Basic science:

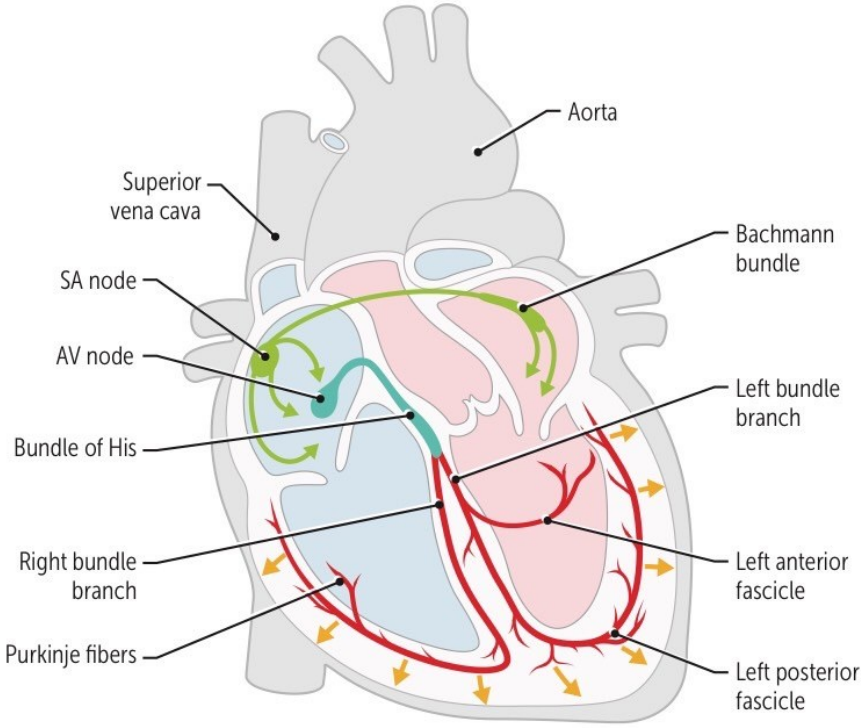
Pediatric Electrocardiogram

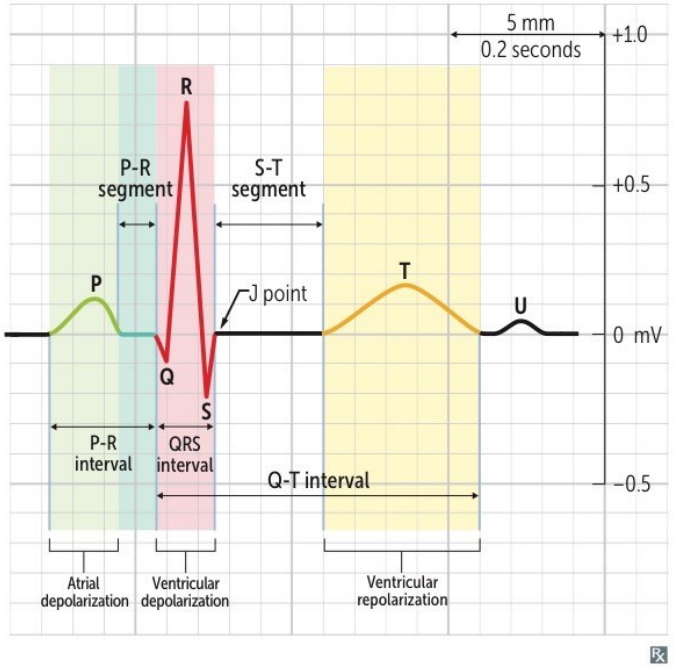
Resident 2 Worawit/Aj. Orakan

Table of contents

01

Cardiac cycle


Aorta
Superior vena cava
SA node
AV node
Bundle of His
Right bundle branch
Purkinje fibers
Bachmann bundle
Left bundle branch
Left anterior fascicle
Left posterior fascicle


5 mm
0.2 seconds
+1.0
+0.5
0 mV
−0.5
R
P-R segment
S-T segment
P
J point
T
U
Q
S
P-R interval
QRS interval
Q-T interval
Atrial depolarization
Ventricular depolarization
Ventricular repolarization

Cardiac cycle

1
Isovolumic contraction

Mitral valve closing to Aortic valve opening

2
Systolic ejection

Aortic valve opening to closing

3
Isovolumetric relaxation

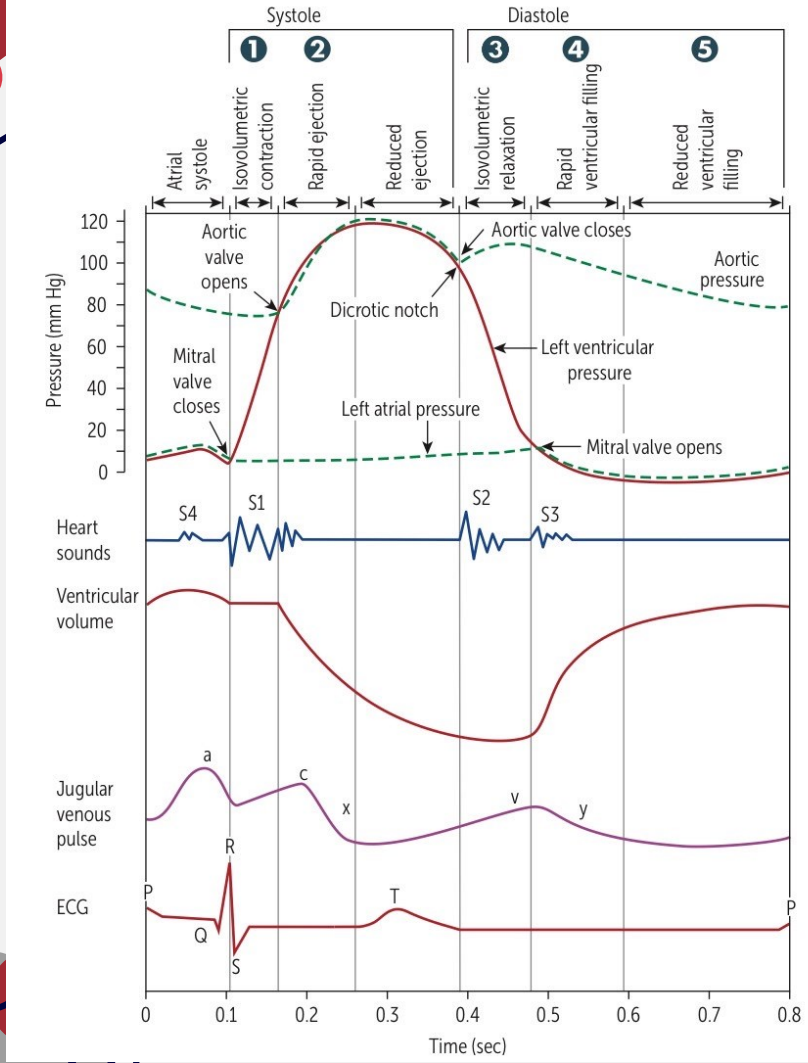
Aortic valve closing to mitral valve opening

4
Rapid filling

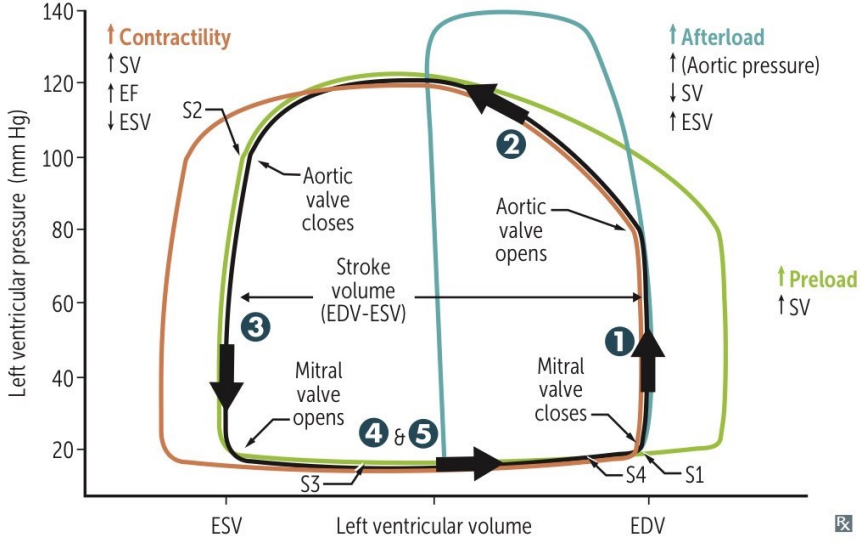
Just after mitral valve opening

5
Reduced filling

Just before mitral valve closing



Pressure-volume loops and cardiac cycle



02

Vectorial Approach

Vector

- **The Vectorcardiogram (VCG)** = The registration of the direction and magnitude of the moment to moment electromotive forces of heart during one complete cycle.
- **A scalar ECG** = ECG obtained in clinical practice, show only magnitude of multiple consecutive cardiac cycles against time (two or more scalar leads can infer the direction)

Vector

- **Vector** = Quantity with magnitude and direction
- Magnitude = height or depth of the wave form of ECG
- Direction of the forces determined by a combination of the leads which represent the **frontal projection** and the **horizontal projection** of the VCG

