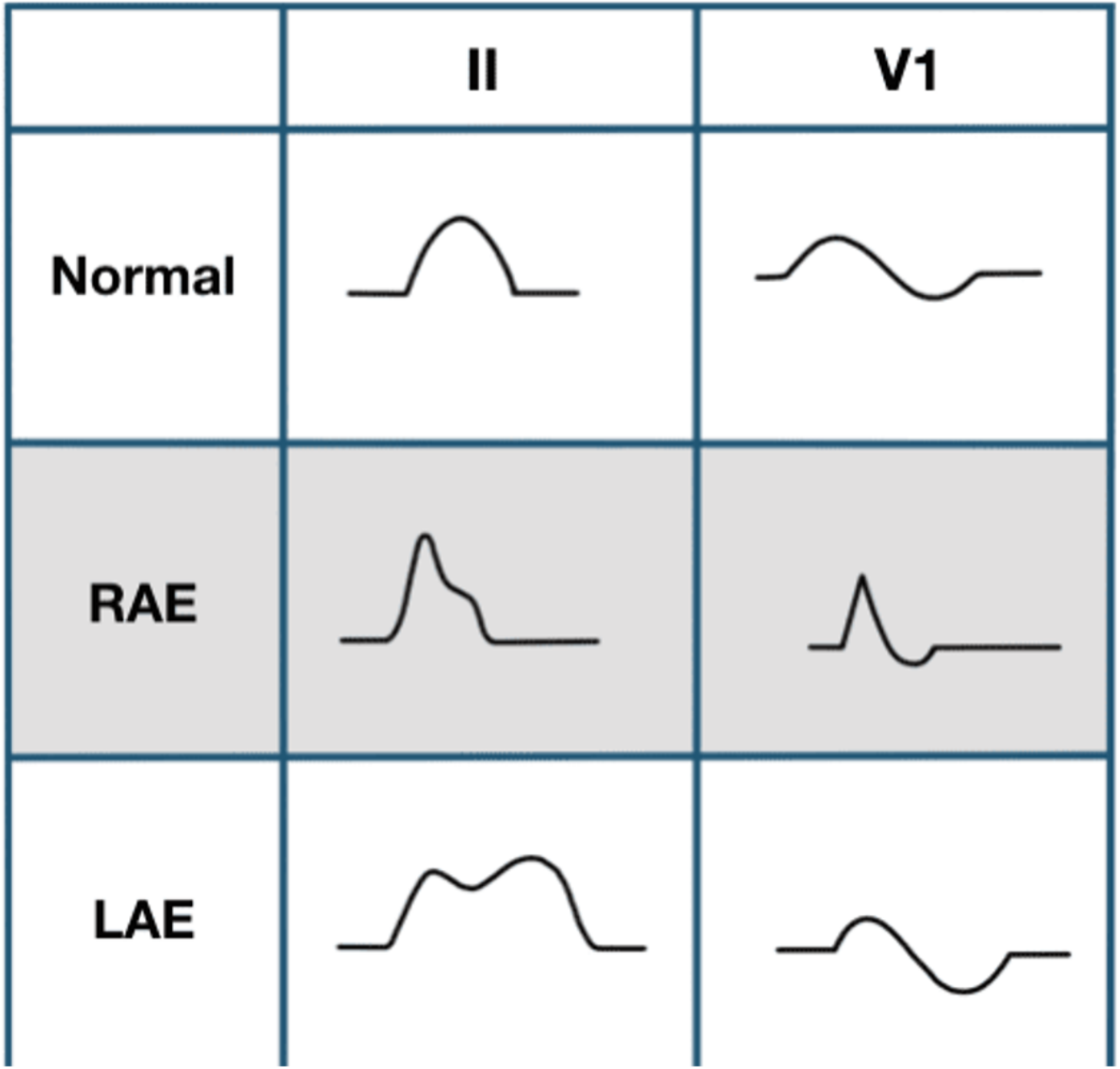


→ Shapes

P Wave – Right atrial enlargement

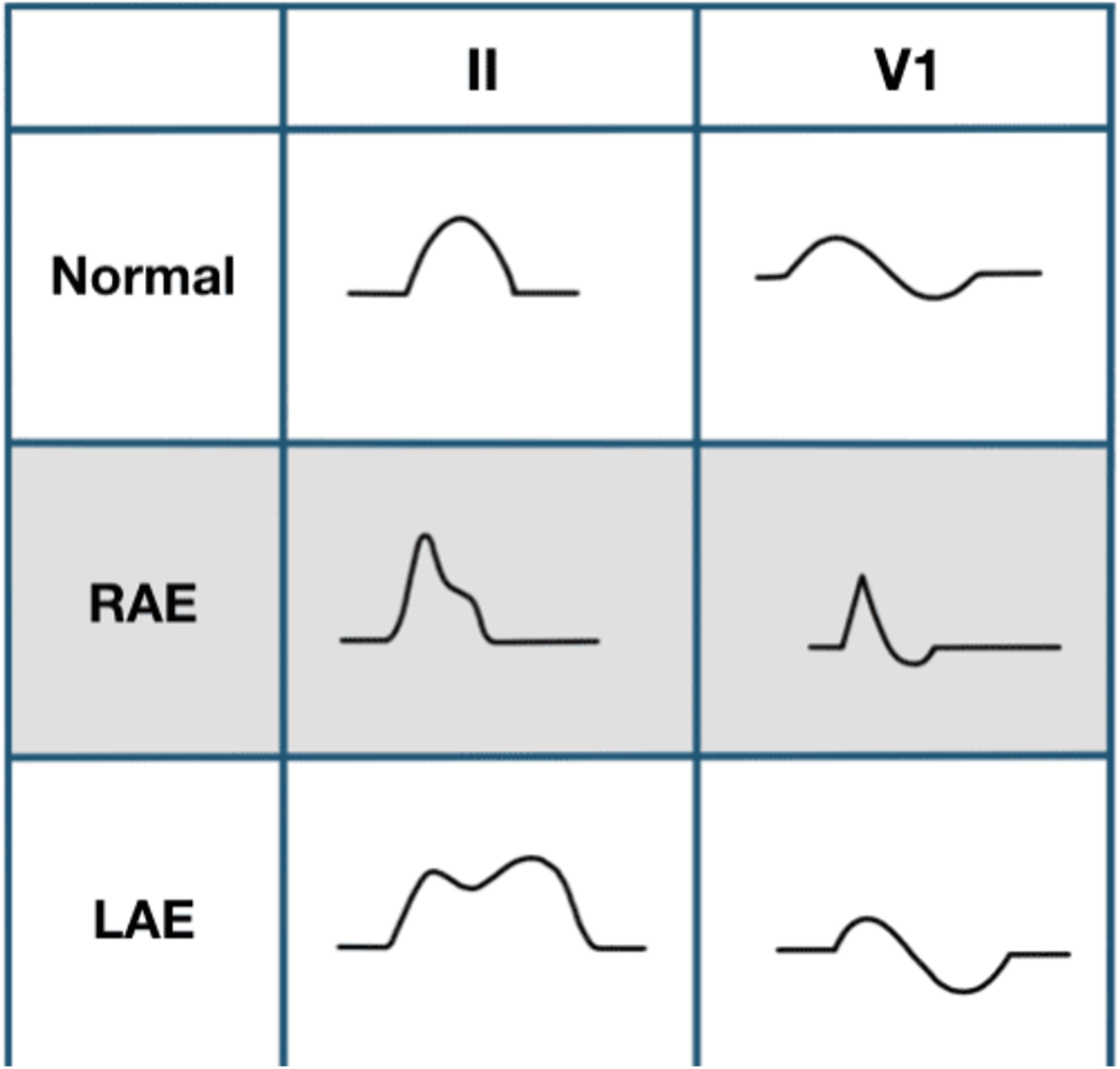
- Tall, peaked P waves in leads II and V1
- *Normal P wave is **<u><2mm in height</u>** and <120 ms (3 small boxes)*



→ Shapes

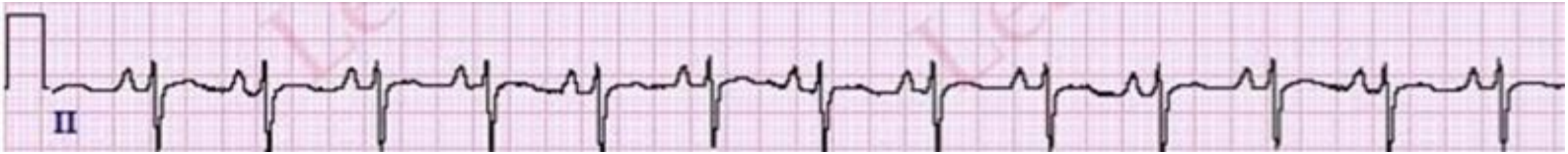
P Wave – Left atrial enlargement

- Wide and M-shaped, **"P mitral"**
- *Normal P wave is <2mm in height and* ***<120 ms (3 small boxes)***