Vectorcardiogram

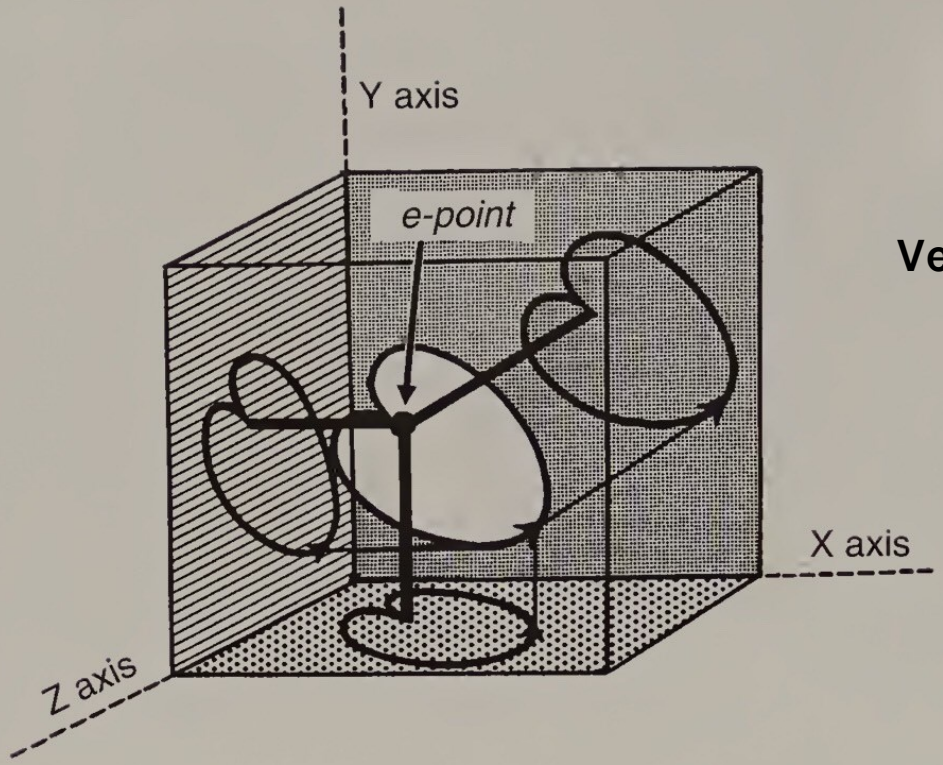
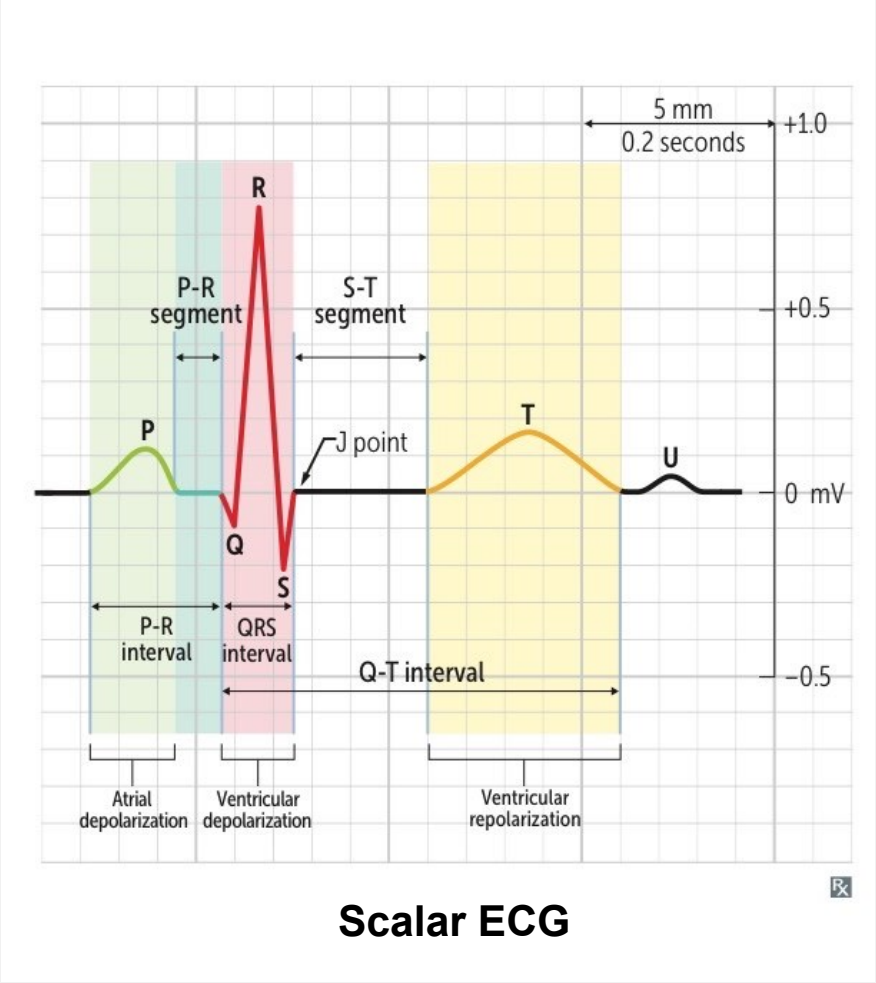
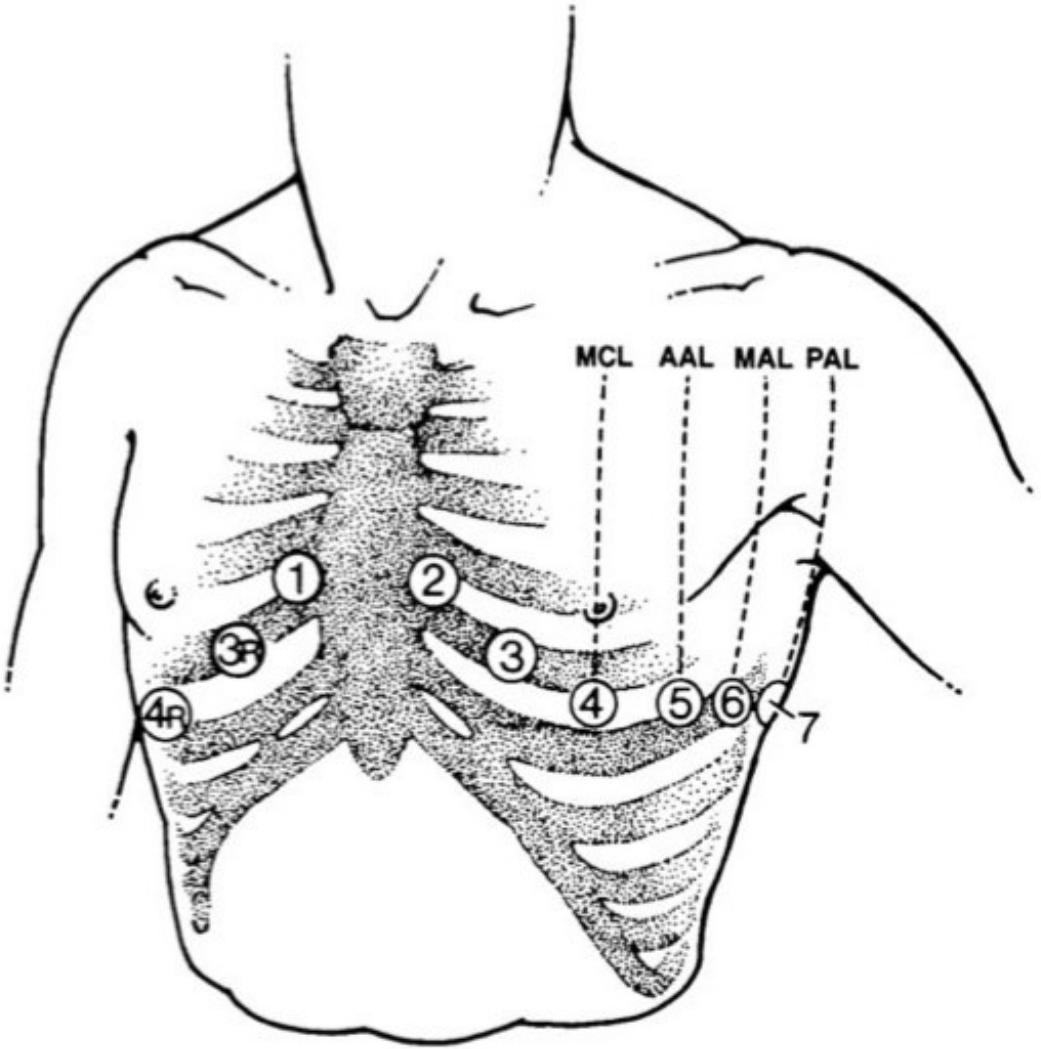


FIG 1-1.
Diagrammatic representation of a three-dimensional QRS vector loop (*solid unshaded*) on the frontal, horizontal, and sagittal planes. Frontal and horizontal planes are important in the understanding of the vectorial approach (modified from Nadas AN. *Pediatric Cardiology*, 2nd ed., Philadelphia: WB Saunders; 1964, with permission).


5 mm
0.2 seconds
+1.0
+0.5
0 mV
−0.5
R
P-R
segment
S-T
segment
P
J point
T
U
Q
S
P-R
interval
QRS
interval
Q-T interval
Atrial
depolarization
Ventricular
depolarization
Ventricular
repolarization

Scalar ECG


MCL
AAL
MAL
PAL
1
2
3
3R
4
4R
5
6
7

Reference system

Hexaxial reference system
- Lead I, II, III, aVR, aVL, aVF
- Provides the frontal projection of the electromotive forces

Horizontal reference system
- All precordial leads
- Provides the anteroposterior and the left-right relationship

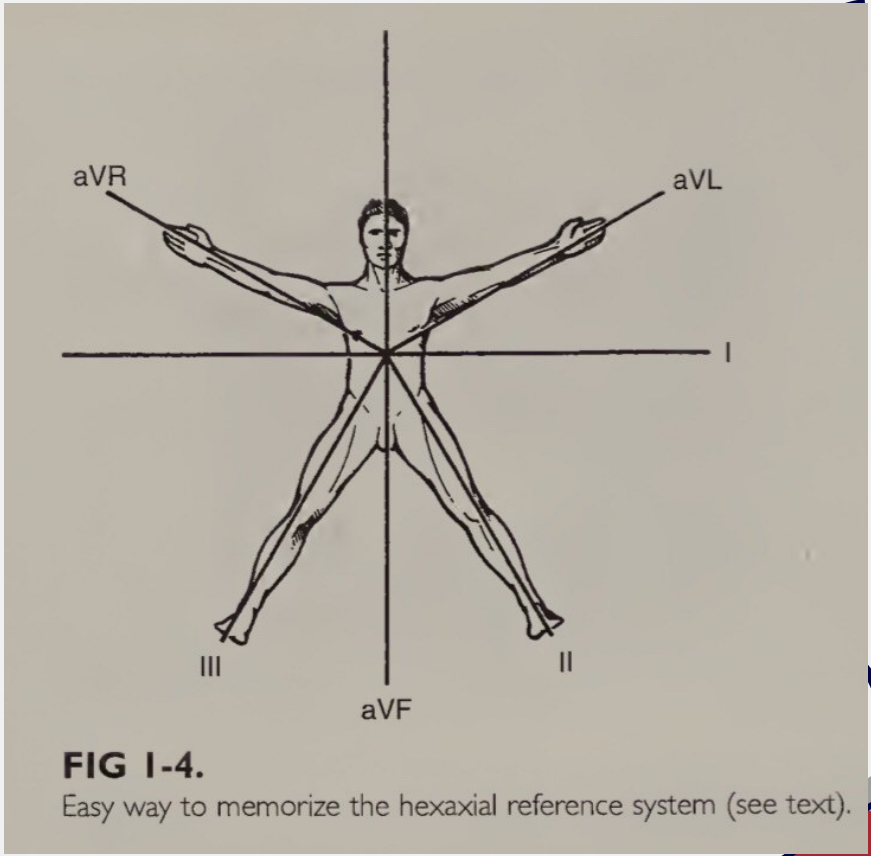


FIG 1-4.
Easy way to memorize the hexaxial reference system (see text).

Hexaxial reference system

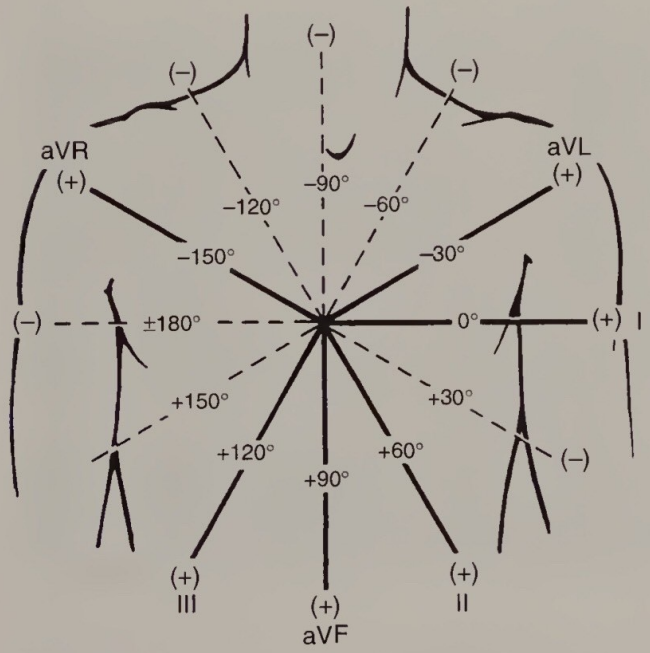


FIG 1-3.
Hexaxial reference system (viewed from the patient's front). Positive pole of each lead is indicated by (+) sign. The angle between two adjacent limb leads is 30 degrees.

Frontal and horizontal projection

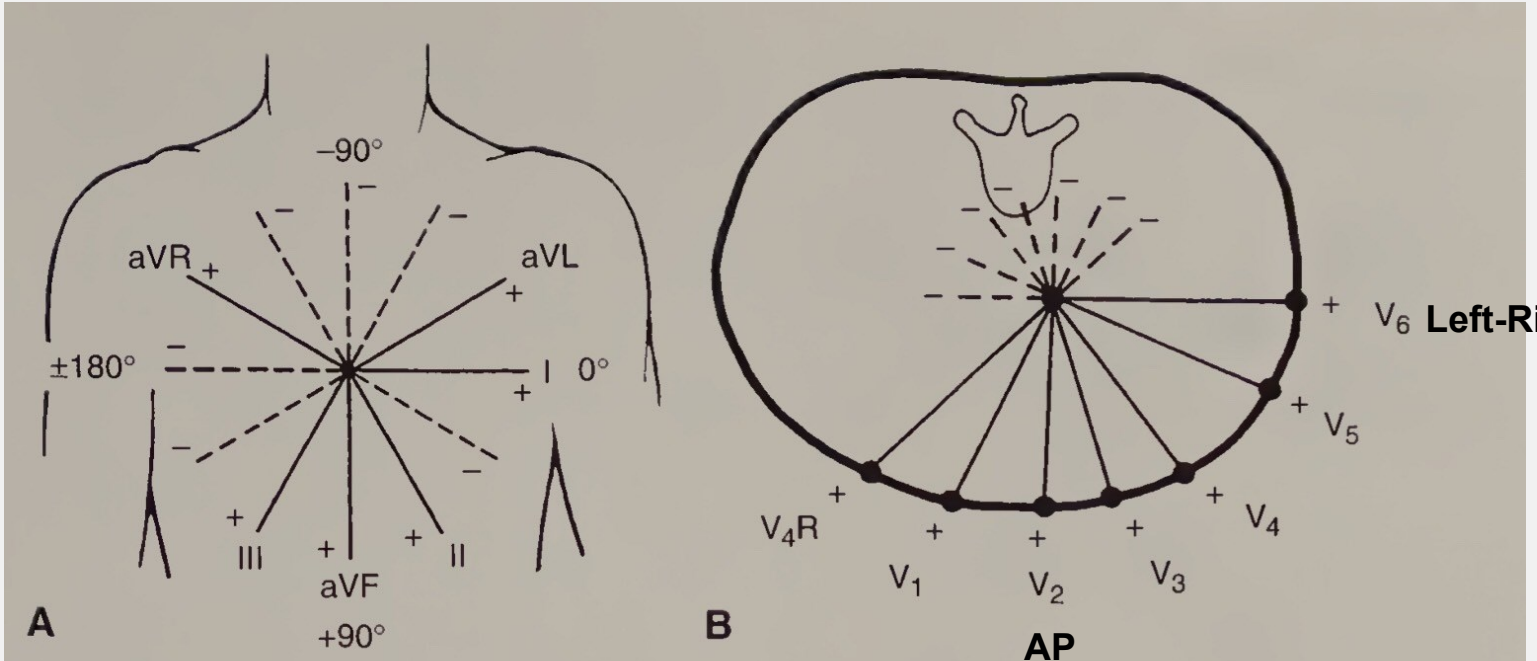
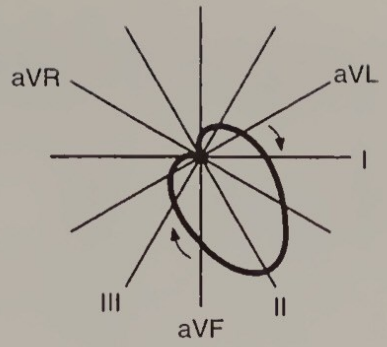


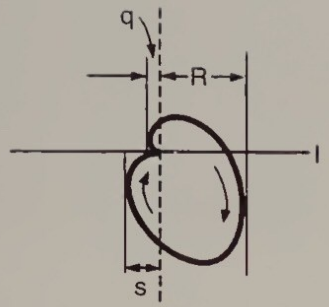
FIG 1-2.