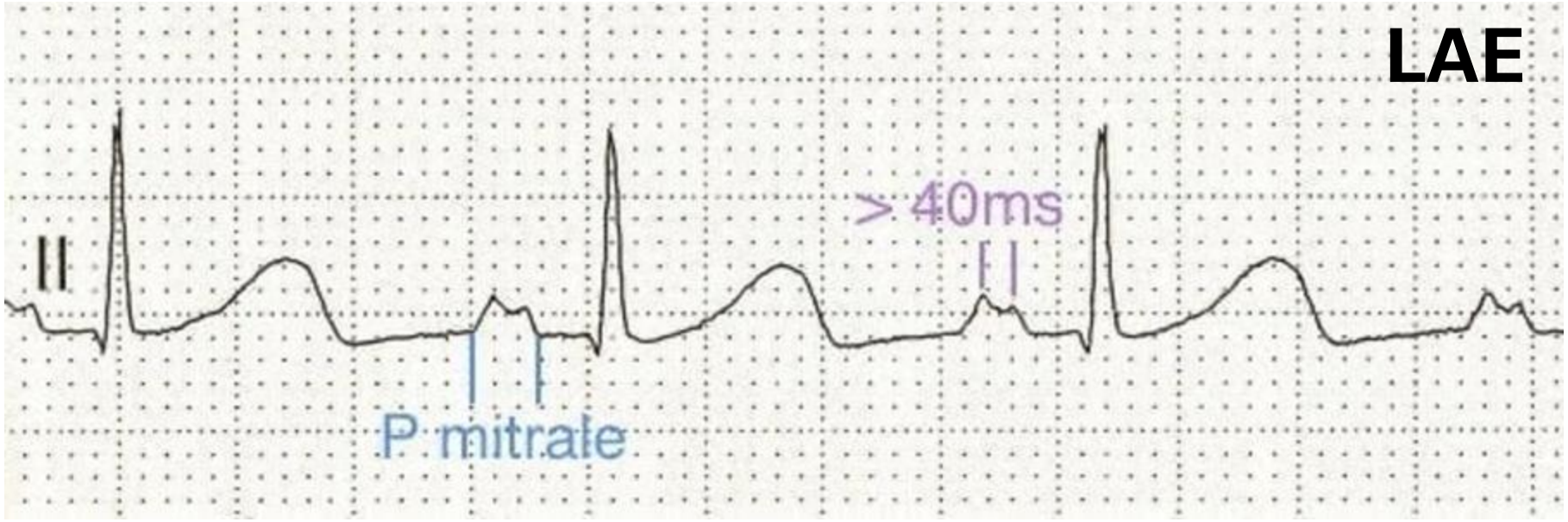


→ Shapes

RAE



LAE



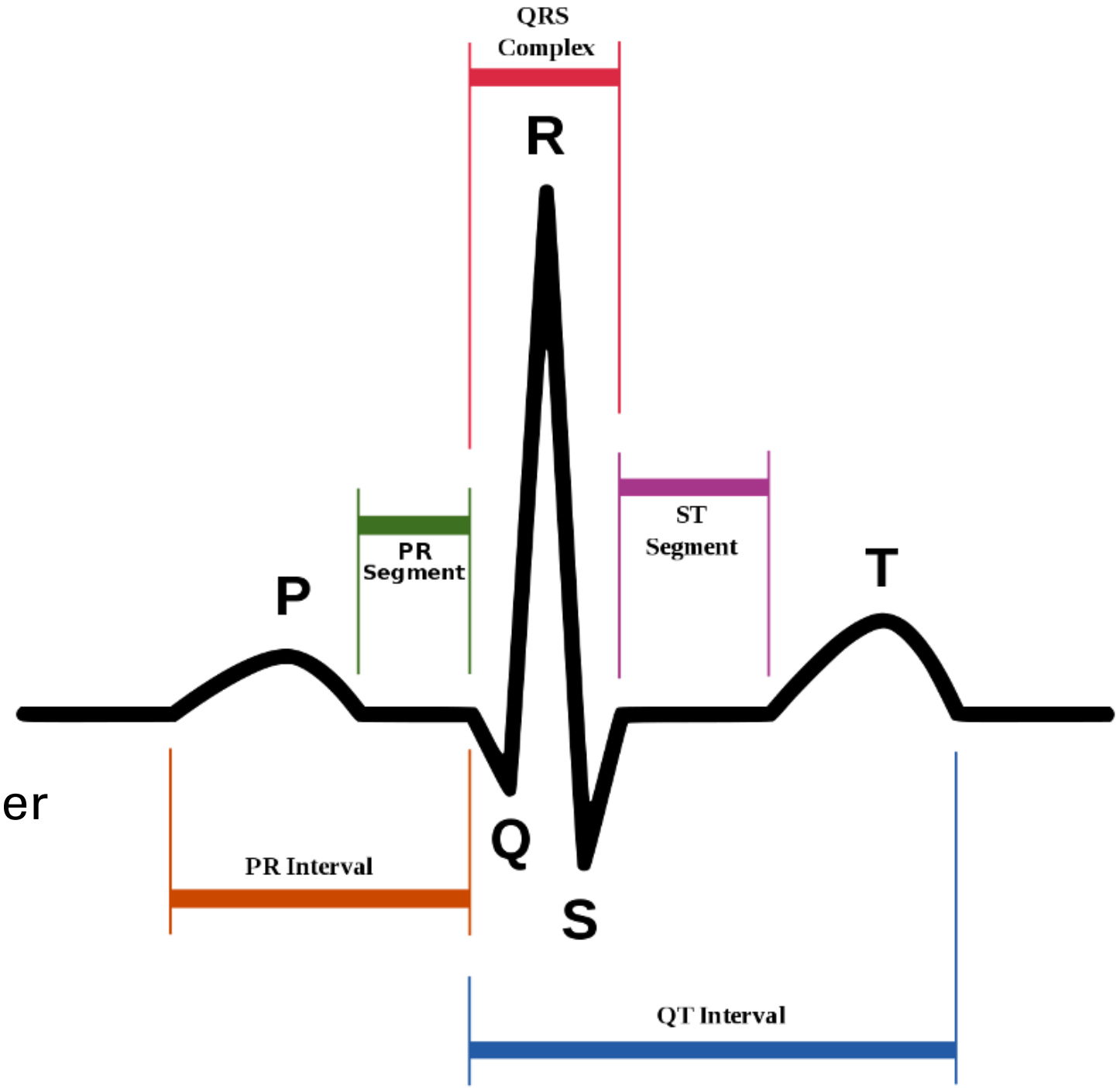
→ Shapes

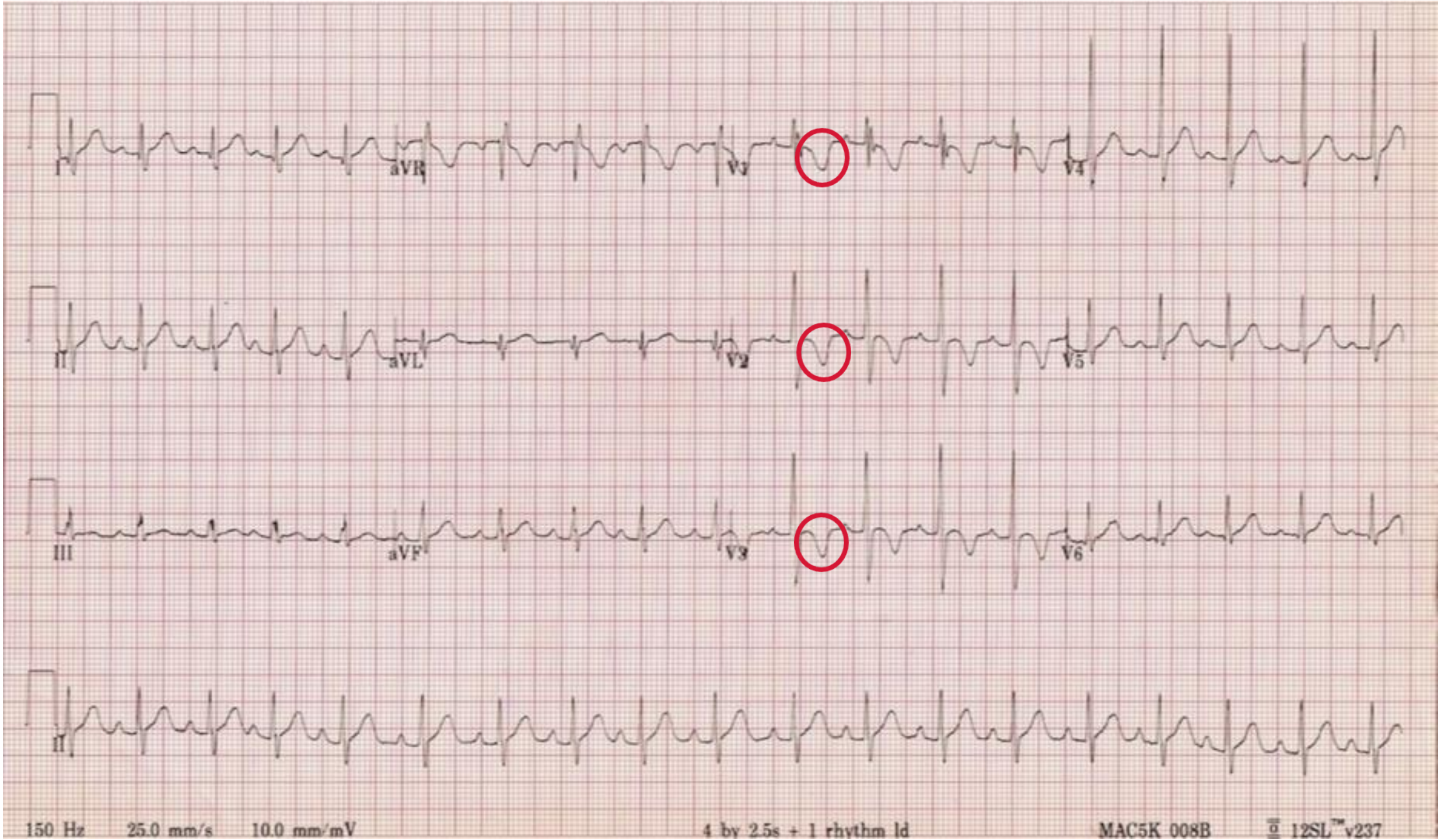
T Wave

- Measures ventricular repolarization

- T wave pattern:
  - Upright at birth
  - Inverted ~1 week of life until puberty (~9-10 years old)
  - Slowly flips upright again after puberty

- *T waves **SHOULD NEVER** be inverted in V5-V6 in any age!

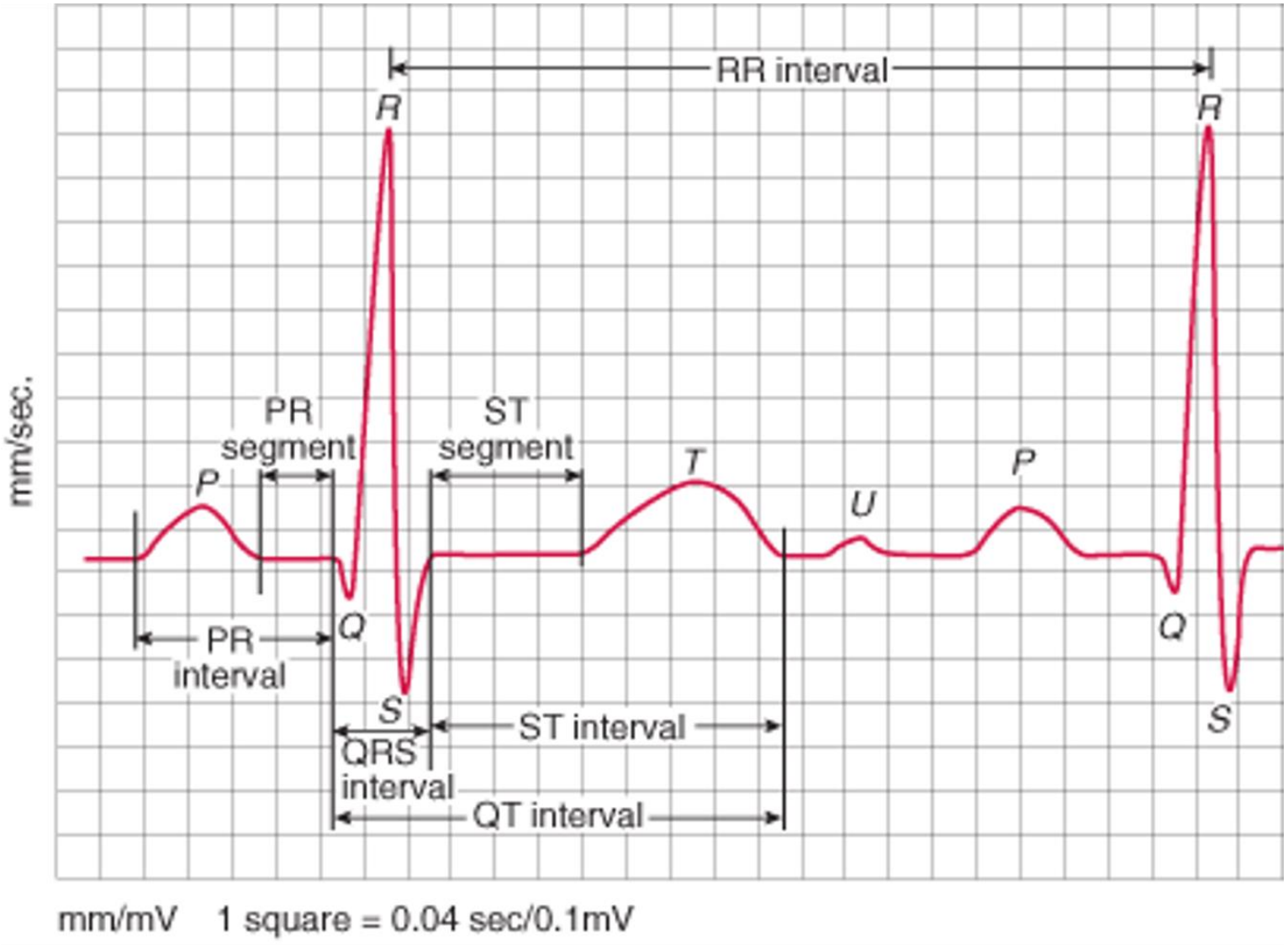



I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
150 Hz
25.0 mm/s
10.0 mm/mV
4 by 2.5s + 1 rhythm ld
MAC5K 008B
12SL™v237

→ Shapes

U Wave

- Seen with **HYPO**kalemia
- Occurs right after the T wave



STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

→ Intervals and Shapes

→ Hypertrophy

→ Ischemia

→ Other

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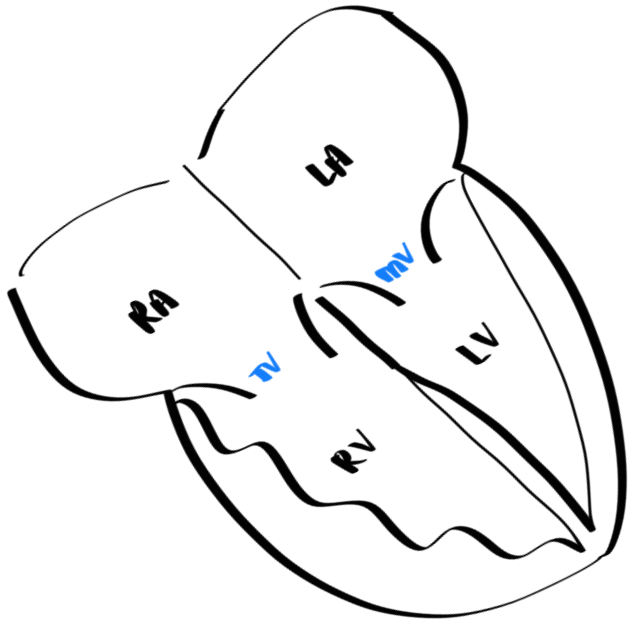
STEPS TO READING PEDIATRIC ECGs

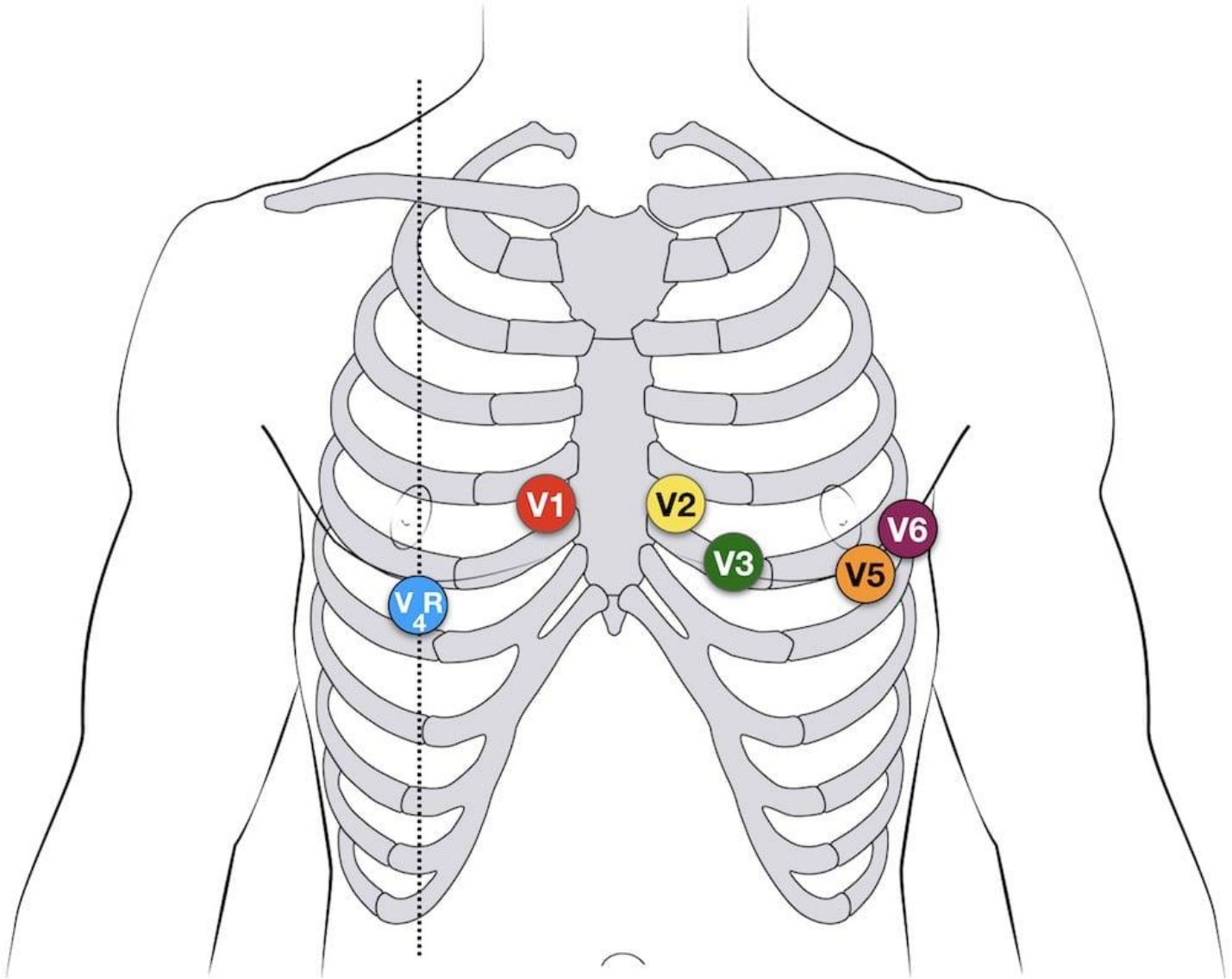
→ Hypertrophy

1. **What leads represent RVH?**
2. **What leads represent LVH?**
3. **What are the normal values for the patient's age?**

STEPS TO READING PEDIATRIC ECGs

→ Hypertrophy

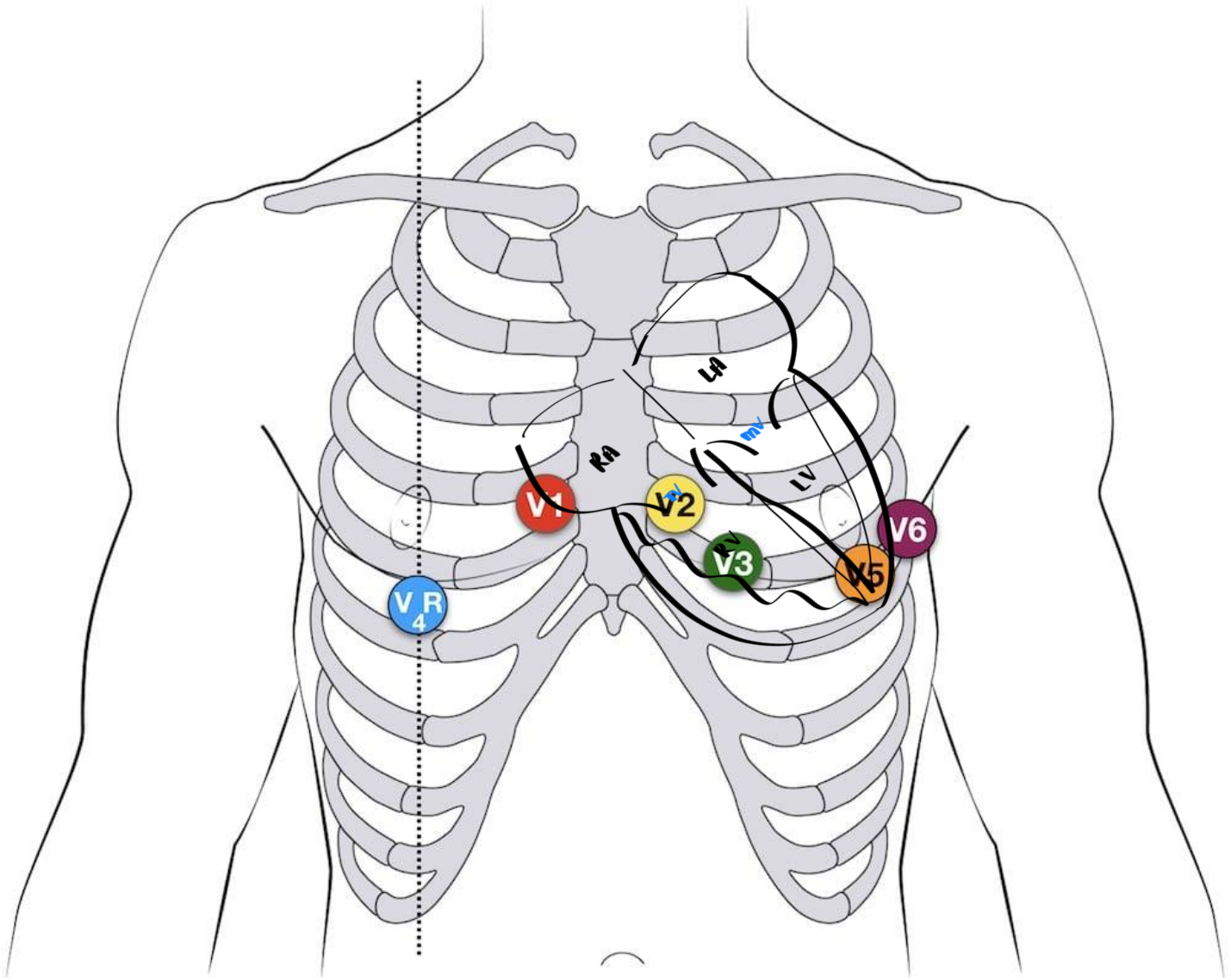




STEPS TO READING PEDIATRIC ECGs

→ Hypertrophy

1. **What leads represent RVH?**
   - V1
2. **What leads represent LVH?**
   - V6



STEPS TO READING PEDIATRIC ECGs

→ Hypertrophy

1. **Look a the R wave in V1 (for RVH) and V6 (for LVH).**
   - V1
     - Tall R wave (+) in V1 shows high RV forces (RVH)
     - Deep S wave (-) in V1 shows high LV forces (LVH)

   - V6
     - Tall R wave (+) in V6 shows high LV forces (LVH)
     - Deep S wave (-) in V6 shows high RV forces (RVH)

STEPS TO READING PEDIATRIC ECGs

→ Hypertrophy

3. What are the normal values for the patient's age?

Normal ECG Values by Age

Age	HR (bpm) 2nd-98th %ile	QRS axis (°) 2nd-98th %ile	PR (ms) 2nd-98th %ile	R, V1 (mm), 98th %ile	R, V6 (mm) 98th %ile
0-1 mo	130-215	+70 to +155	80-120	>22	>18
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5-8 yr	65-115	0 to +110	100-160	>15	>30
8-12 yr	55-110	0 to +110	105-170	>12	>30
12-16 yr	50-110	0 to +110	105-180	>12	>30

STEPS TO READING PEDIATRIC ECGs

→ Hypertrophy

3. What are the normal values for the patient's age?

Age	RVH criteria			LVH criteria		
	V1 R height (mm)	V1 R/S ratio	V6 S depth (mm)	V1 S depth (mm)	V6 R height (mm)	V6 R/S ratio
0 - 1 months	> 22	> 10	> 10	> 19	> 18	> 11
1 - 3 months	> 22	> 7	> 10	> 11	> 26	> 12
3 - 6 months	> 22	> 7	> 8	> 15	> 28	> 18
6 - 12 months	> 21	> 4	> 7	> 18	> 28	> 22
1 - 3 years	> 21	> 4	> 6	> 21	> 30	> 28
3 - 5 years	> 18	> 3	> 5	> 22	> 30	> 30
5 - 8 years	> 15	> 2	> 4	> 24	> 30	> 30
8 - 12 years	> 12	> 2	> 4	> 25	> 30	> 33
12 - 16 years	> 12	> 2	> 3.5	> 21	> 30	> 39
> 16 years	> 12	> 2	> 3.5	> 20	> 30	> 39

STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

→ Intervals and Shapes

→ Hypertrophy

→ Ischemia

→ Other

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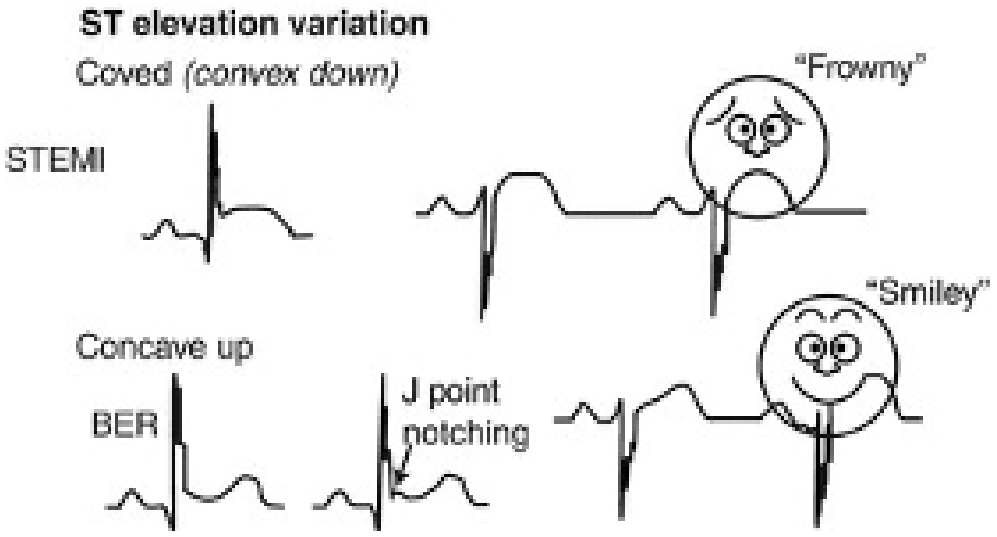
STEPS TO READING PEDIATRIC ECGs

→ Ischemia

1. **ST segment**
2. **Q waves**

STEPS TO READING PEDIATRIC ECGs

→ Ischemia



1. **ST segment**
   - DEPRESSION
     - Cardiomyopathy*
     - Concerns for subendocardial ischemia
     - Drug effects (i.e. Digoxin)
   - ELEVATON
     - *STEMI is not common in pediatrics
     - Commonly seen in pericarditis, which causes diffuse ST segment elevation

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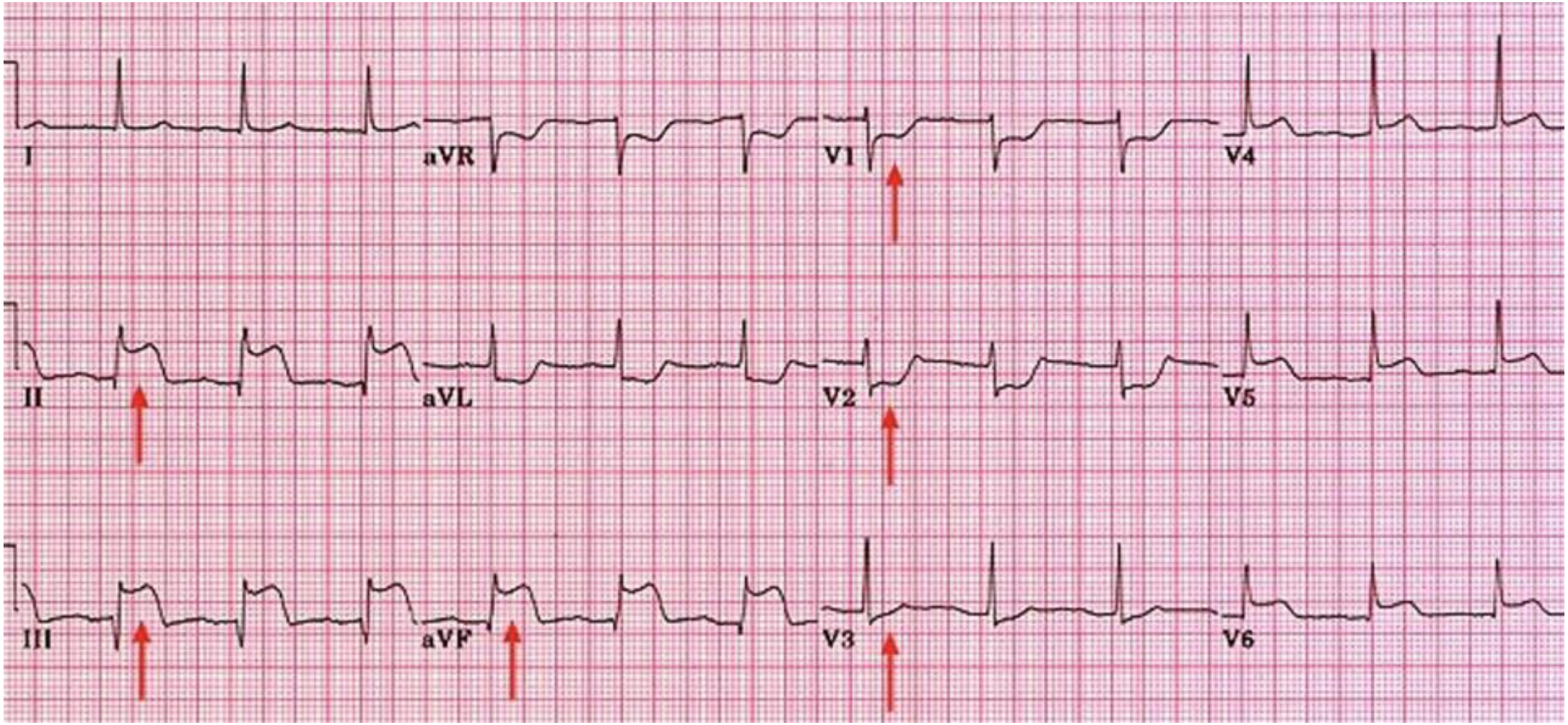
STEPS TO READING PEDIATRIC ECGs

→ Ischemia

1. **ST segment abnormalities**
   - More commonly seen in pediatrics:
     1. Heart transplant patients
     2. Vasculitis
     3. Dyslipidemia
     4. Cocaine use
     5. S/p congenital heart surgery



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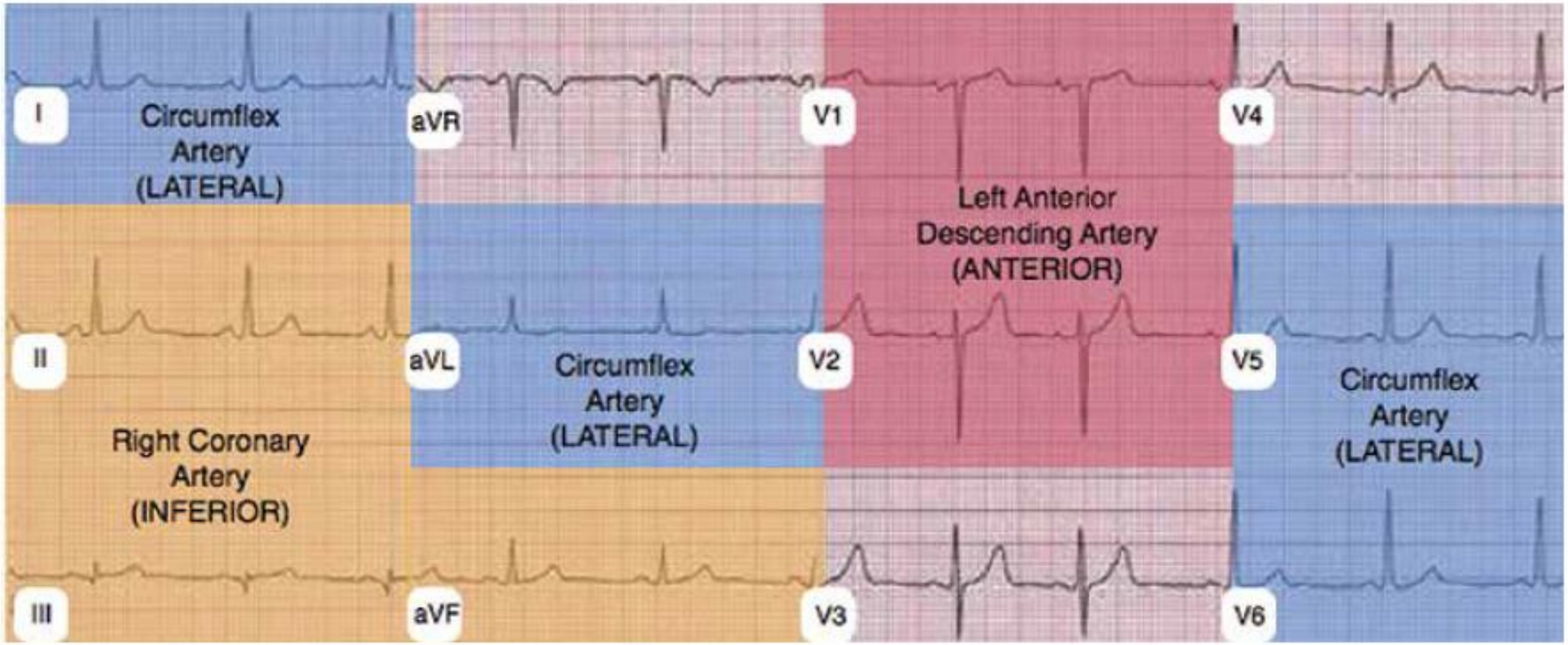
STEPS TO READING PEDIATRIC ECGs