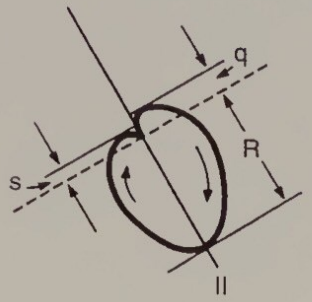
Hexaxial **(A)** and horizontal **(B)** reference systems. The combination of **A** and **B** constitutes the 12- (or 13-) lead ECG.

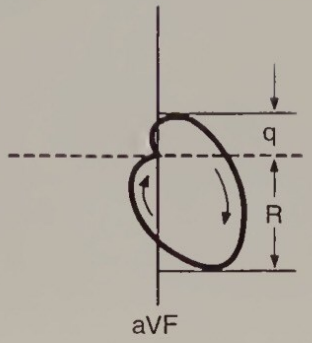
Correlation of the VCG and scalar ECG

- VCG and Scalar ECG are two different ways of looking at the same electrical activity in the heart
- When the depolarization current moves toward positive electrode, an upward deflection is recorded on ECG paper
- When the depolarization current moves away from the positive pole, a negative deflection is recorded.

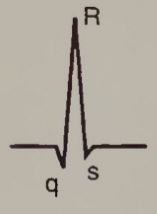

aVR
aVL
I
III
II
aVF


q
R
I
s


q
R
s
II

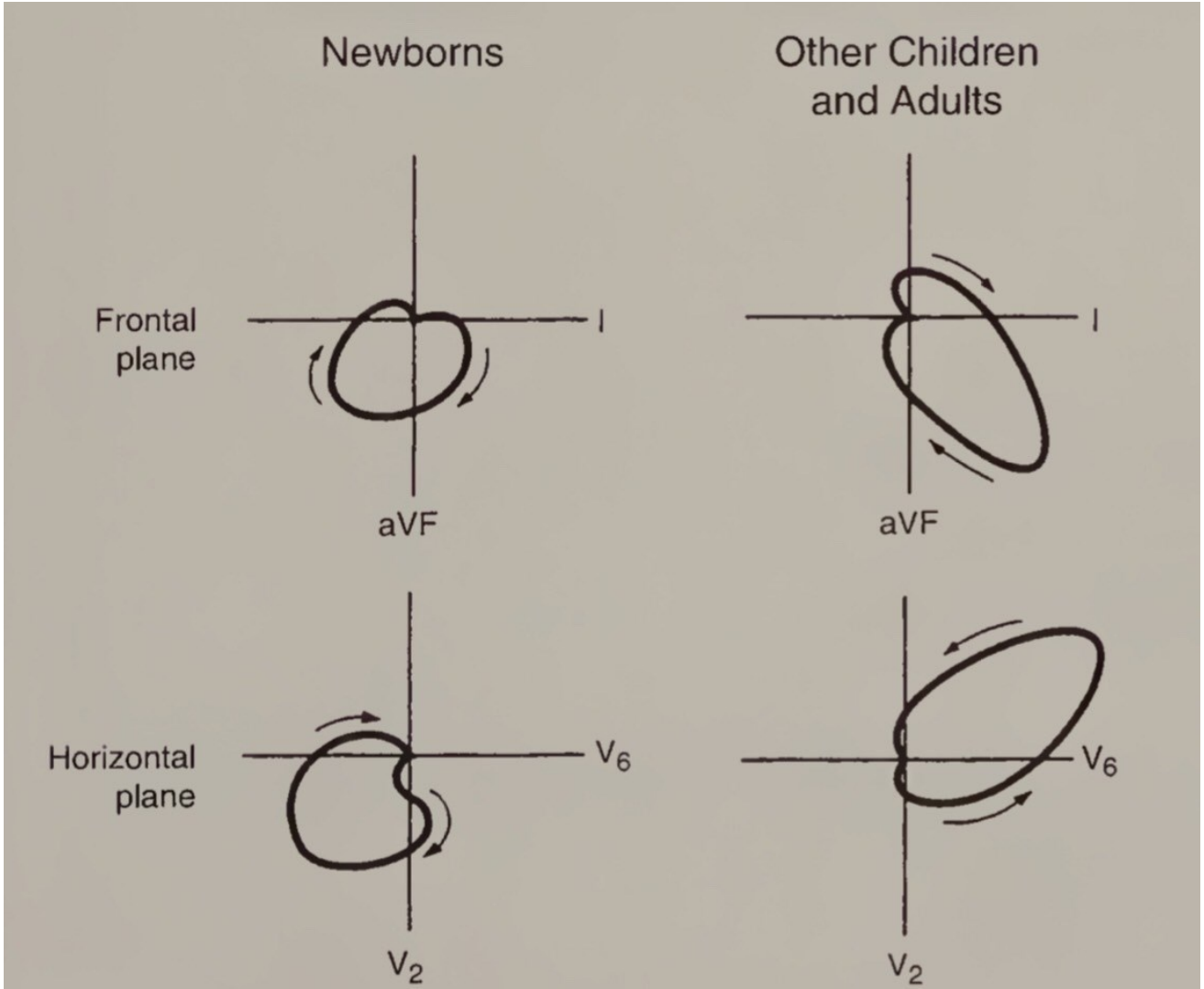

q
R
aVF


R
q
s
I


R
q
s
II


R
q
aVF

Normal newborn
In the frontal plane, the major QRS vector is to the subject's right and inferior



03

Basic measurements

Before routine measurements

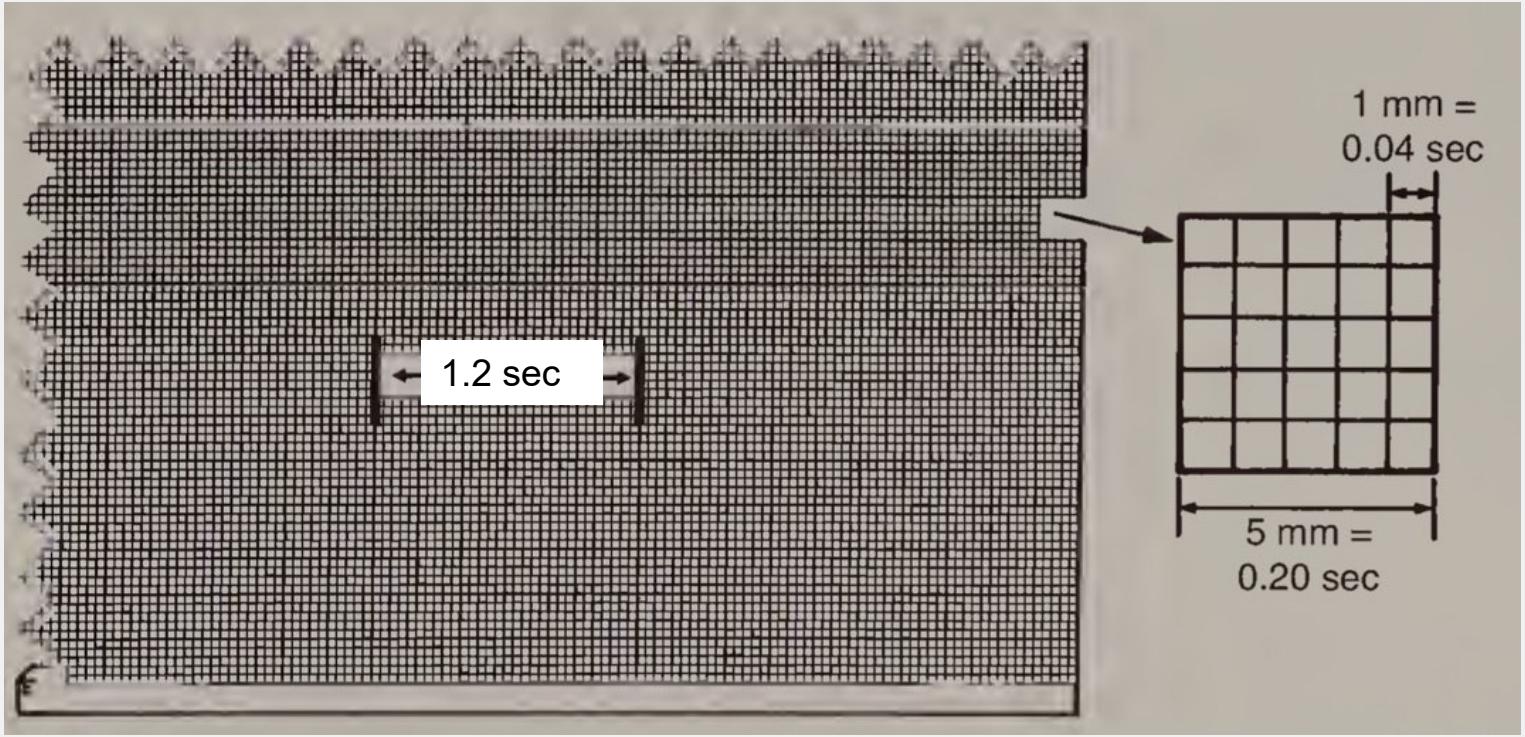
Standard!

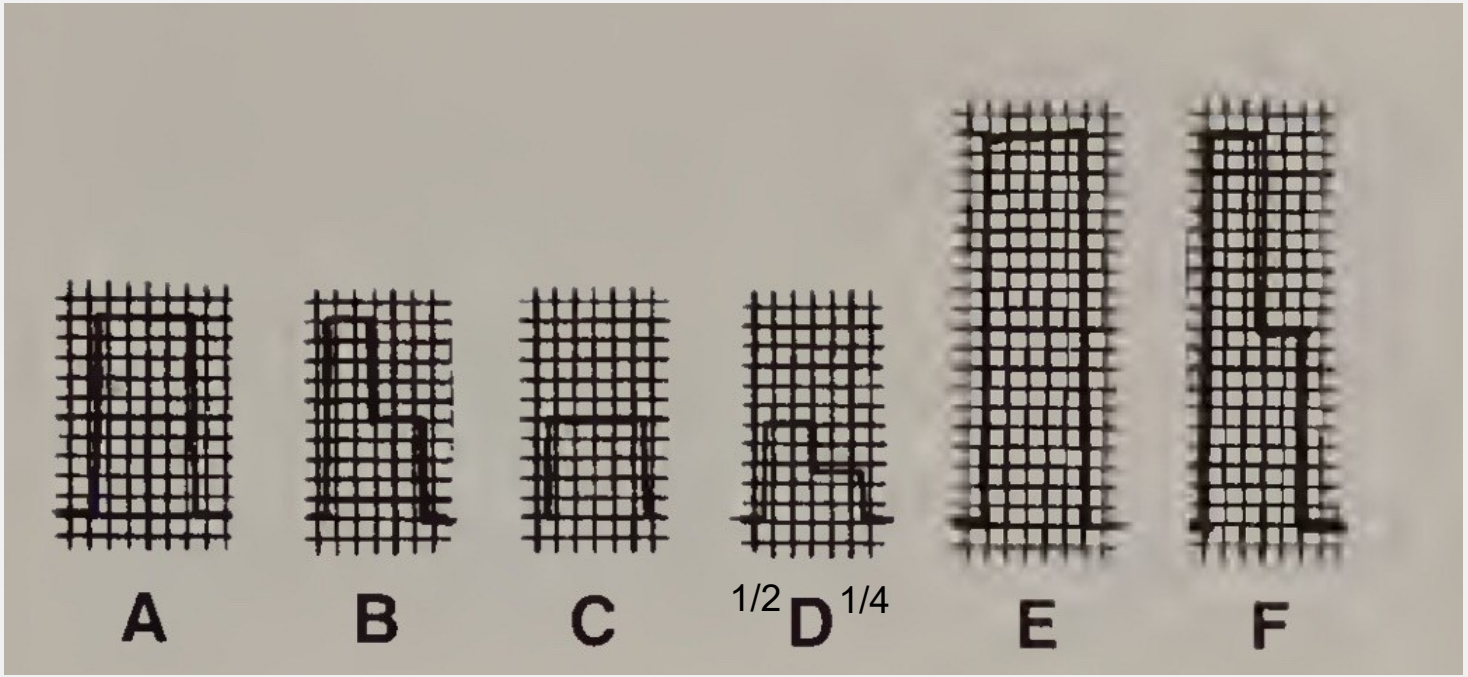
Recording speed of paper = 25 mm/sec

1 mm = 0.04 sec (one small box)
5 mm = 0.20 sec (one large box)
30 mm = 1.2 sec (six large divisions)