→ Ischemia

1. **ST segments**
   - Correlates with coronary distribution



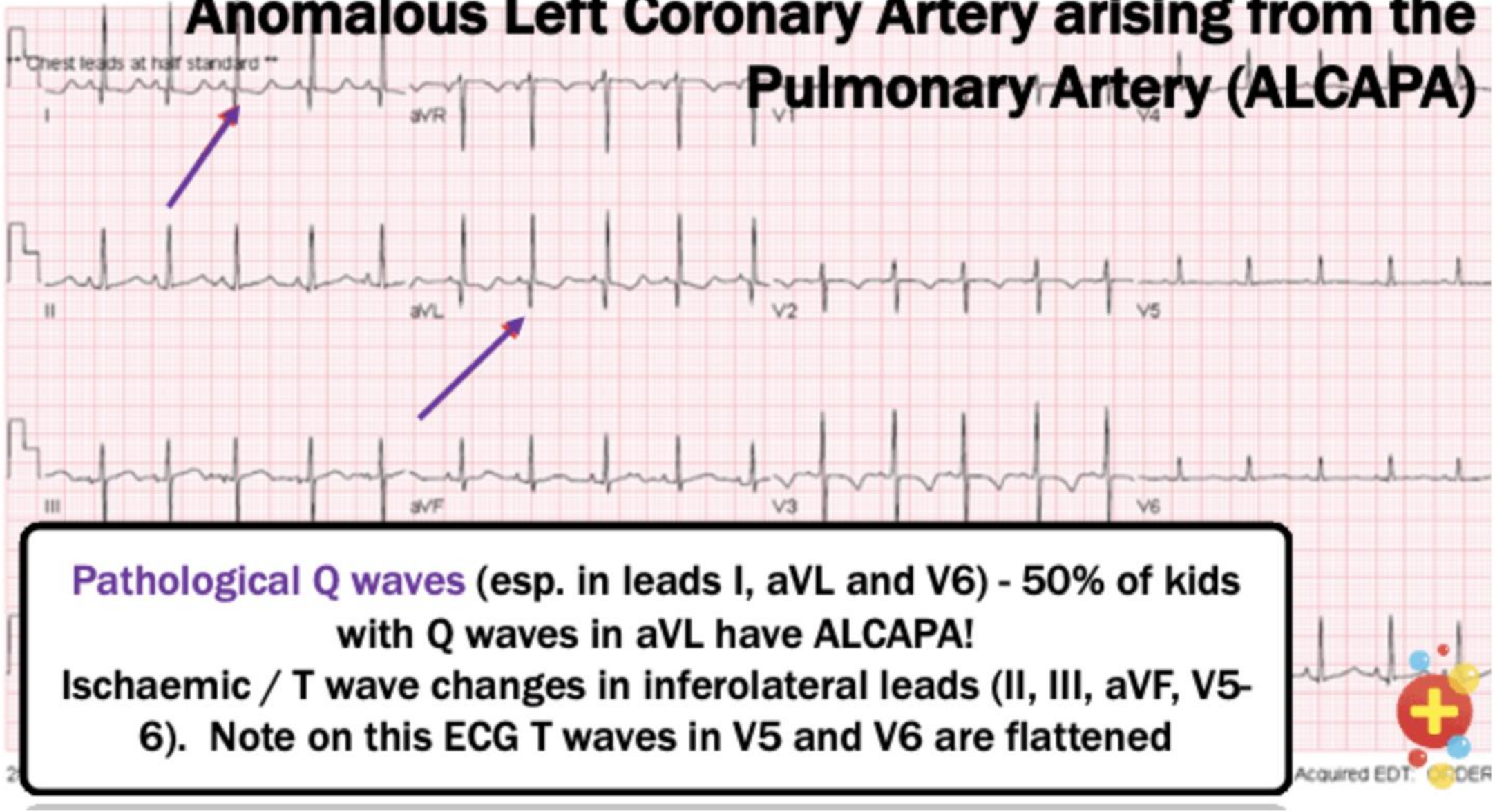
STEPS TO READING PEDIATRIC ECGs

→ Ischemia

1. **Q waves**
   - Q waves that are DEEP are consided pathological
     - Any Q wave > 2 boxes DEEP and > 1 box WIDE

2. ***** ALCAPA in pediatrics**
   - Deep Q waves in leads I and aVL

Anomalous Left Coronary Artery arising from the Pulmonary Artery (ALCAPA)



Pathological Q waves (esp. in leads I, aVL and V6) - 50% of kids with Q waves in aVL have ALCAPA!

Ischaemic / T wave changes in inferolateral leads (II, III, aVF, V5-6). Note on this ECG T waves in V5 and V6 are flattened

STEPS TO READING PEDIATRIC ECGs

→ Rate

→ Rhythm

→ Axis

→ Intervals and Shapes

→ Hypertrophy

→ Ischemia

→ Other

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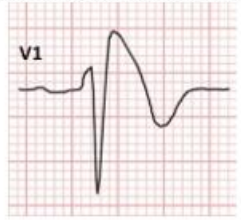
STEPS TO READING PEDIATRIC ECGs

→ Other

***Will be in handout, but should be for another lecture!**

WPW = short PR interval, wide QRS. Accessory pathway. Risk of a-fib / flutter turning into v-fib / flutter.

Brugada = V1, V2, V3 'coved' ST elevation with neg T-wave. Risk of sudden cardiac death.

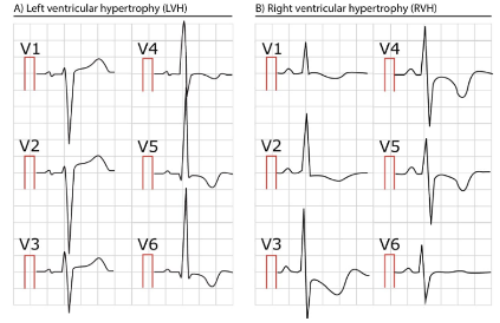


Right Bundle = wide QRS, M shape in V1-V3, wide S in V6
Incomplete RBBB or RV conduction delay = RBBB pattern but narrow QRS (common in peds)

Left Bundle = wide QRS, W shape in V1, M shape in V6

LV strain = ST depression and T inversion in 1, aVL, V5-V6 (counts as LVH criteria)

RV strain = ST depression and T inversion in V1-V3 and 2,3,aVF



NORMAL PEDIATRIC ECG VALUES

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Normal ECG Values by Age

Age	HR (bpm) 2nd-98th %ile	QRS axis (°) 2nd-98th %ile	PR (ms) 2nd-98th %ile	R, V1 (mm), 98th %ile	R, V6 (mm) 98th %ile
0-1 mo	130-215	+70 to +155	80-120	>22	>18
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3-5 yr	75-125	0 to +110	100-150	>18	>30
5-8 yr	65-115	0 to +110	100-160	>15	>30
8-12 yr	55-110	0 to +110	105-170	>12	>30
12-16 yr	50-110	0 to +110	105-180	>12	>30

Right ventricular hypertrophy: R in V1 >98th %ile for age **Left ventricular hypertrophy**: R in V6 >98th %ile for age **Biventricular hypertrophy**: R+S in any lead >60 mm	
QTc interval: Borderline = 450-460, prolonged >460	
Bundle branch blocks: a. 0-5 yr = >90 ms b. 5-12 yr = >100 ms d. >13 yr = 120 ms	**Incomplete bundle branch block (or nonspecific intraventricular conduction delay):** Wide QRS or RSR' without meeting BBB criteria

Note: For ease of use, this table of normal values was derived from resources such as:

- **Rijnbeek PR et al. New normal limits for the paediatric electrocardiogram. 2001.**
- **Saarel EV, et al. Electrocardiograms in Healthy North American Children in the Digital Age. 2018.**

There is variability among all publications on "normal" pediatric ECG values, definitions of ventircular hypertrophy, etc. There is no agreed-upon gold standard. Please interpret this table while understanding its limitations.