Amplitude 1 mV = 10 mm

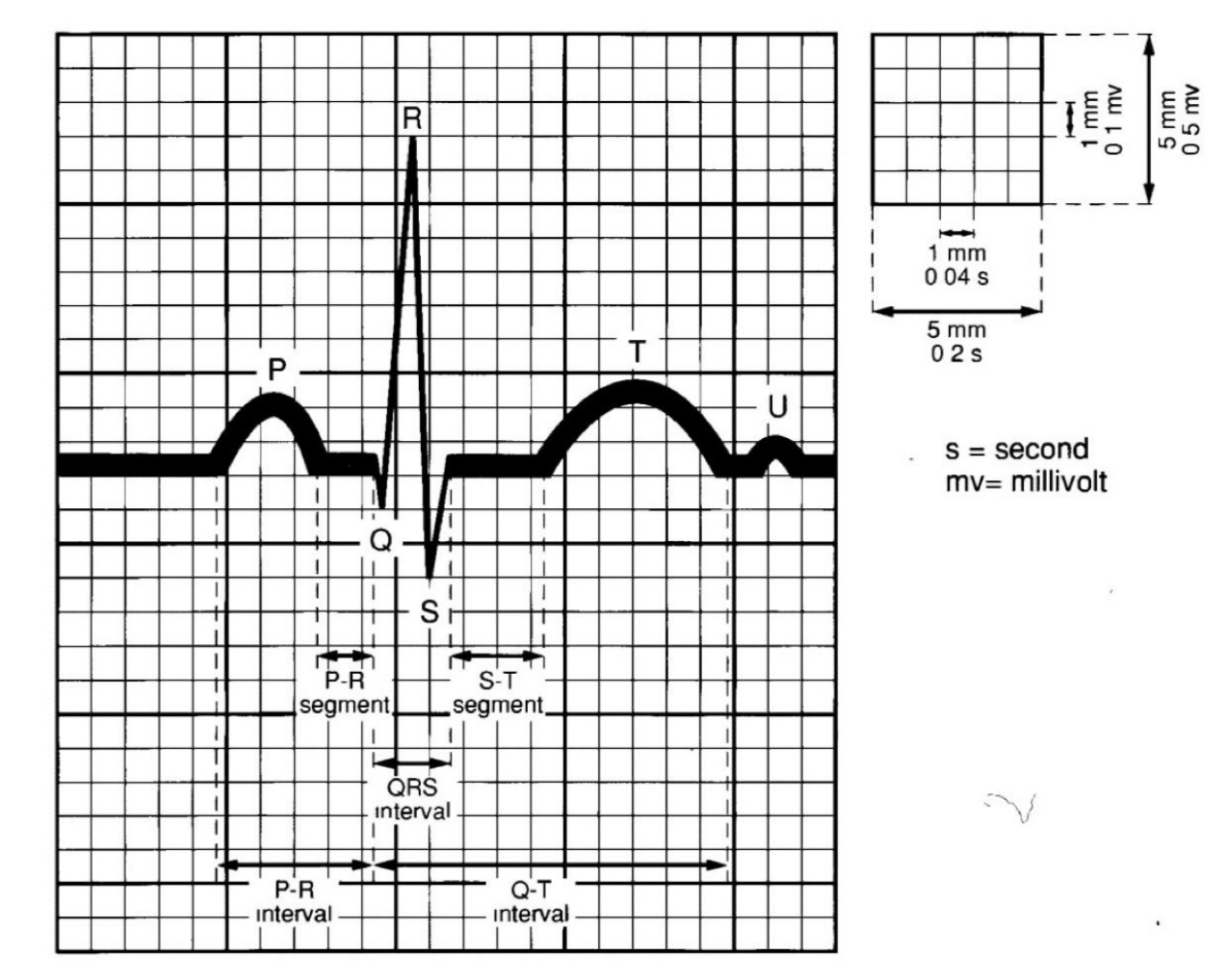
1 mV = 10 mm = ten small boxes


1 mm =
0.04 sec
1.2 sec
5 mm =
0.20 sec



1 mV = 20 mm

Components of ECG wave form



Basic measurements

Rhythm

Rate

Axis

P wave

PR interval

QRS axis

QRS interval

QTc interval

ST-T segment

Chamber enlargement and hypertrophy

Rhythm

- Sinus rhythm = ต้นกำเนิดมาจาก SA node
  - Upright P waves in leads I, II and aVF
- Normal sinus rhythm (NSR)
  - SA node เป็นต้นกำเนิดของกระแสไฟฟ้า
  - Normal and Monomorphic P wave
  - P wave นำหน้า QRS complex ทุกตัว
  - PR interval ปกติและคงที่
  - QRS complex ปกติทั้งรูปร่างและความกว้าง
  - Normal rate ตามอายุ

Rhythm

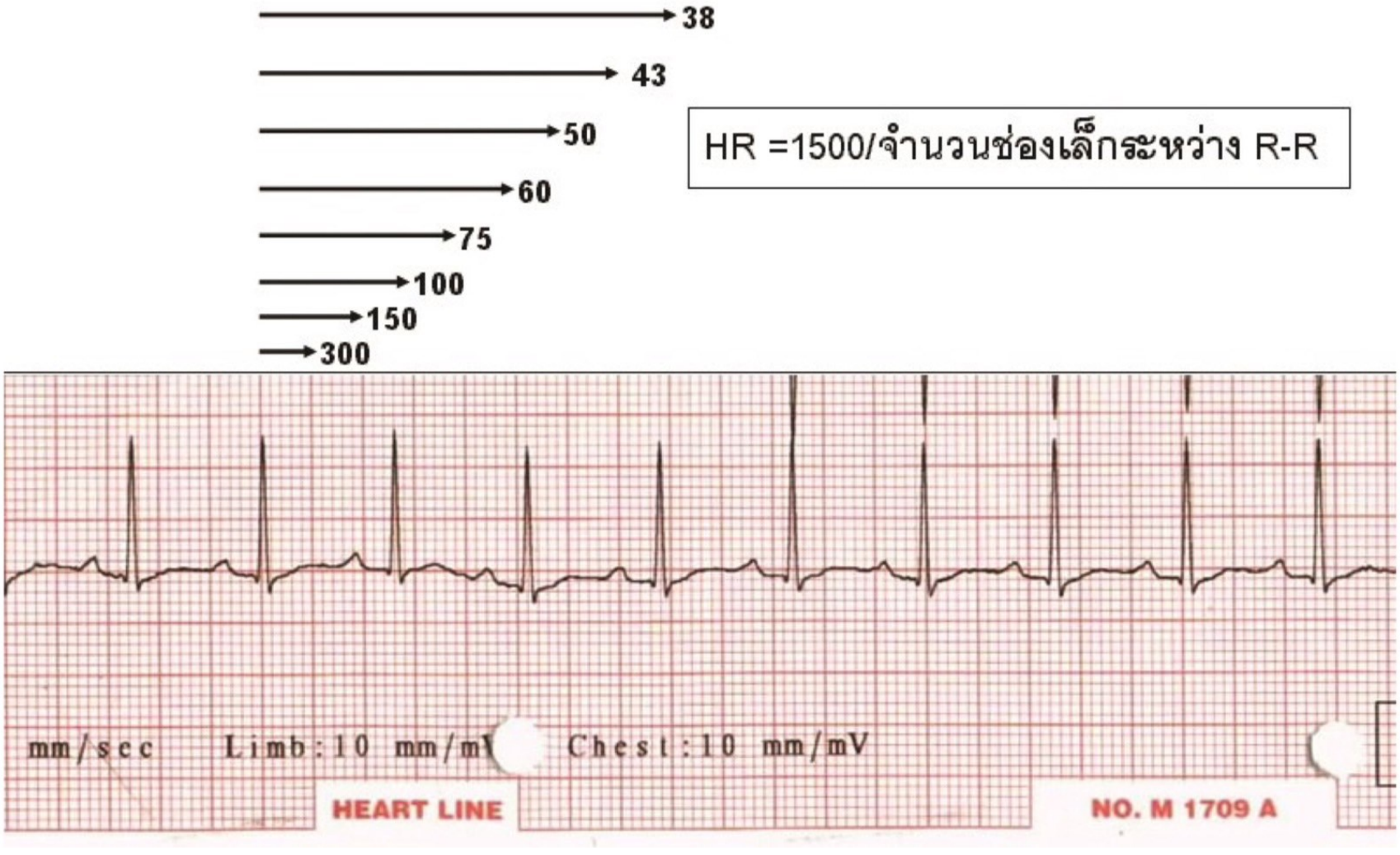
Sinus arrhythmia

- P-P interval ที่เปลี่ยนแปลงทำให้ R-R interval ไม่สม่ำเสมอ
- คุณลักษณะอื่นเป็นไปตาม NSR
- พบได้ปกติในเด็ก

Rate

$$\text{Rate} = \frac{\mathbf{1500}}{\boldsymbol{n}} = \frac{300}{N}$$

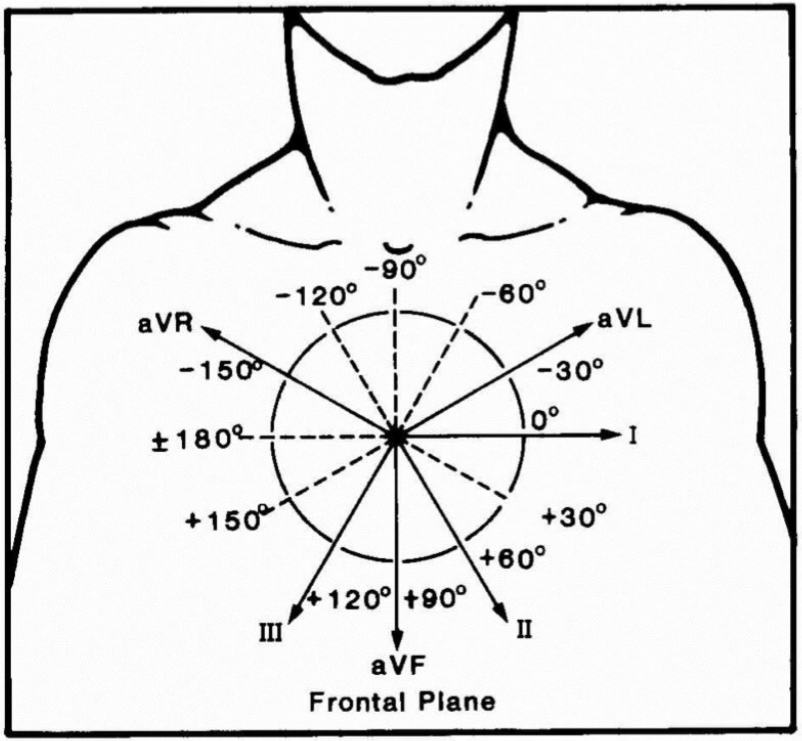
n = จำนวนช่องเล็กที่อยู่ระหว่าง R wave ของ beat ที่อยู่ติดกัน
N = จำนวนช่องใหญ่ที่อยู่ระหว่าง R wave ของ beat ที่อยู่ติดกัน


38
43
50
60
75
100
150
300
HR =1500/จำนวนช่องเล็กระหว่าง R-R
mm/sec
Limb:10 mm/mV
Chest:10 mm/mV
HEART LINE
NO. M 1709 A

Axis

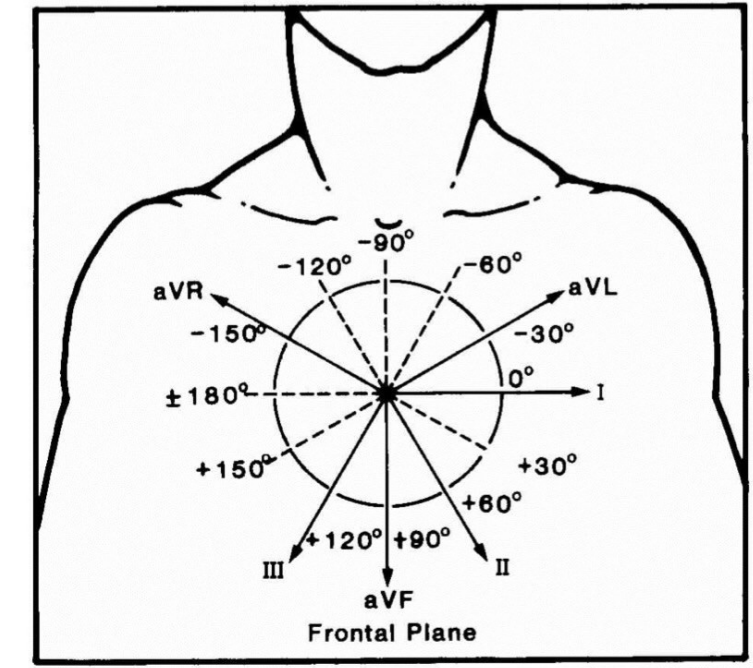
= Vector of frontal plane
Evaluation of P, QRS, and T axis

6 Limb leads



Step 1

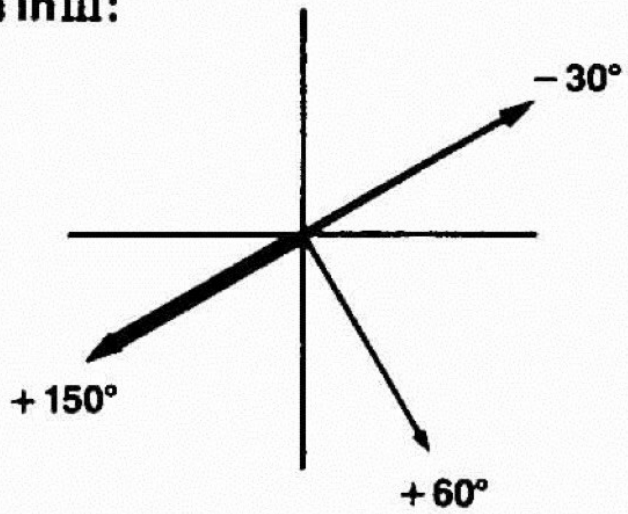
กำหนดว่า **axis** อยู่ใน **Quadrant** ใดอย่างหยาบๆพิจารณาที่ **Lead I** และ **aVF**
รวม **Vector** ของ **QRS complex** โดยค่าที่อยู่เหนือ **Isoelectric line** เป็นบวก อยู่ใต้ **Isoelectric line** มีค่าเป็นลบ



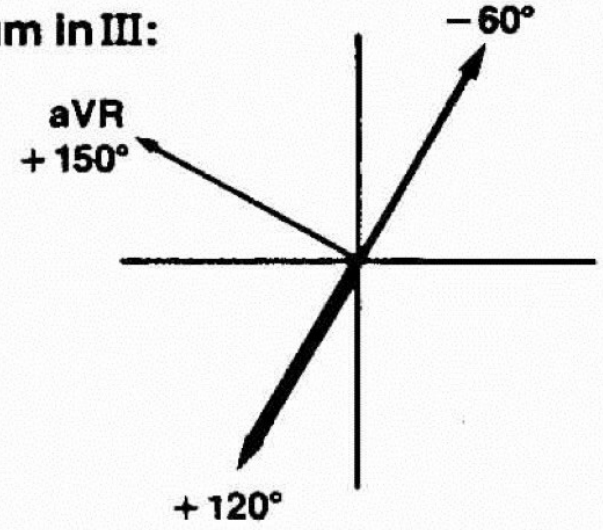
Step 2: Fine tuning

QRS FRONTAL PLANE
MEAN VECTOR — PERPENDICULAR METHOD

1. Inspection: Isoelectric to leads II and aVR
   maximum positive : lead III
2. Deduction:
   a. isoelectric to II:
      either −30° or +150°
   b. maximum in III:
      +150°



   a. Isoelectric to aVR:
      either −60° or 120°
   b. maximum in III:
      +120°



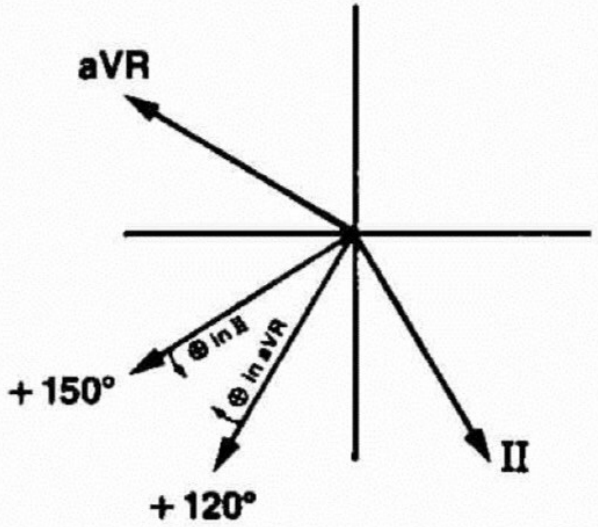
3. Fine Tuning:

a. II slightly positive (Q (−2mm) + R (+8mm) + S (−4mm) = +2mm)

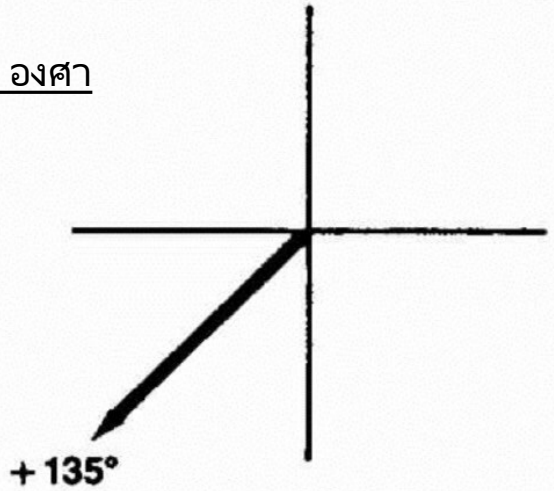
∴ slightly towards II from +150°

b. aVR slightly positive (R (+1mm) + S (−4mm) + R' (+6mm) = +3mm)

∴ slightly towards aVR from + 120°



อ่านละเอียดถึงระดับ 15 องศา

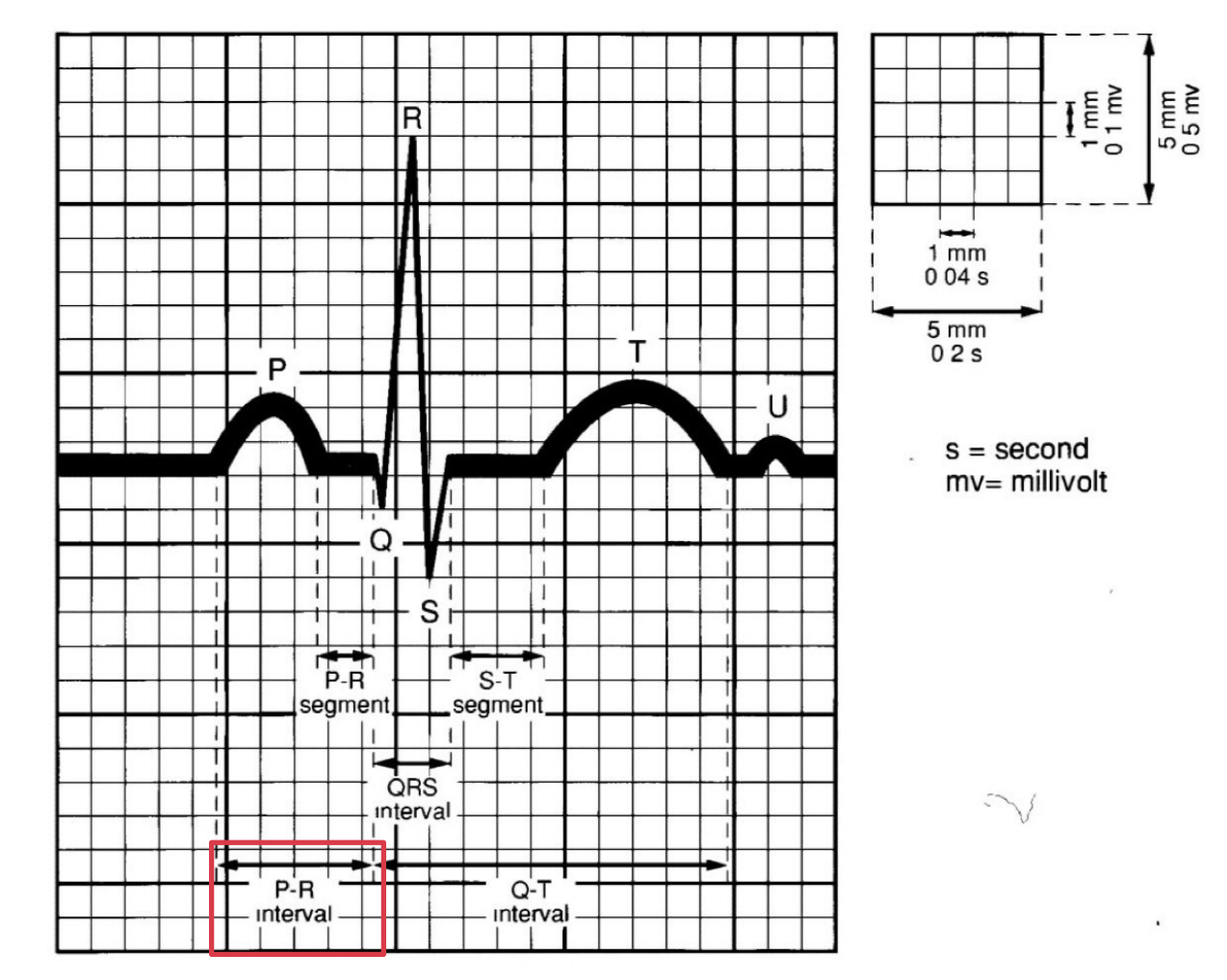


4. Conclusion = Mean vector between +120° and +150° = +135°

P wave

- P wave axis = Vector ที่ชี้ทิศทางของการกระตุ้นไฟฟ้าจากจุดกำเนิด
- Sinus rhythm ต้องมีจุดกำเนิดมาจาก Right Atrium ส่วนบน-> P axis 0 ถึง +90 องศา
- P wave axis abnormal = Ectopic foci

PR interval


R
P
T
U
Q
S
P-R segment
S-T segment
QRS interval
P-R interval
Q-T interval
1 mm 0 1 mv
5 mm 0 5 mv
1 mm 0 04 s
5 mm 0 2 s
s = second
mv= millivolt

PR interval

- จุดเริ่มต้น P wave ถึง เริ่มต้น Q wave/R wave (No Q wave)
- มักเลือกวัดที่ Lead II

Prolonged PR interval:
> 160 msec

- 1st degree AV block
- Complete AVSD
- Ebstein's anomaly
- Rheumatic fever
- Digitalis effects

Short PR interval: PR interval ≤ 100 msec

- Preexcitation syndrome (WPW)
- Glycogen storage disease:

Increased AV nodal size and conduction

QRS axis

Normal axis = อยู่ระหว่าง 0 องศาถึงค่าปกติที่ขึ้นกับอายุ

Right axis deviation:
> 98th percentile สำหรับค่าปกติตามช่วงอายุ

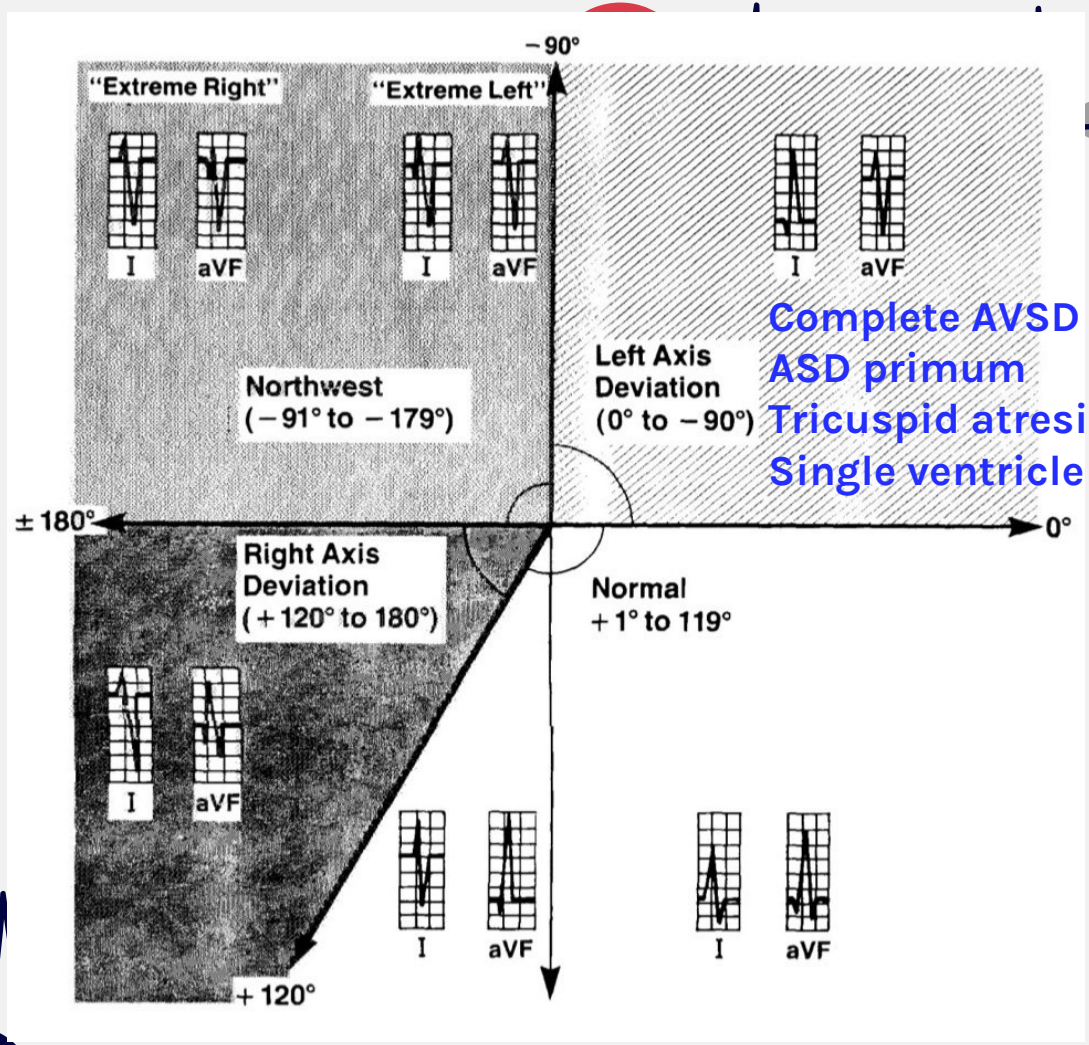
Left axis deviation = 0 ถึง -90 องศาพบใน

- **Complete AVSD**
- **ASD primum**
- **Tricuspid atresia**
- **Single ventricle**