>Example ECGs

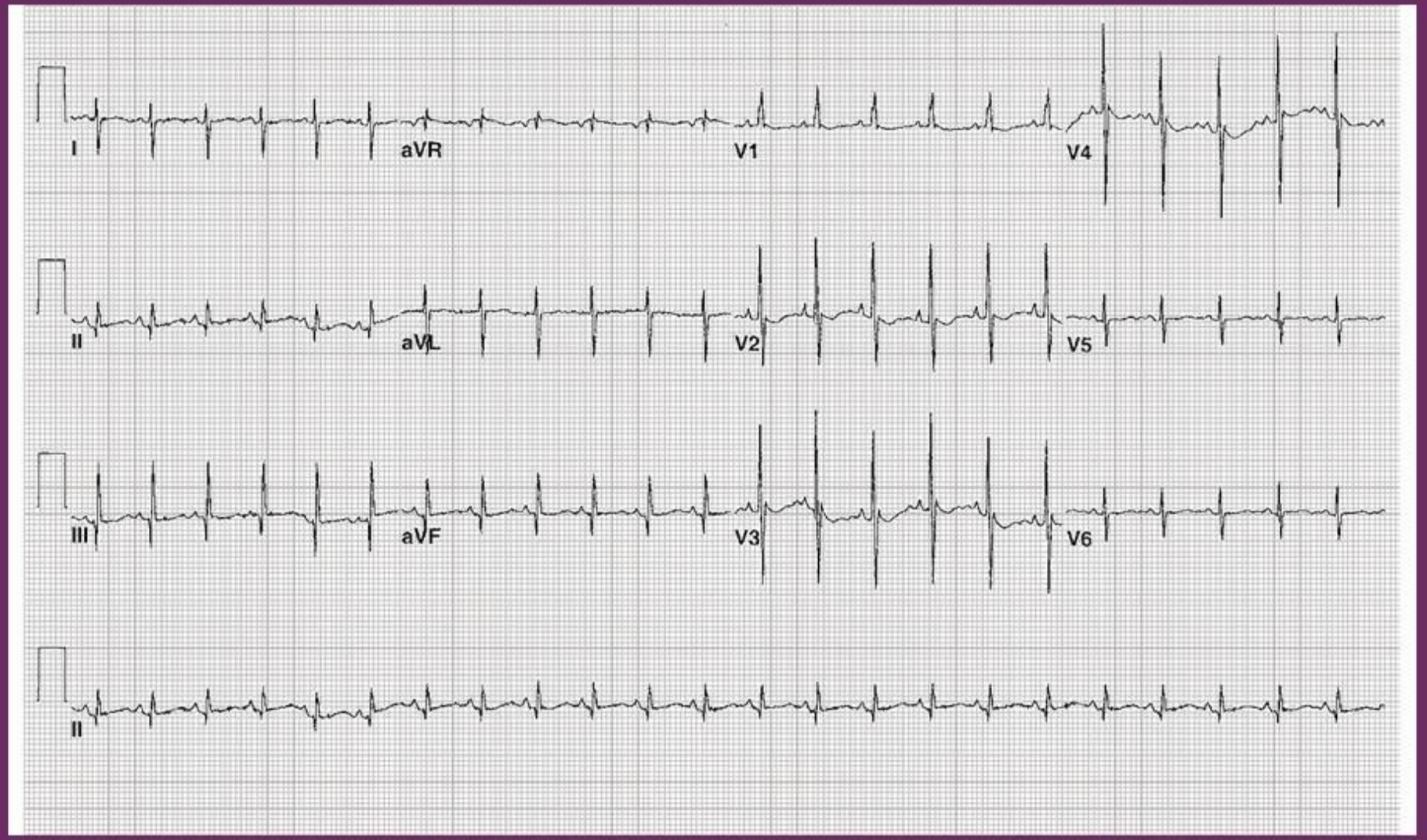


Figure 1: 1-day-old infant

Figure 2: 2-week-old infant

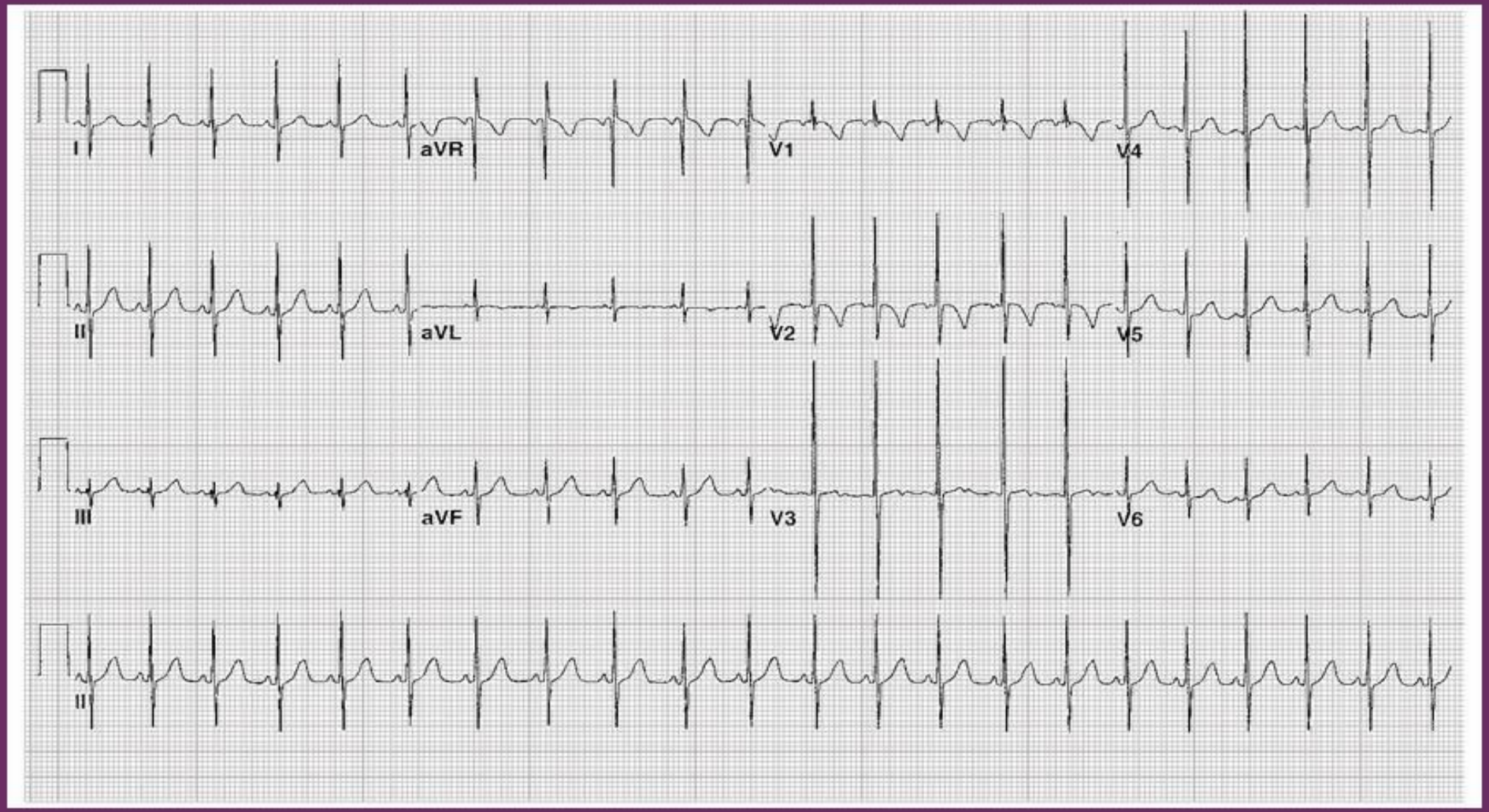


Figure 3: 5-month-old female

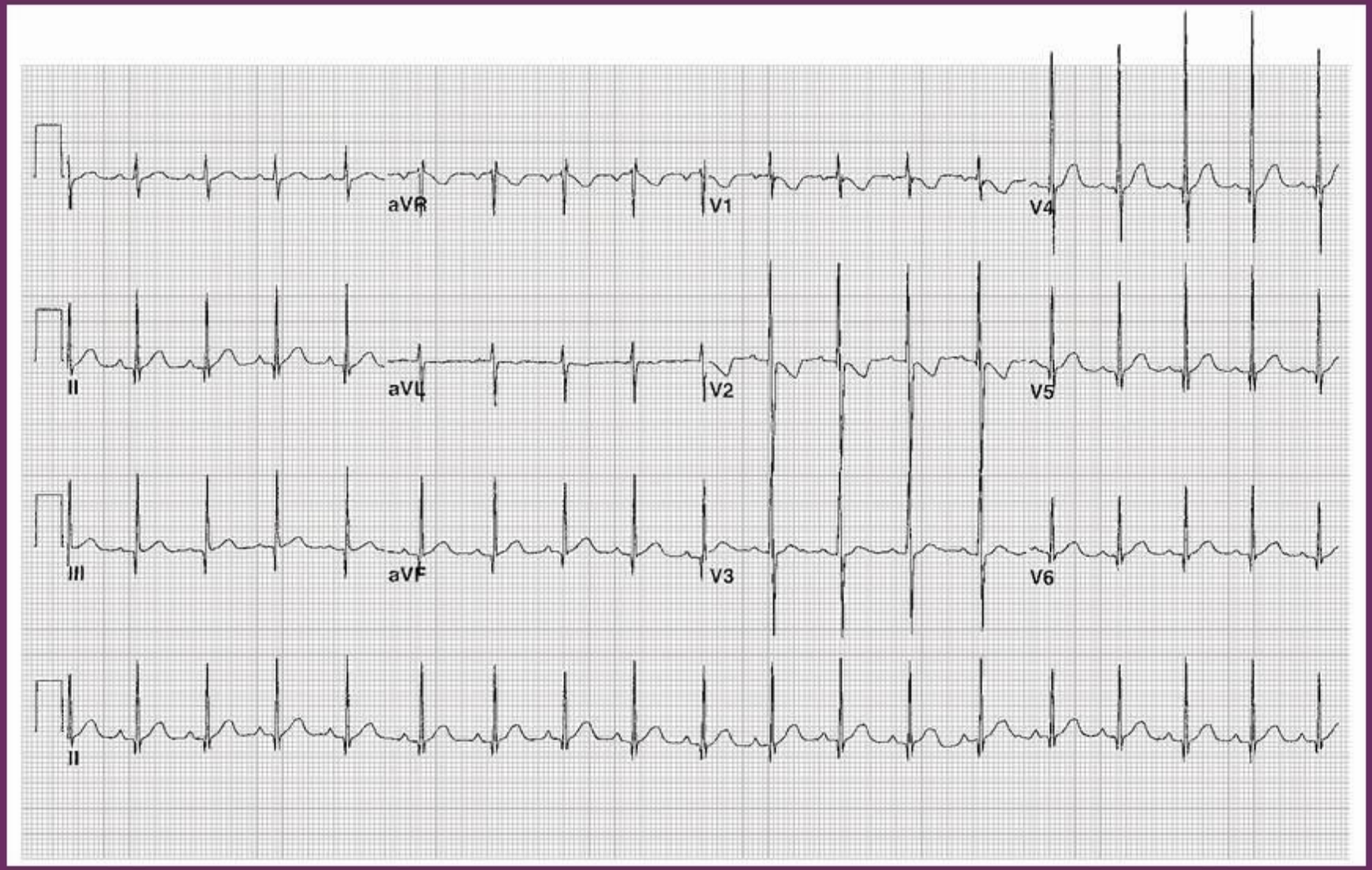


Figure 4: Asymptomatic 1-year-old male

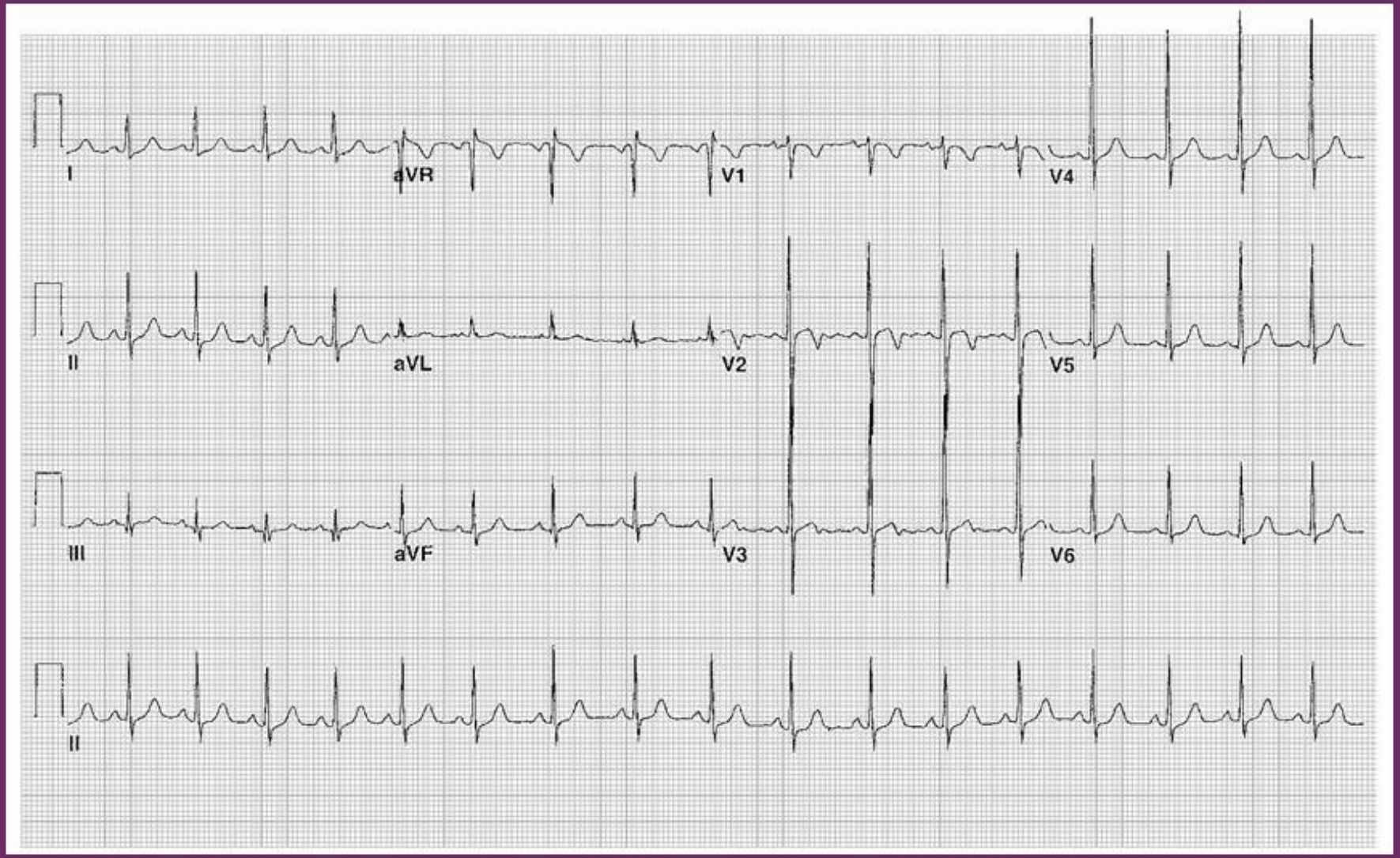


Figure 5: Asymptomatic 5-year-old female

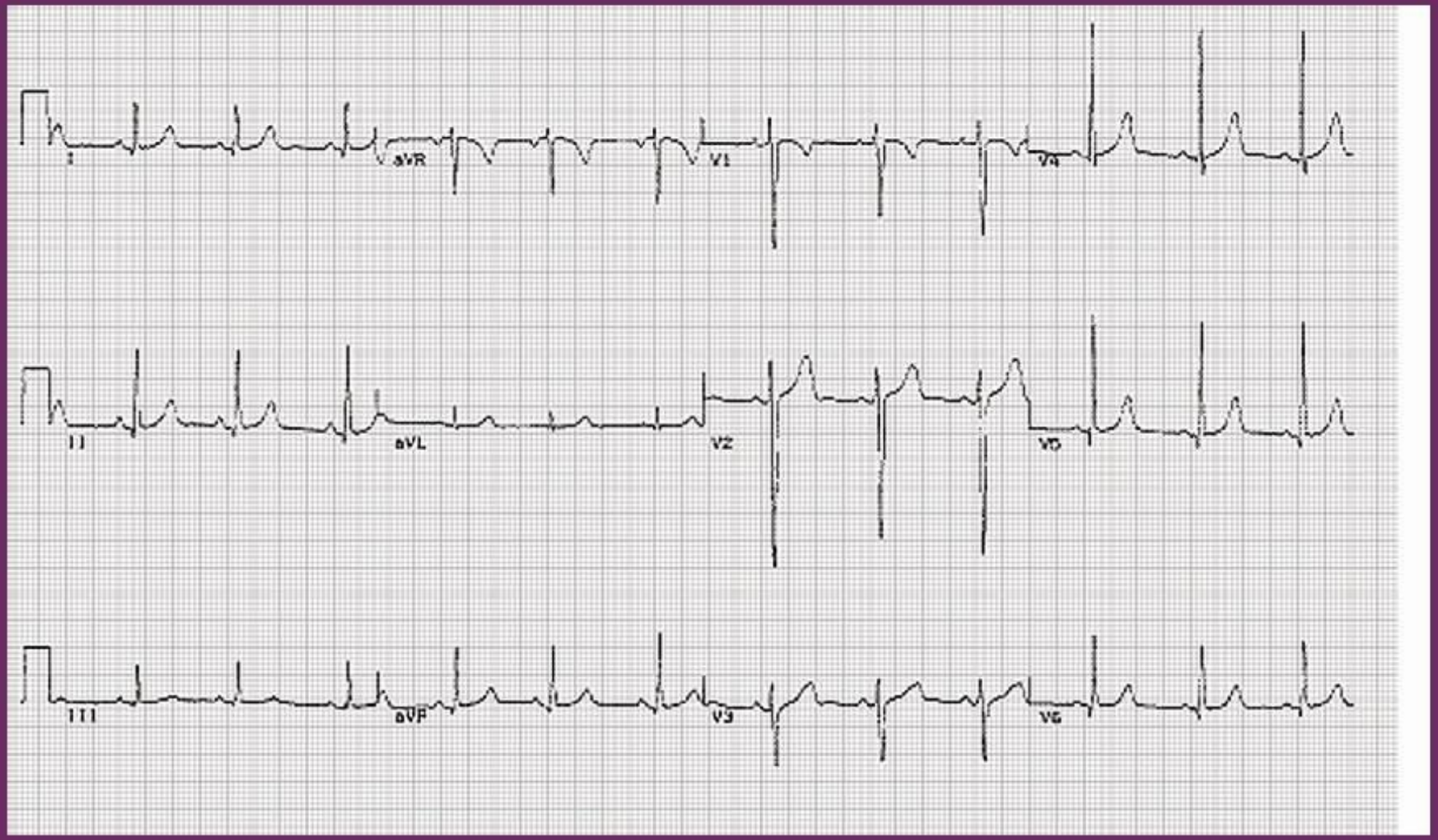


Figure 6: Asymptomatic 8-year-old female

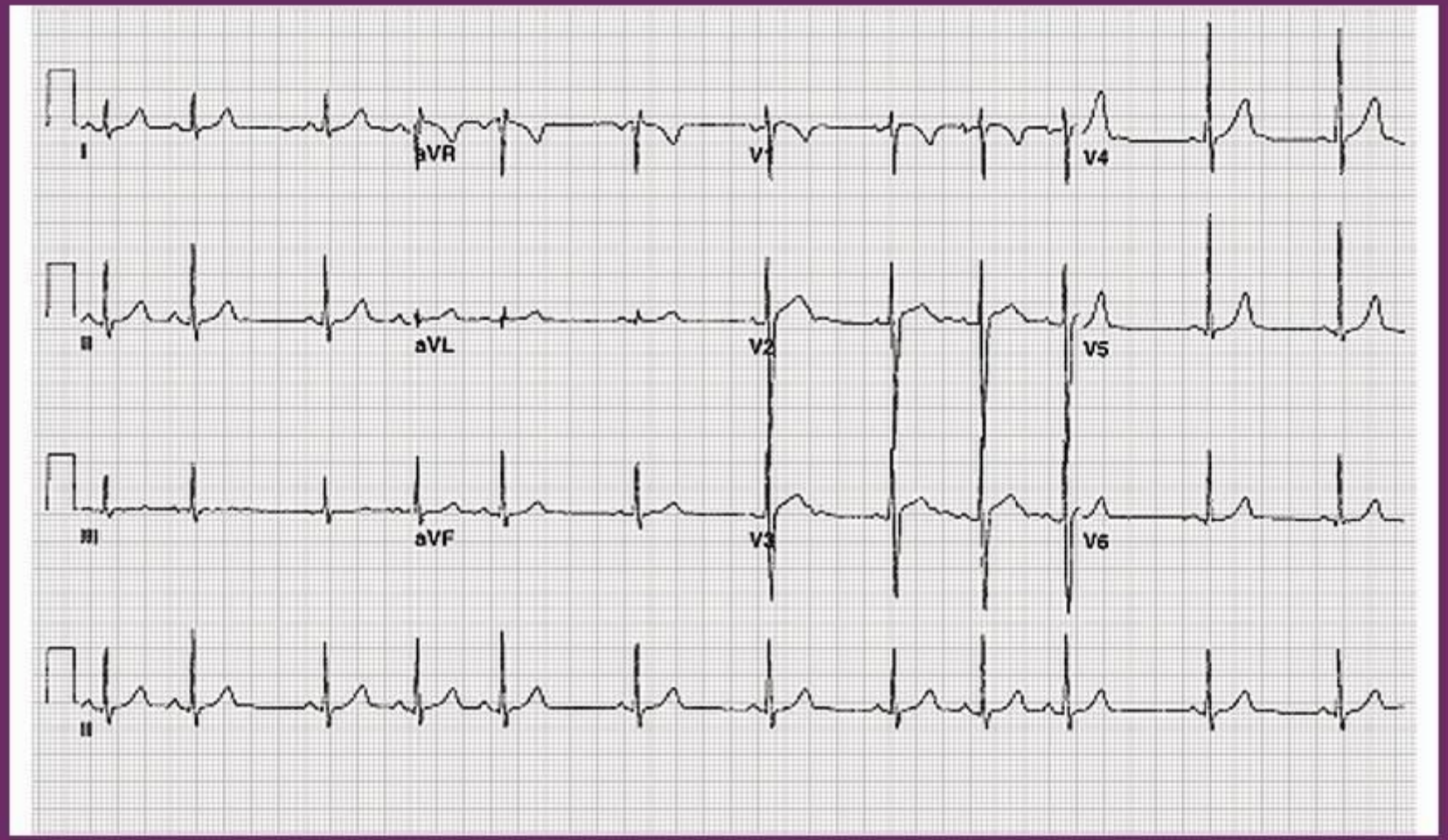


Figure 8: 8-year-old boy referred for irregular heart rhythm