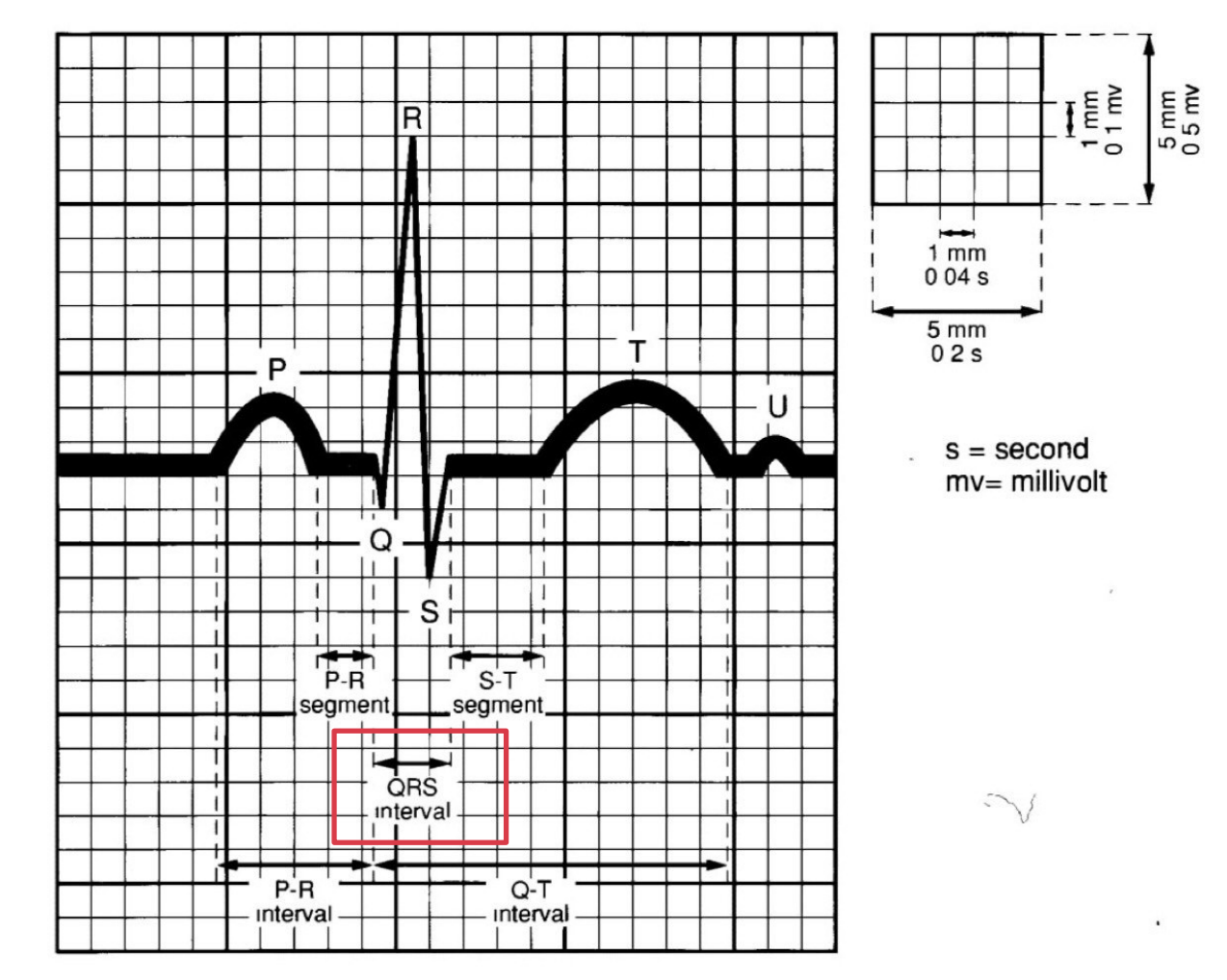
QRS axis

Northwest axis = ระหว่าง -90 องศา ถึง -180 องศา

- Q wave in lead I or aVL = **extreme left axis deviation**
- Q wave or QS pattern in lead II, III or aVF = **extreme right axis deviation**

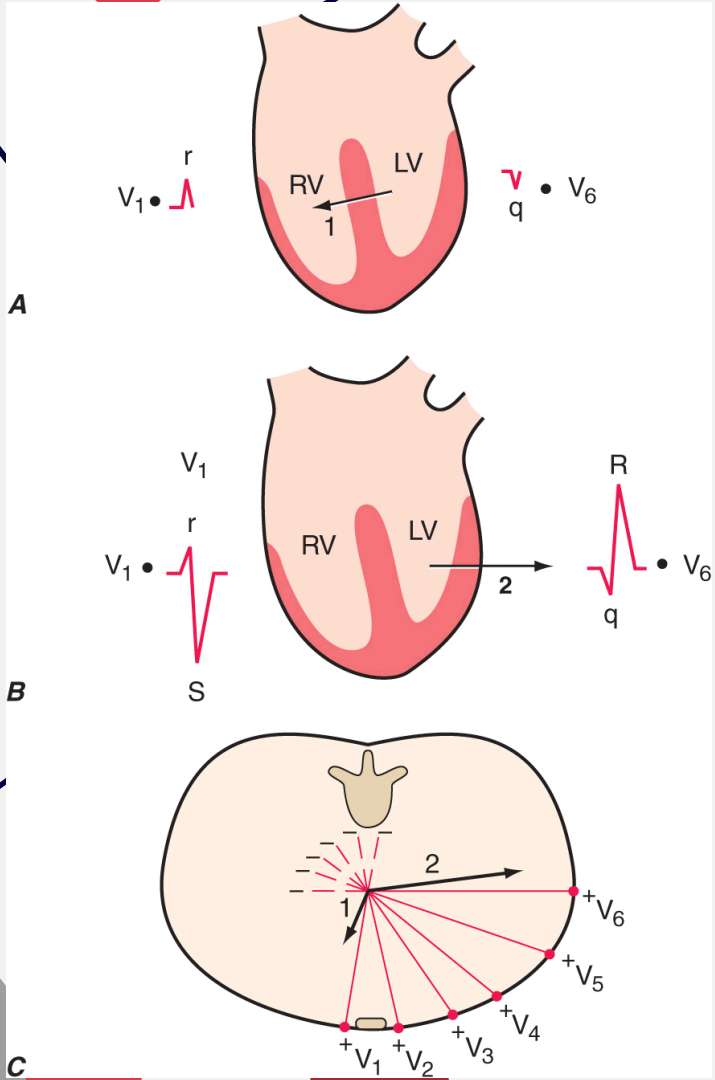

−90°
"Extreme Right"
"Extreme Left"
I
aVF
I
aVF
I
aVF
Northwest
(−91° to −179°)
Left Axis
Deviation
(0° to −90°)
Complete AVSD
ASD primum
Tricuspid atresia
Single ventricle
±180°
0°
Right Axis
Deviation
(+120° to 180°)
Normal
+1° to 119°
I
aVF
I
aVF
I
aVF
+120°

QRS complex


R
P
T
U
Q
S
P-R segment
S-T segment
QRS interval
P-R interval
Q-T interval
1 mm 0 1 mv
5 mm 0 5 mv
1 mm 0 04 s
5 mm 0 2 s
s = second
mv= millivolt

QRS complex

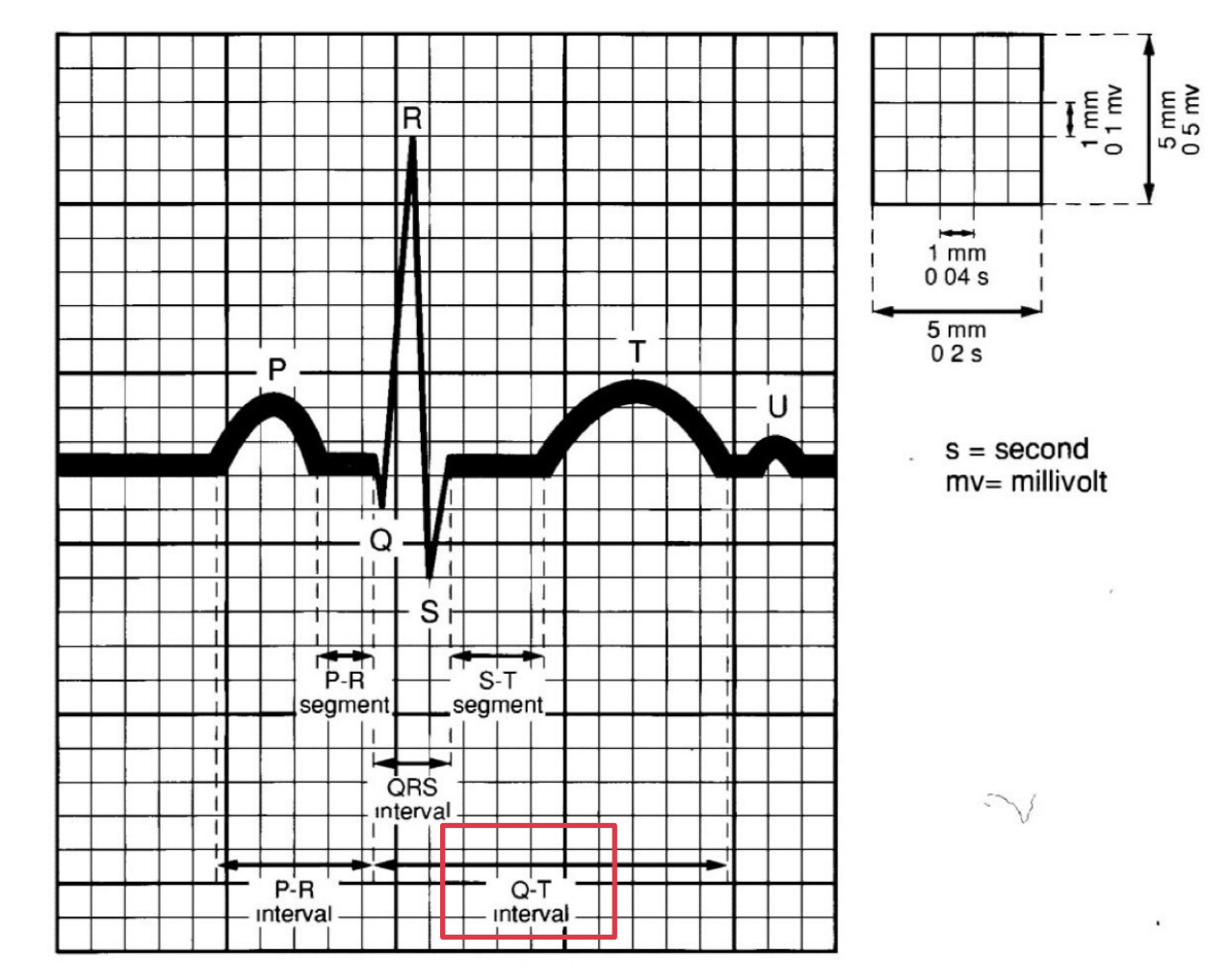
- ควรเลือกวัดใน lead ที่มี initial Q wave
- ทิศทางของ Q wave ใน precordial lead บ่งบอกทิศทางของ septal depolarization; ปกติควรมีใน lead V5 – V6
- **Pathologic Q wave** = กว้างเกิน 30 msec หรือ ลึกเกิน 4 mm (Myocardial infarction)
- **Low voltage QRS** = R+S wave < 5 mm in limb leads or R+S < 8 mm in chest leads (Myocardial edema)
- **Wide QRS** = > 2.5 mm



- The first phase is depolarization of the interventricular septum from the left to the right and anteriorly (vector 1).
- The second results from the simultaneous depolarization of the right and left ventricles; it normally is dominated by the more massive left ventricle, so that vector 2 points leftward and posteriorly.

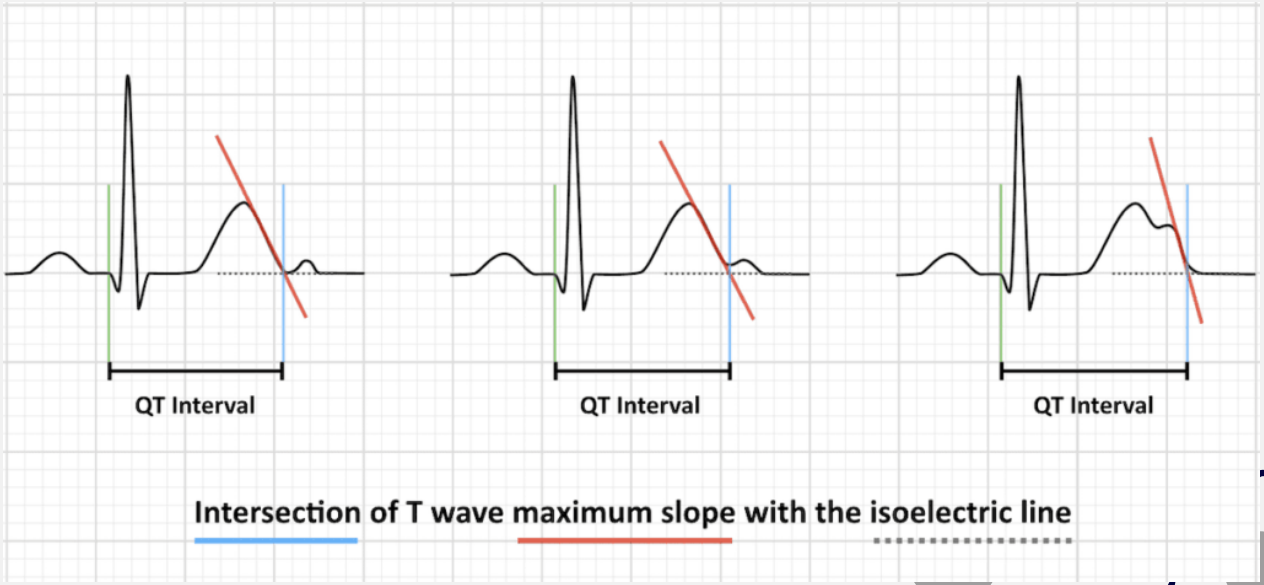
https://thoracickey.com/electrocardiography-5/

QRS complex


R
P
T
U
Q
S
P-R segment
S-T segment
QRS interval
P-R interval
Q-T interval
1 mm 0 1 mv
5 mm 0 5 mv
1 mm 0 04 s
5 mm 0 2 s
s = second
mv= millivolt

QT interval

- เริ่มต้น QRS complex ไปจนสิ้นสุด T wave
- ควรวัดที่ Lead II, V5 และ V6 โดยเลือกอ่านค่าที่ยาวที่สุด



https://litfl.com/qt-interval-ecg-library/

Corrected QT interval (QTc)

- **Corrected with heart rate**
- **Bazett formula**

$$\text{QTc} = \frac{QT\ (sec)}{\sqrt{RR}(sec)}$$

Age < 6 months old: < 450 msec

Age > 6 months old: < 440 msec

Corrected QT interval (QTc)

Long QTc: Risk for VT/VF

- Hypocalcemia
- Hypokalemia
- Hypomagnesemia
- Amiodarone effects
- Macrolide/ Trimethoprim
- Infant of autoimmune mother, Anti-Ro antibodies positive

Short QTc

- Hypercalcemia
- Hypermagnesemia
- Digitalis effects

Chamber enlargement and hypertrophy

RVH

- QR pattern in right chest lead
- T wave change
- R wave amplitude in V1
- S wave amplitude in V6
- R/S ratio in V1
- RSR’ in V1
- RAD

LVH

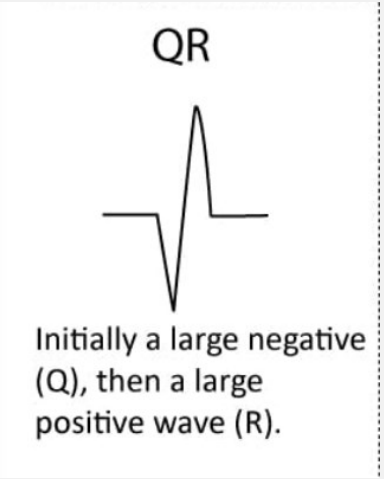
- T wave change
- R wave amplitude in V6 or S wave amplitude in V1
- Amplitude of R wave in V6 + Amplitude of S wave in V1
- Q wave abnomalities

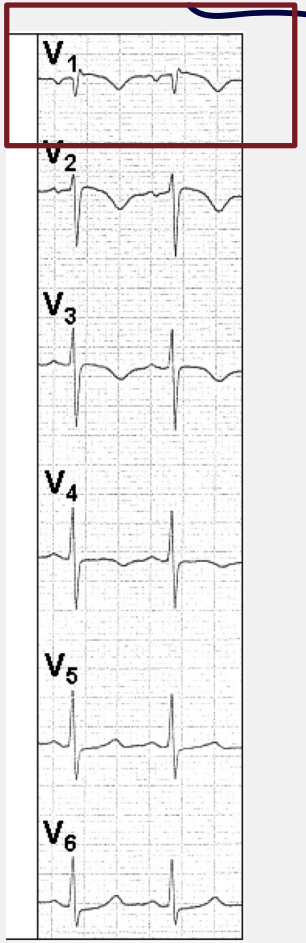
Biventricular hypertrophy

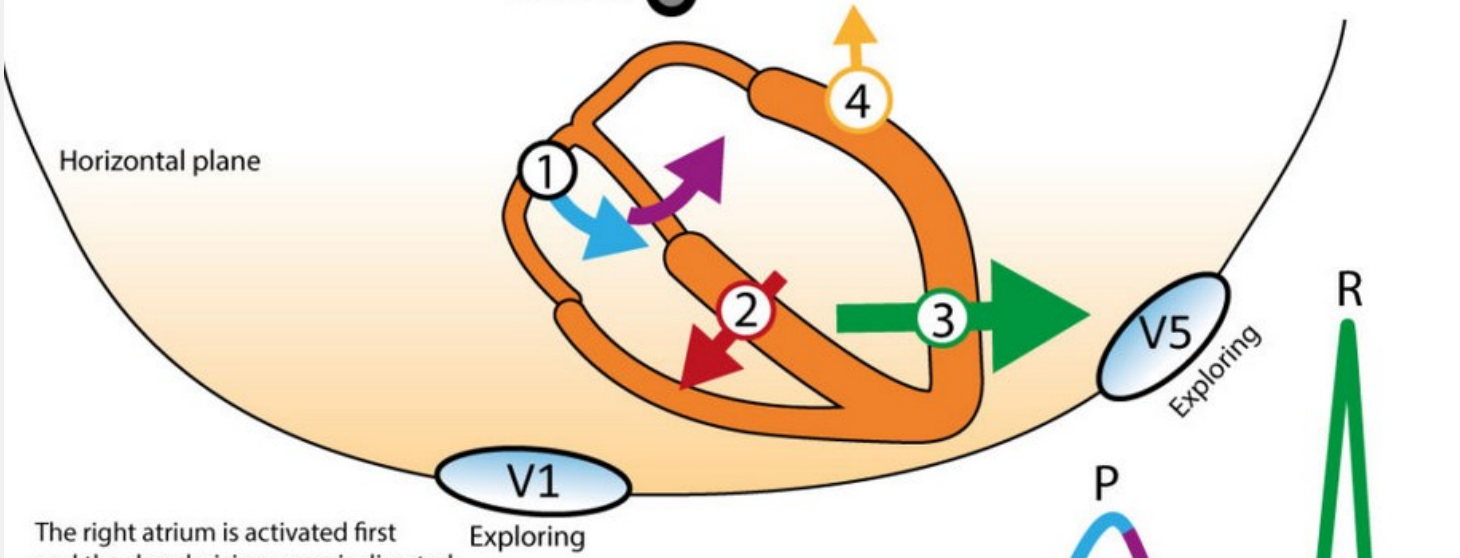
- Abnormal voltage in both the right and left chest leads
- Katz-Wachtel criterion

QR pattern in the right chest leads (RVH)

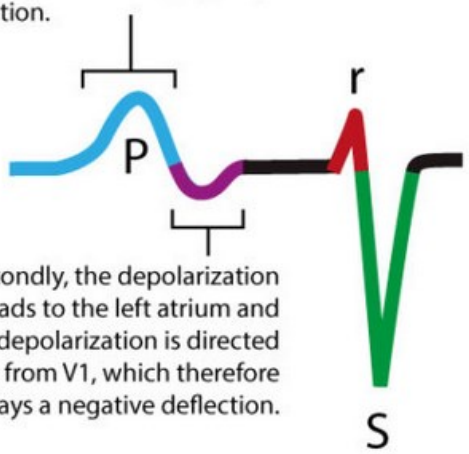
QR pattern:
- Most reliable sign of RVH
- Systolic pressure of right ventricle > 70 mmHg







The right atrium is activated first and the depolarizing wave is directed towards V1, which displays a positive deflection.



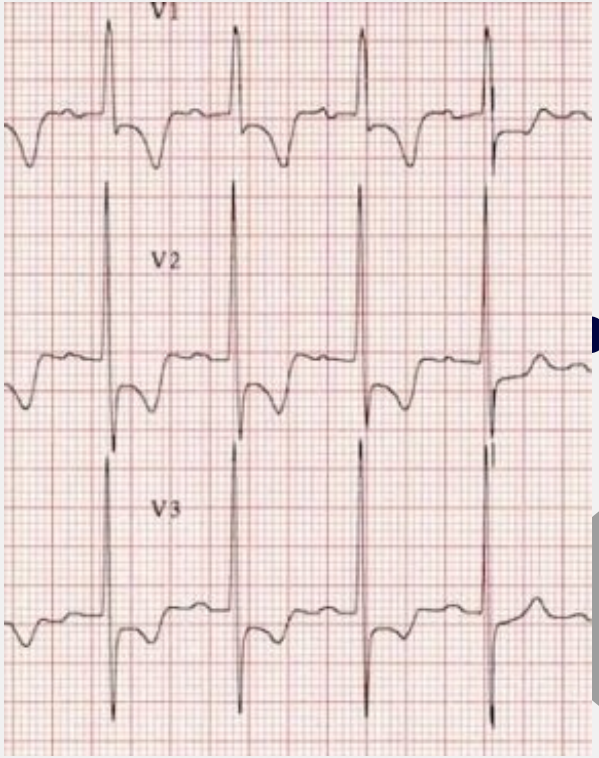
Secondly, the depolarization spreads to the left atrium and the depolarization is directed away from V1, which therefore displays a negative deflection.

Note the successive transition of the QRS-komplex from V1 to V6.

T wave changes (RVH)

Normal T wave in V1-3
- Upright in age < 7 days
- Inverted T in age > 7 days to adolescent

RVH: ความดันหัวใจห้องล่างขวาสูงขึ้น
- Upright T in V1 (ต้องไม่มี LV strain หรือ inverted T in V5-6)
- Tall R with asymmetrically inverted T in V1-4 (Right ventricular strain)
  = ความดันในหัวใจล่างขวาเท่ากับหรือสูงกว่าความดันเลือด
- Invert T in aVF



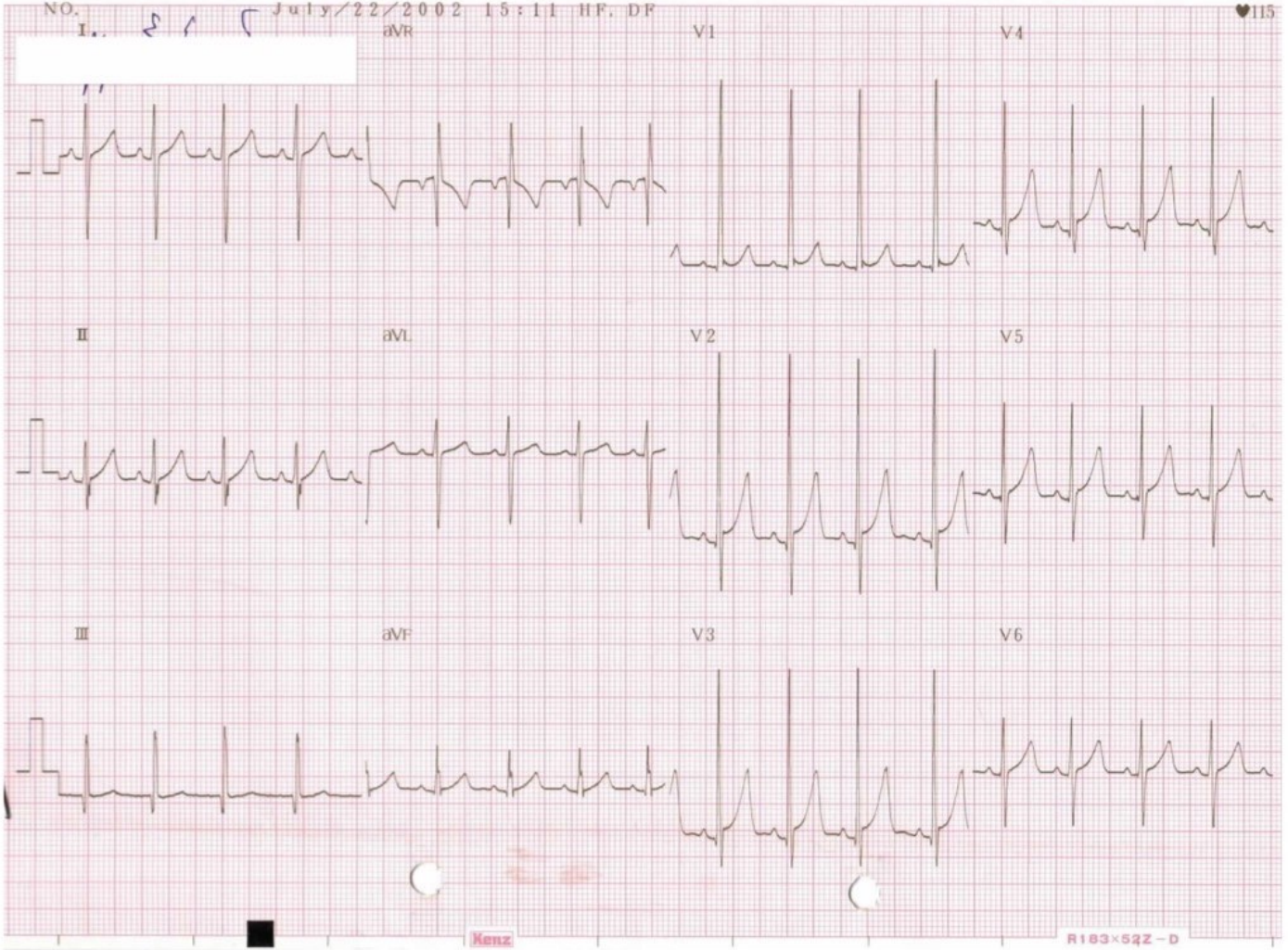
RV strain pattern

R wave amplitude in lead V1 (RVH)

Amplitude of R wave in V1 > 98th percentile
(High specificity, low sensitivity)
If amplitude > 20 mm = ความดันในหัวใจห้องล่างขวาสูงเท่ากับ หรือ มากกว่าความดันเลือด

S wave amplitude in lead V6 (RVH)