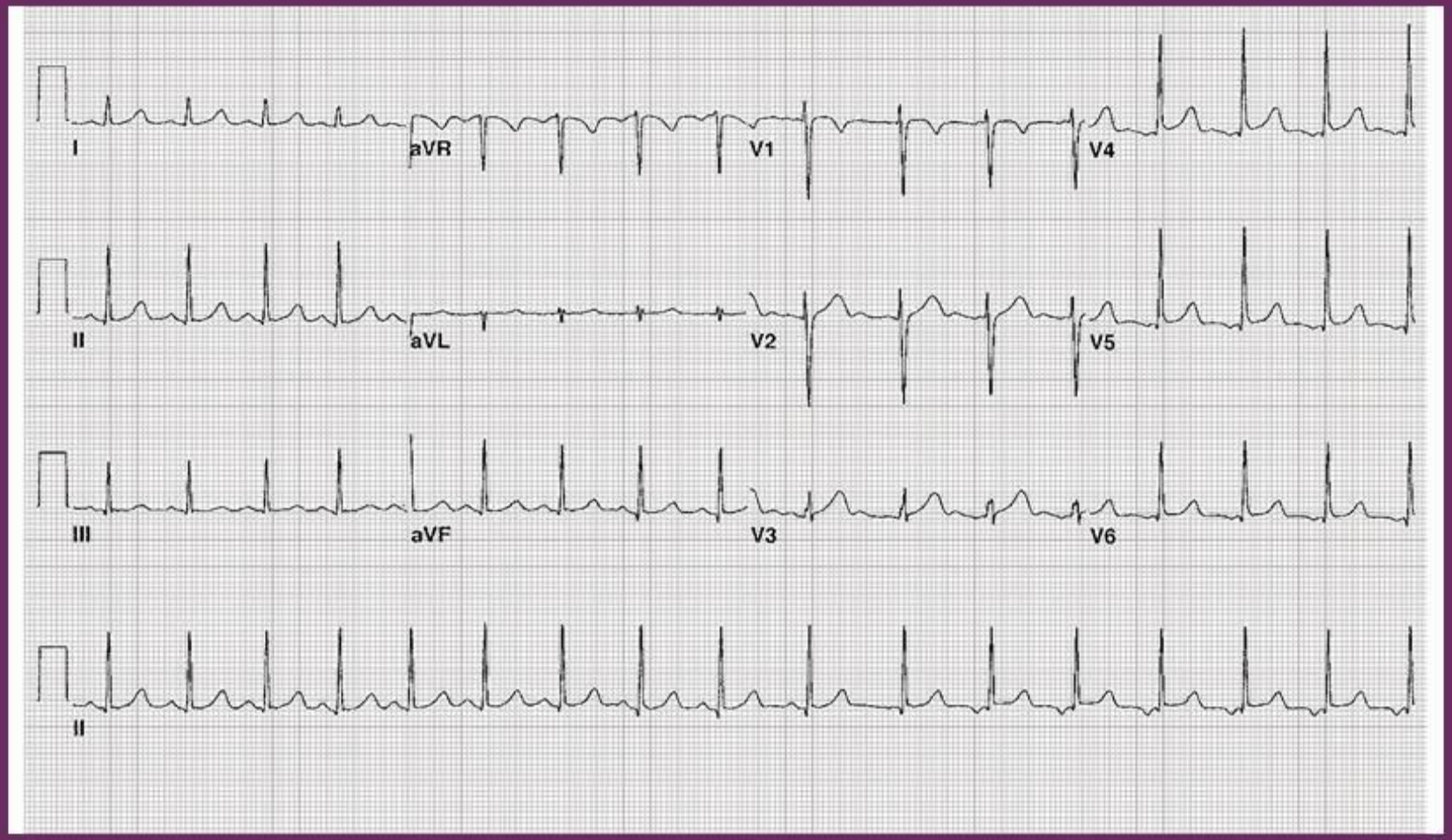


Figure 9: Asymptomatic 14-year-old female

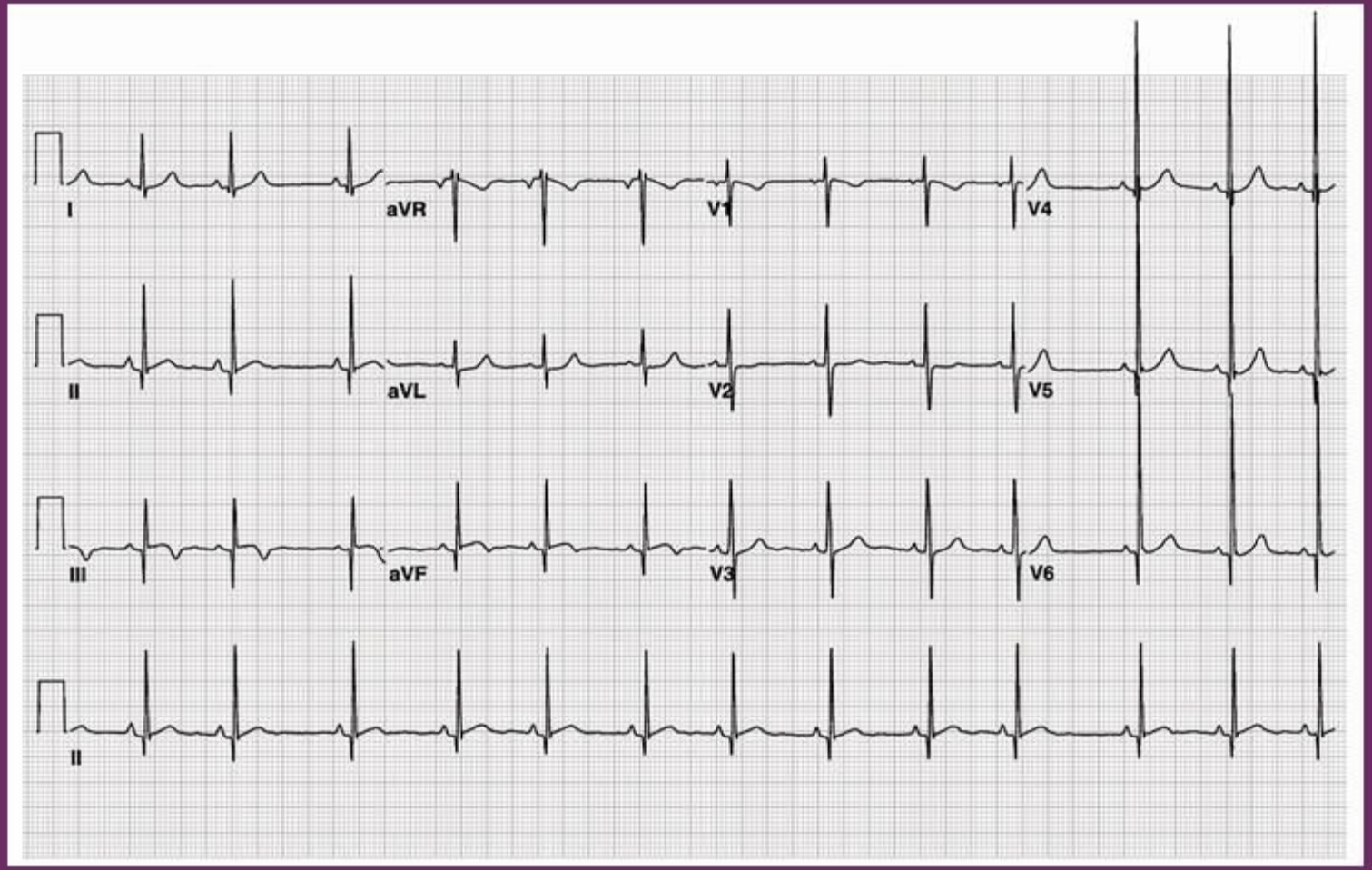


Figure 19: 5-year-old girl with systolic murmur at right upper sternal border

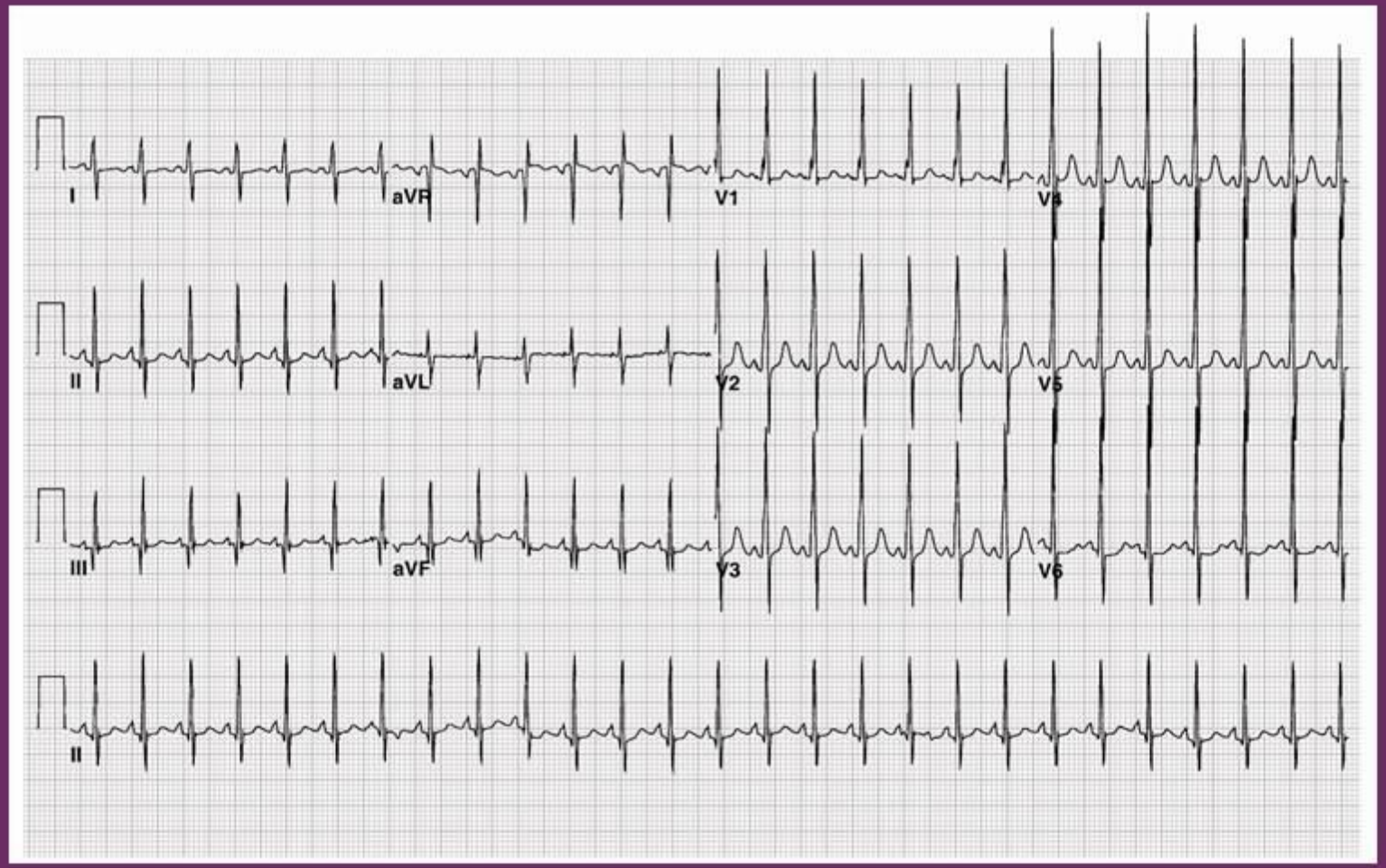


Figure 21: Neonate with critical aortic stenosis

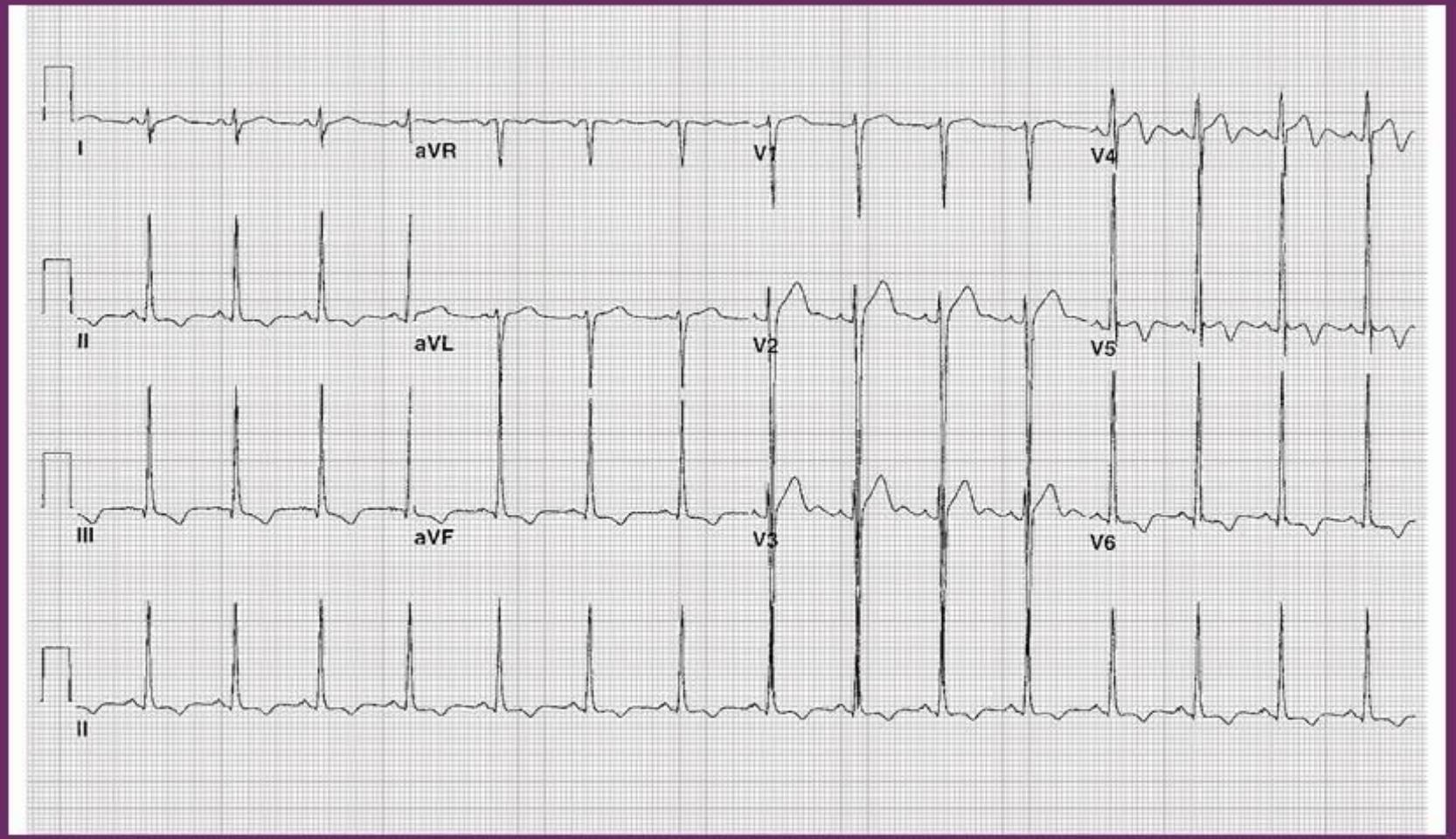


Figure 24: 13-year-old male athlete status post cardiac arrest during sports

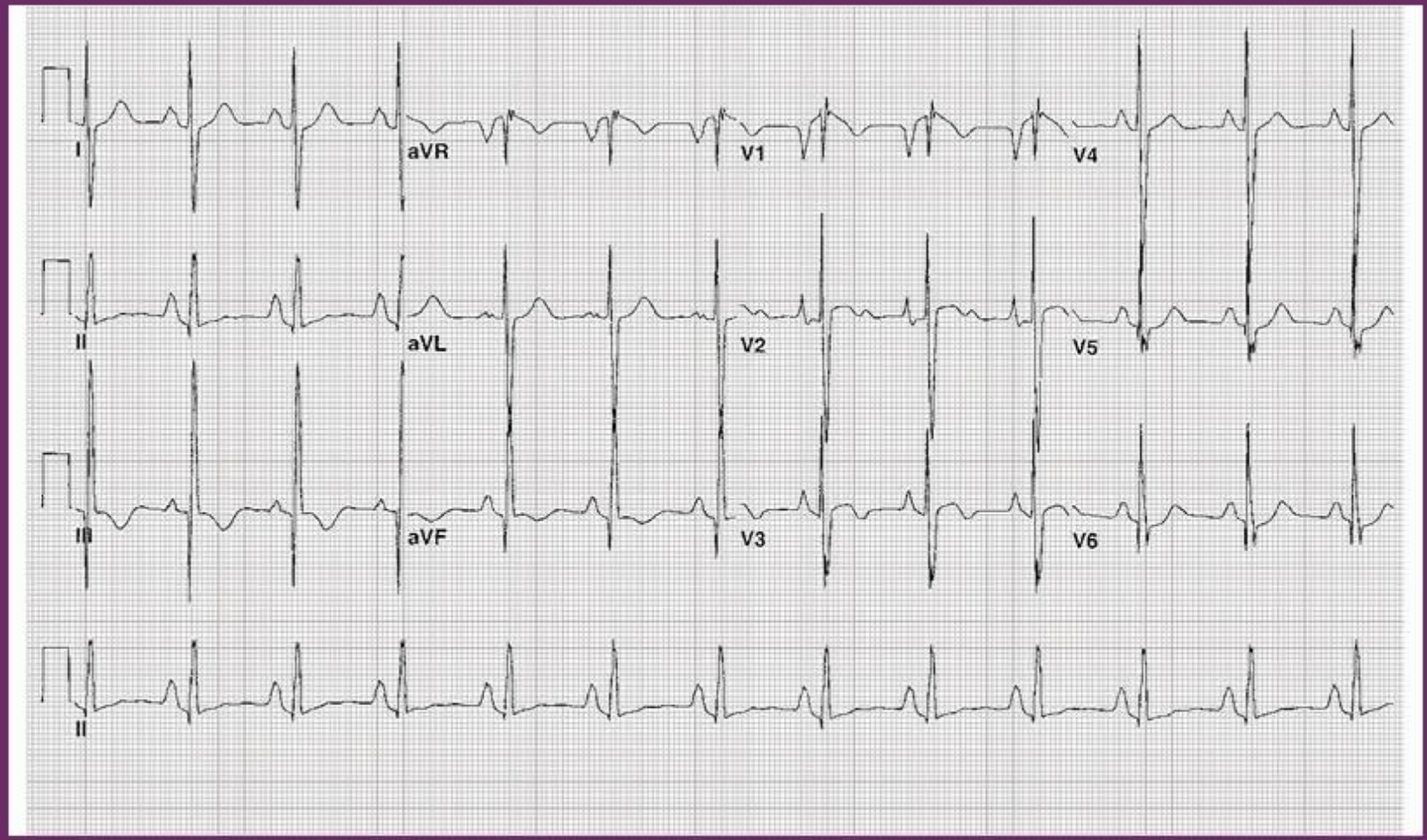


Figure 25: 7-year-old girl evaluated for recurrent syncope

Figure 30: Young adult with renal failure, marked hyperkalemia (K^+= 7.4 mEq/L)

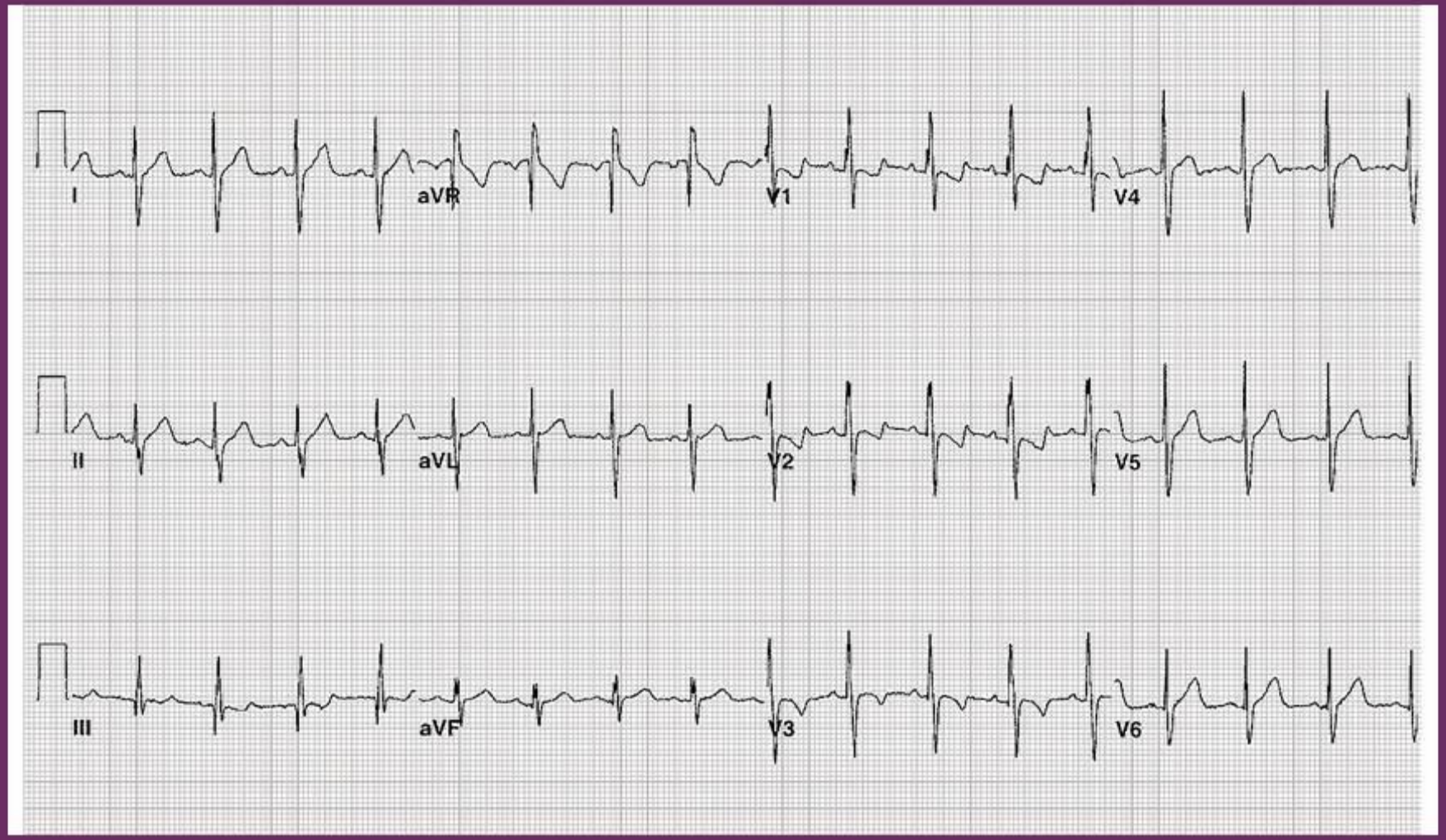


Figure 37: 3-year-old girl referred with systolic murmur at left upper sternal border and fixed splitting of second heart sound

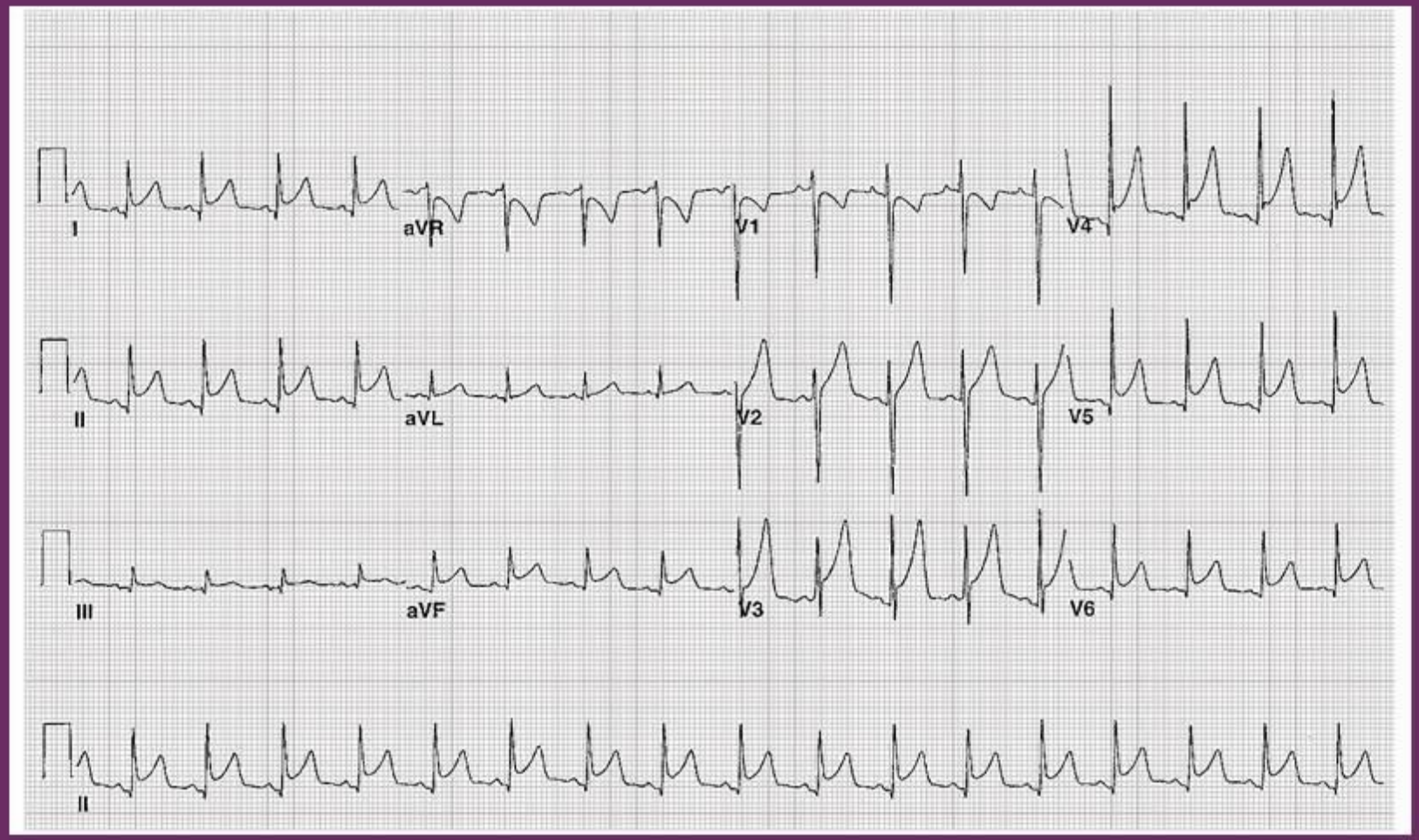


Figure 32: 10-year-old boy with autoimmune collagen vascular disease, presents with chest pain

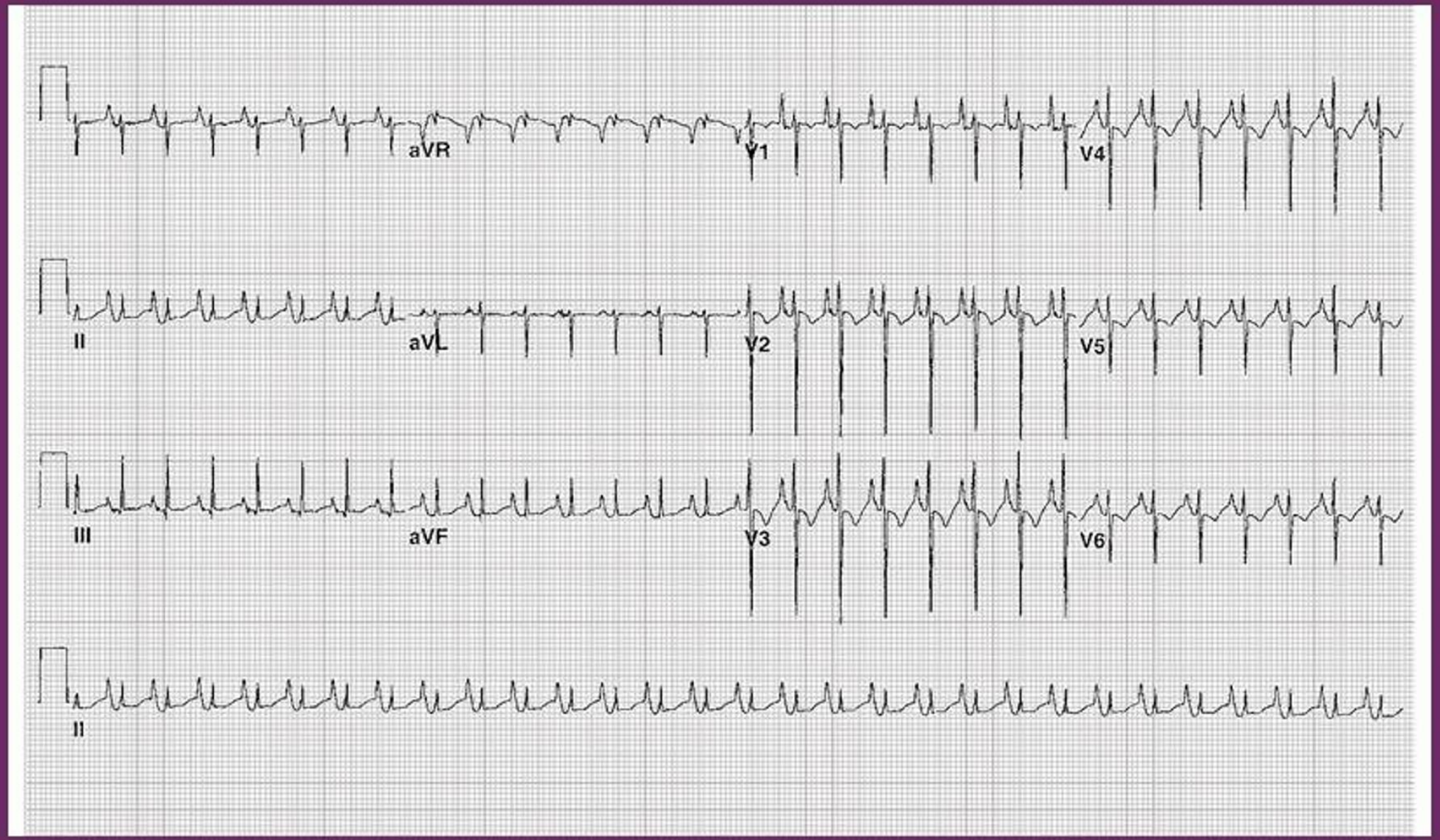


Figure 43: Neonate with severe cyanosis

Figure 56: 21-year-old male with transposition of the great arteries, status post Mustard repair

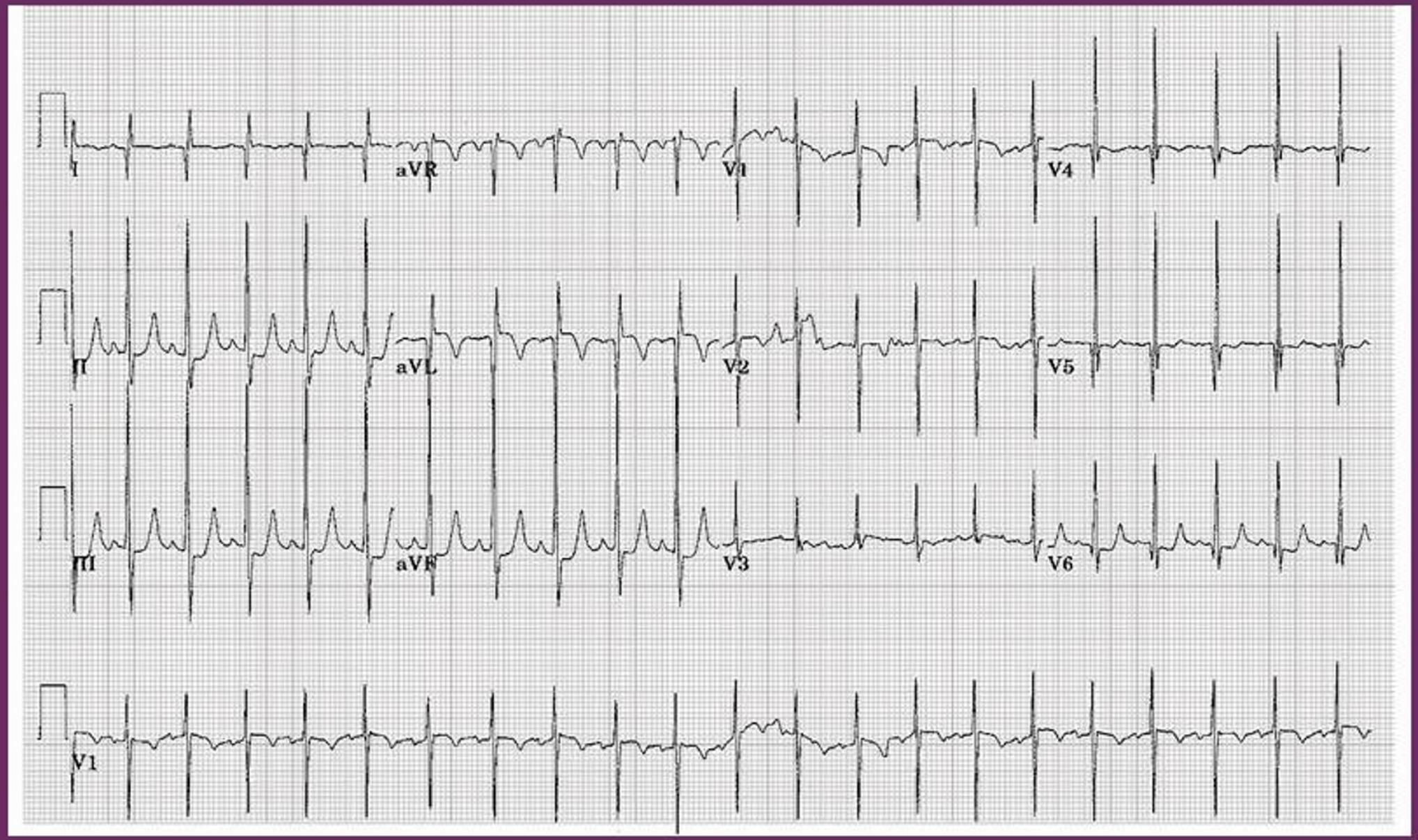


Figure 51: 4-month-old infant with wheezing and cardiomegaly

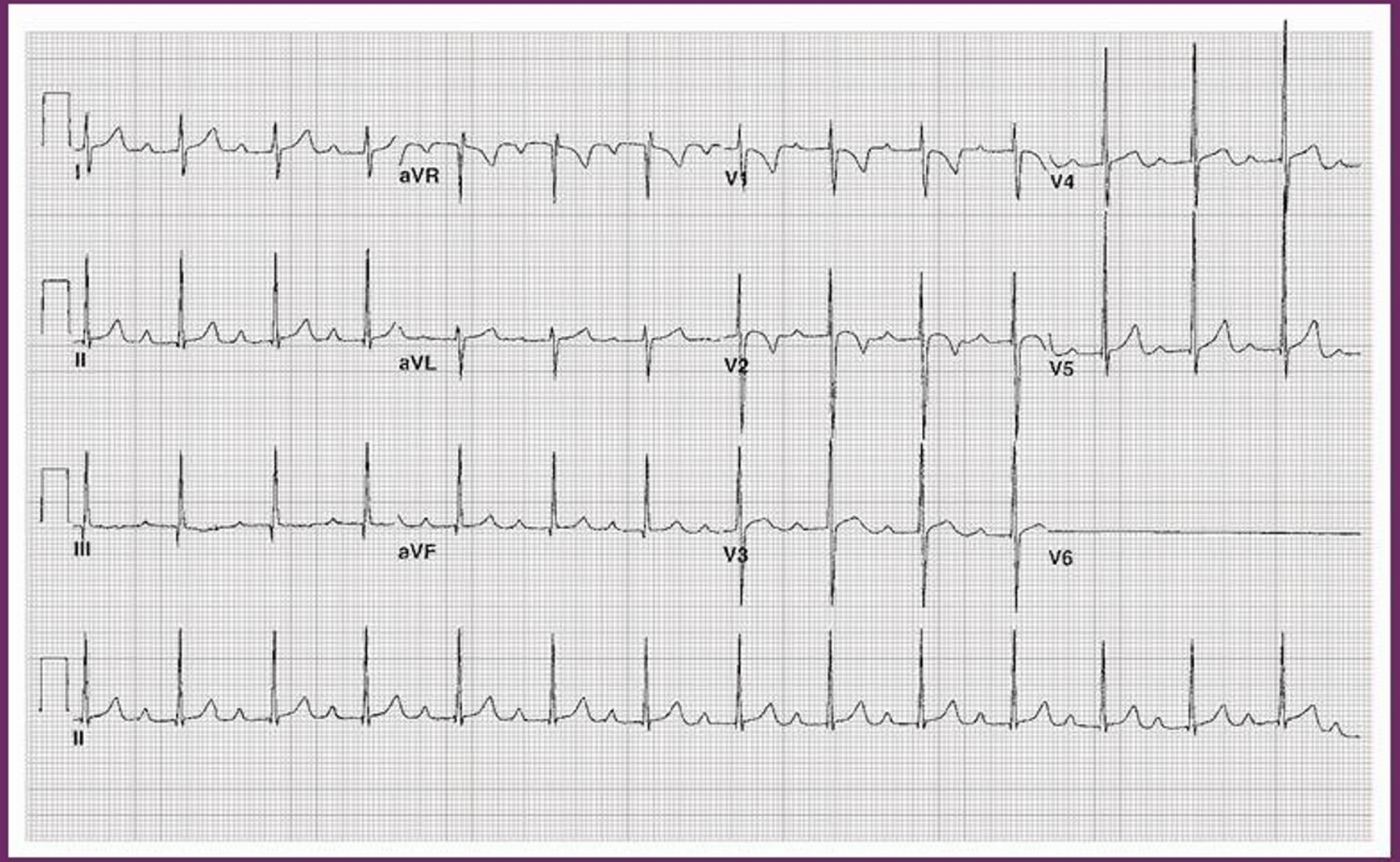


Figure 61: 9-year-old boy with arthralgia and recent sore throat

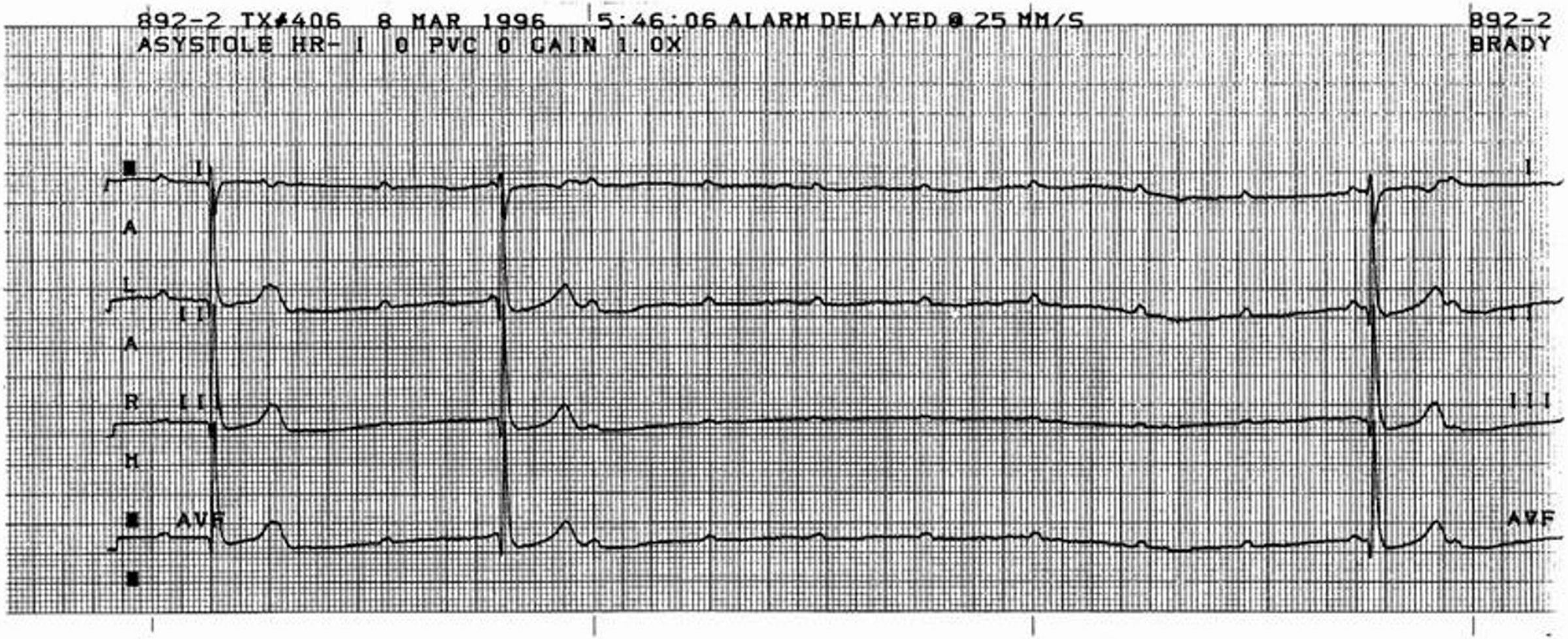
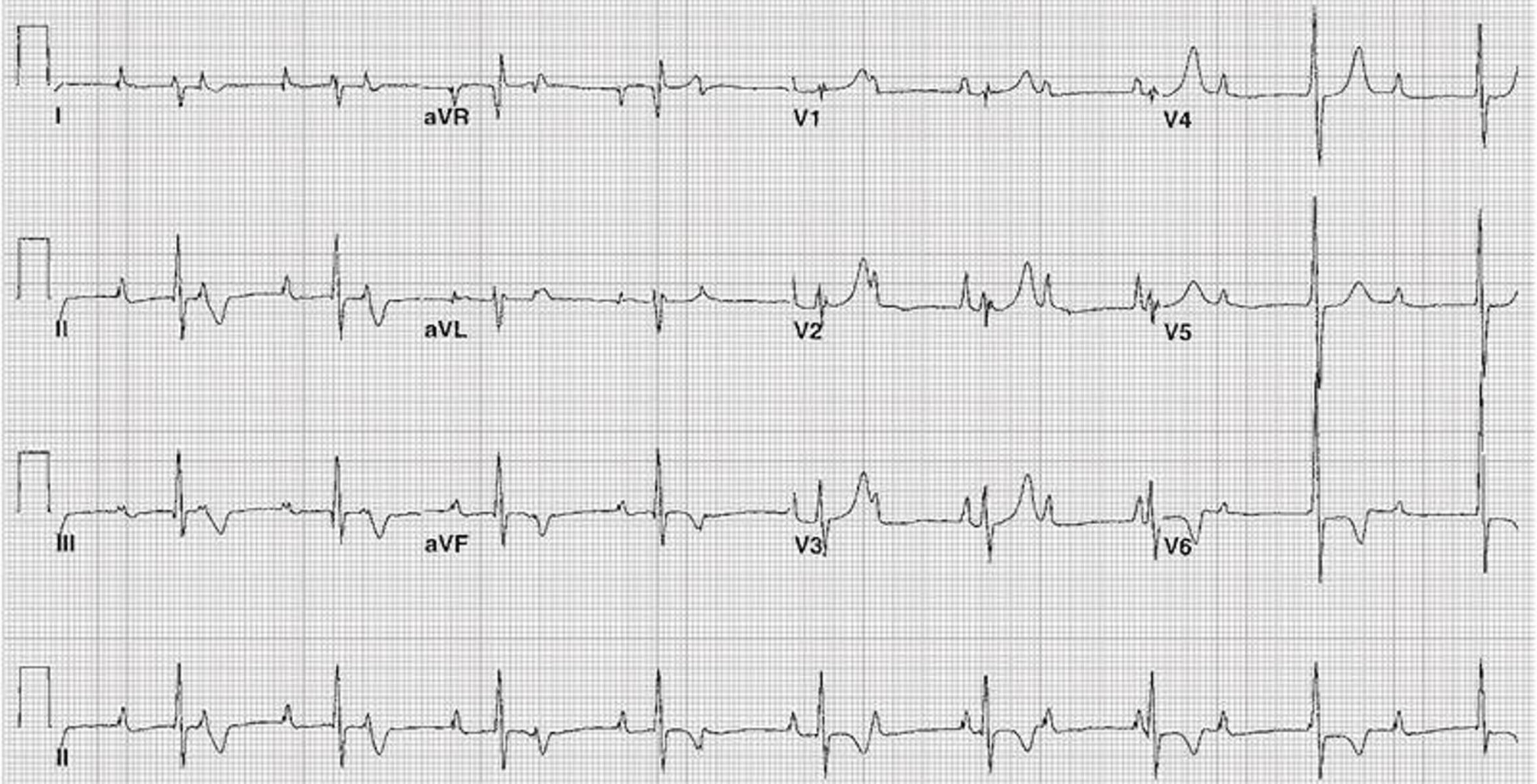
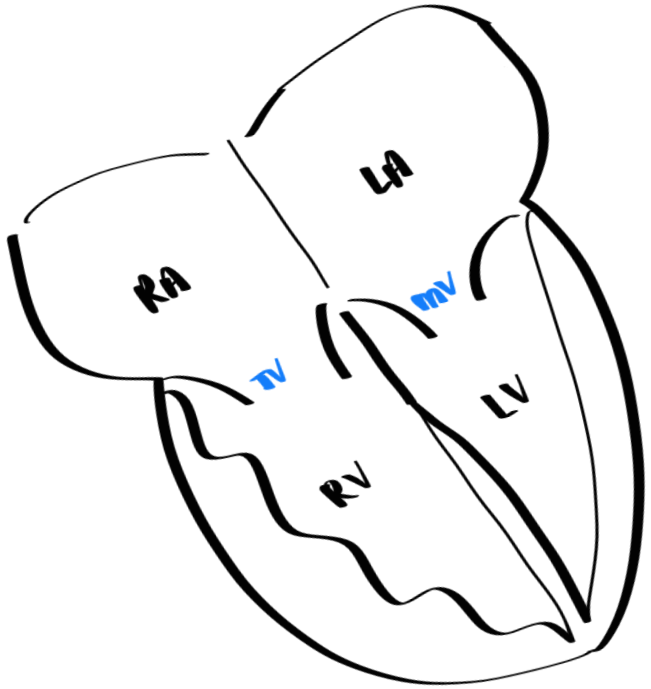


Figure 65: 15-year-old girl with syncope during phlebotomy


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

THANK YOU!

Special acknowledgements to Dr. Hoang Nguyen



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Normal ECG Values by Age

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