Deep amplitude of S wave in V6 > 98th percentile

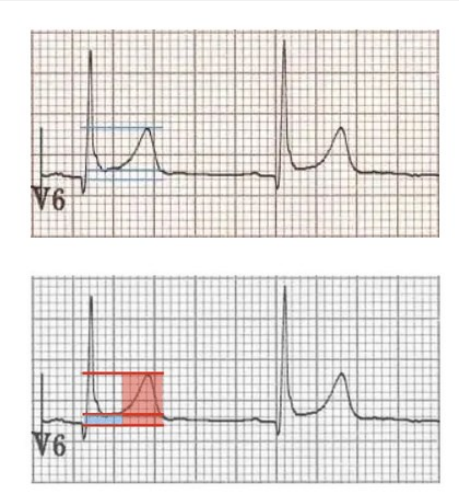


Right axis deviation
Upright T V1
R in V1 34 mm
Deep S in V6

RVH

R/S ratio >1 in lead V1	ไม่ค่อยแม่นยำ ต้องอาศัยเกณฑ์ประกอบอื่นๆ
rSR’ in V1 (normal QRS duration)	With low S wave and tall R’ (> 15 mm if age < 1 year, > 10 mm if age > 1 year) Mild RVH แต่พบในเด็กปกติได้ถึง 7% และใน incomplete RBBB
Right axis deviation	ใช้สนับสนุนการวินิจฉัย RVH

ST-T segment



Early repolarization

Functional T wave changes

- Sympathetic activity (Frightening, Anxiety): Inverted T wave

Early repolarization syndrome

- In adolescent
- J point elevation (mimic ST elevation)
- เกิดจาก T wave ปรากฏเร็วกว่าธรรมดา ในขณะที่ Ventricles ยัง Depolarization อยู่
- Differential with pericarditis (Multi-stage, ST/T ratio > 0.25)

Chamber enlargement and hypertrophy

RVH

- QR pattern in right chest lead
- T wave change
- R wave amplitude in V1
- S wave amplitude in V6
- R/S ratio in V1
- RSR’ in V1
- RAD

LVH

- T wave change
- R wave amplitude in V6 or S wave amplitude in V1
- Amplitude of R wave in V6 + Amplitude of S wave in V1
- Q wave abnomalities

Biventricular hypertrophy

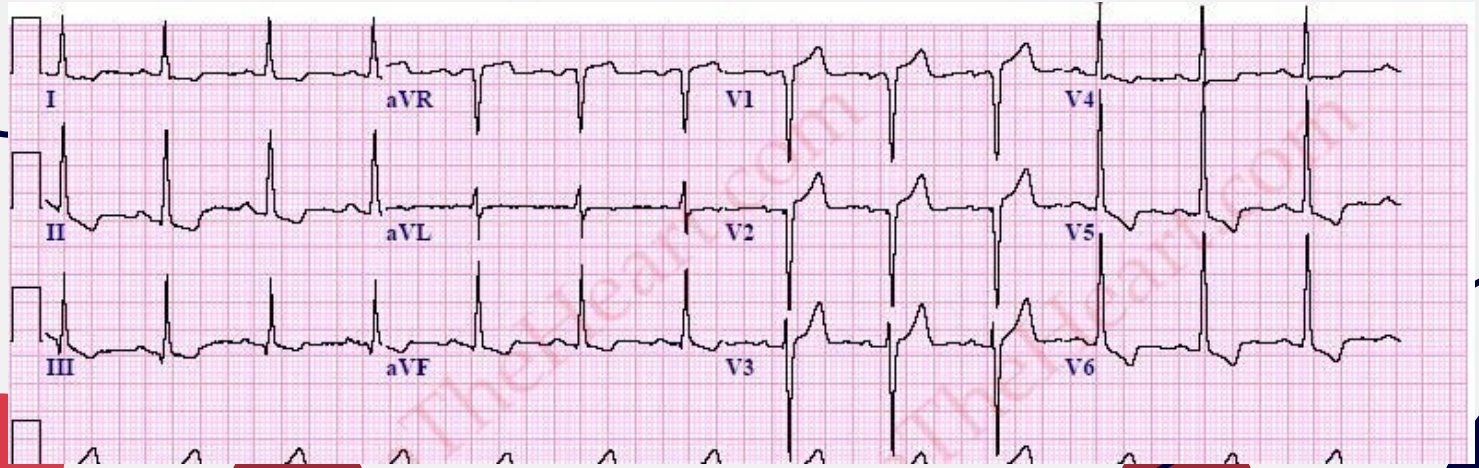
- Abnormal voltage in both the right and left chest leads
- Katz-Wachtel criterion

T wave changes (LVH)

Normal T wave in V5-6
- Upright T

LVH
- Asymmetrically inverted T in V5-6 (LV strain pattern)

(Most reliable sign of LVH)
- Inverted T in aVF
- Inverted T in inferior/Lateral lead without evidence of ischemia



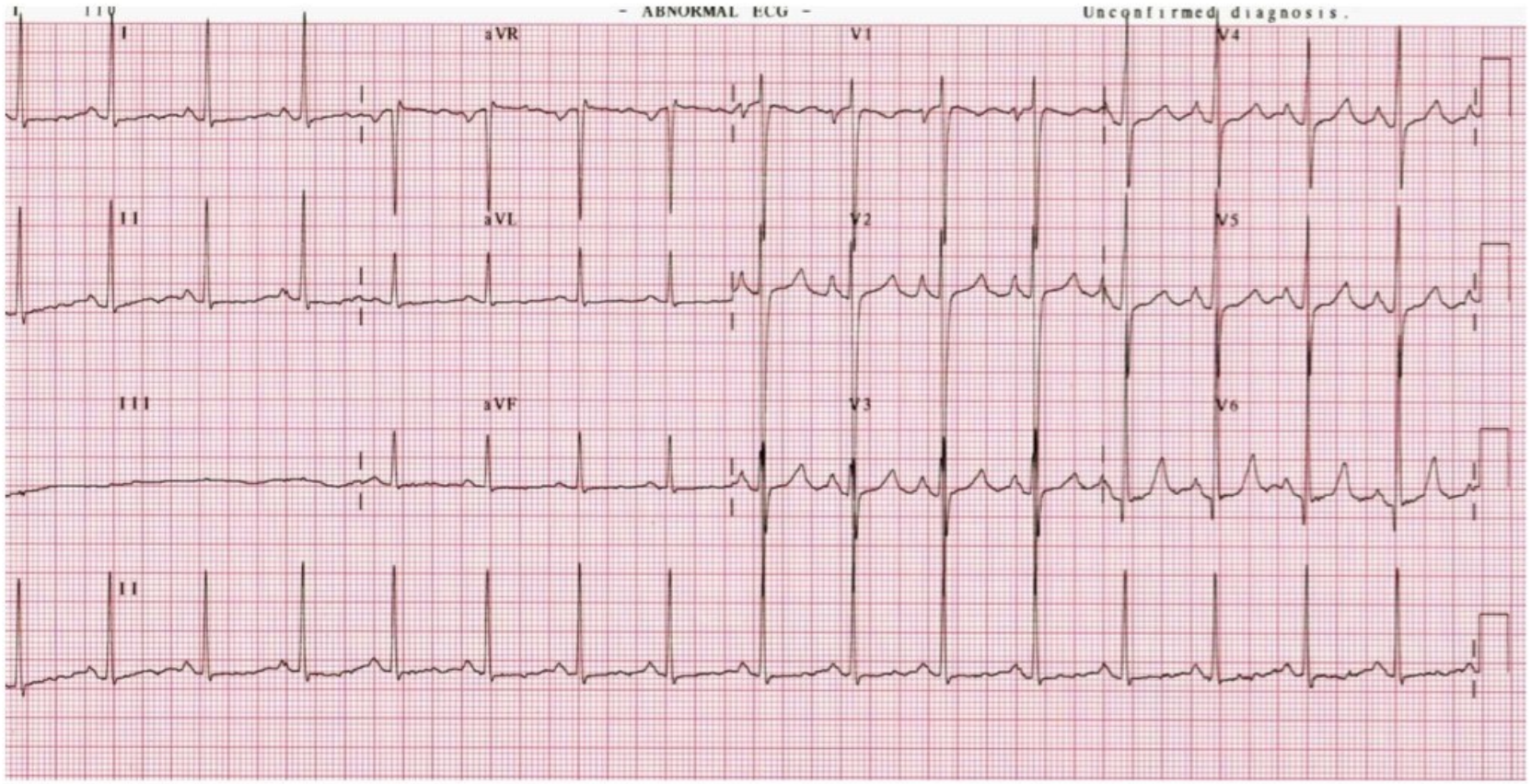
LVH

R wave amplitude in lead V6 or S wave amplitude in V1

- 98th percentile
- Voltage criteria for LVH

Amplitude of R wave in lead V6 plus amplitude of S wave in lead V1

- 98th percentile
- Voltage criteria for LVH



Deep S in V1, Dominant R in V6

Q wave abnormalities

- Deep Q wave more than normal in inferior and lateral leads (II, III, aVF, V5-6) (Volume overload)
- Absent Q wave in V6 (Pressure overload)

Chamber enlargement and hypertrophy

RVH

- QR pattern in right chest lead
- T wave change
- R wave amplitude in V1
- S wave amplitude in V6
- R/S ratio in V1
- RSR’ in V1
- RAD

LVH

- T wave change
- R wave amplitude in V6 or S wave amplitude in V1
- Amplitude of R wave in V6 + Amplitude of S wave in V1
- Q wave abnomalities

Biventricular hypertrophy

- Abnormal voltage in both the right and left chest leads
- Katz-Wachtel criterion

Abnormal voltage in both the right and left chest leads

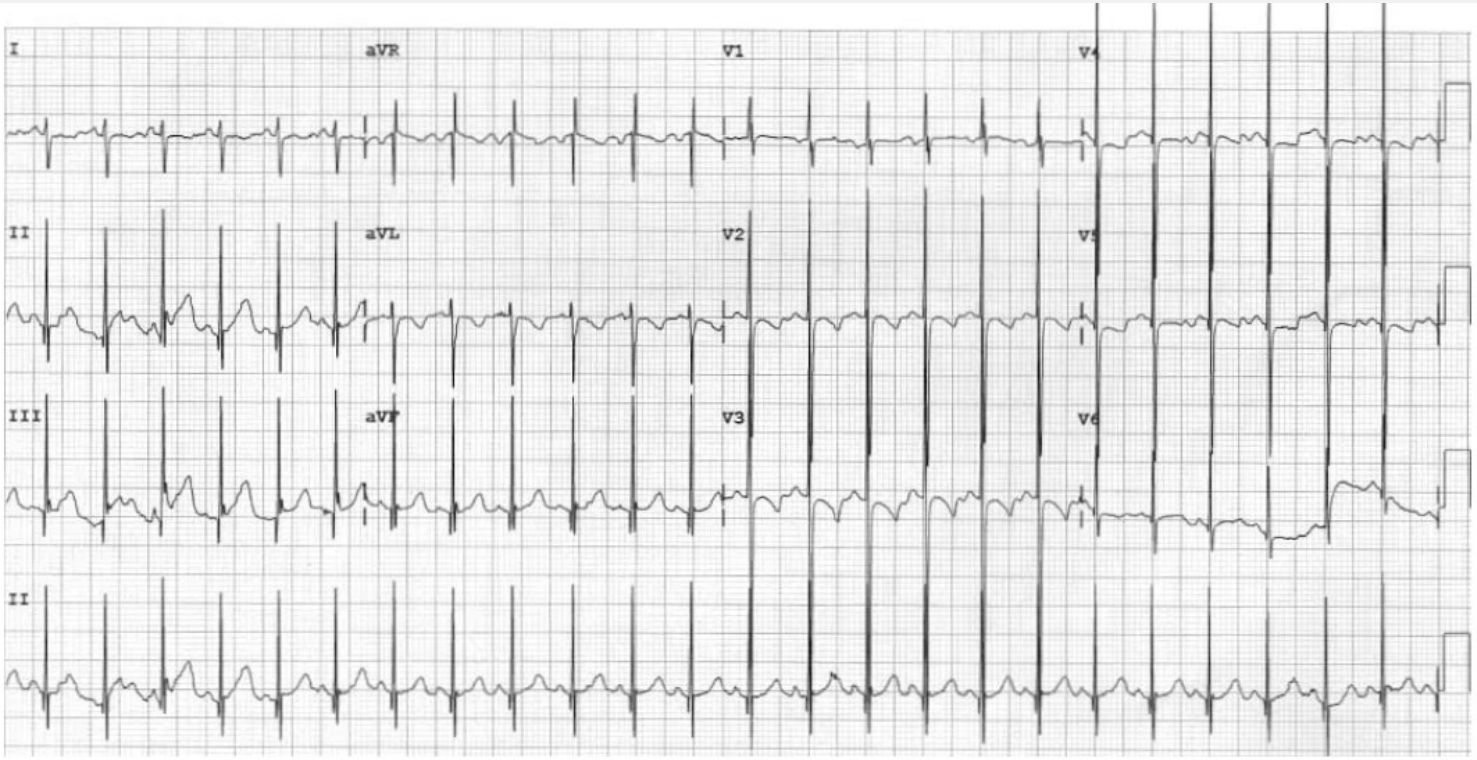
- Tall R in V1 or deep S in V6 (RVH) **plus** S wave in V1 or R wave in V6
- Tall R in V6 or deep S in V1 (LVH) **plus** S wave in V6 or R wave in V1

*Amplitude above normal limit compared to age

Katz-Wachtel criterion

Abnormal voltage in the midprecordial leads

- Amplitude of R wave plus Depth of S wave in V3-4 > 98th percentile (> 60 mm)



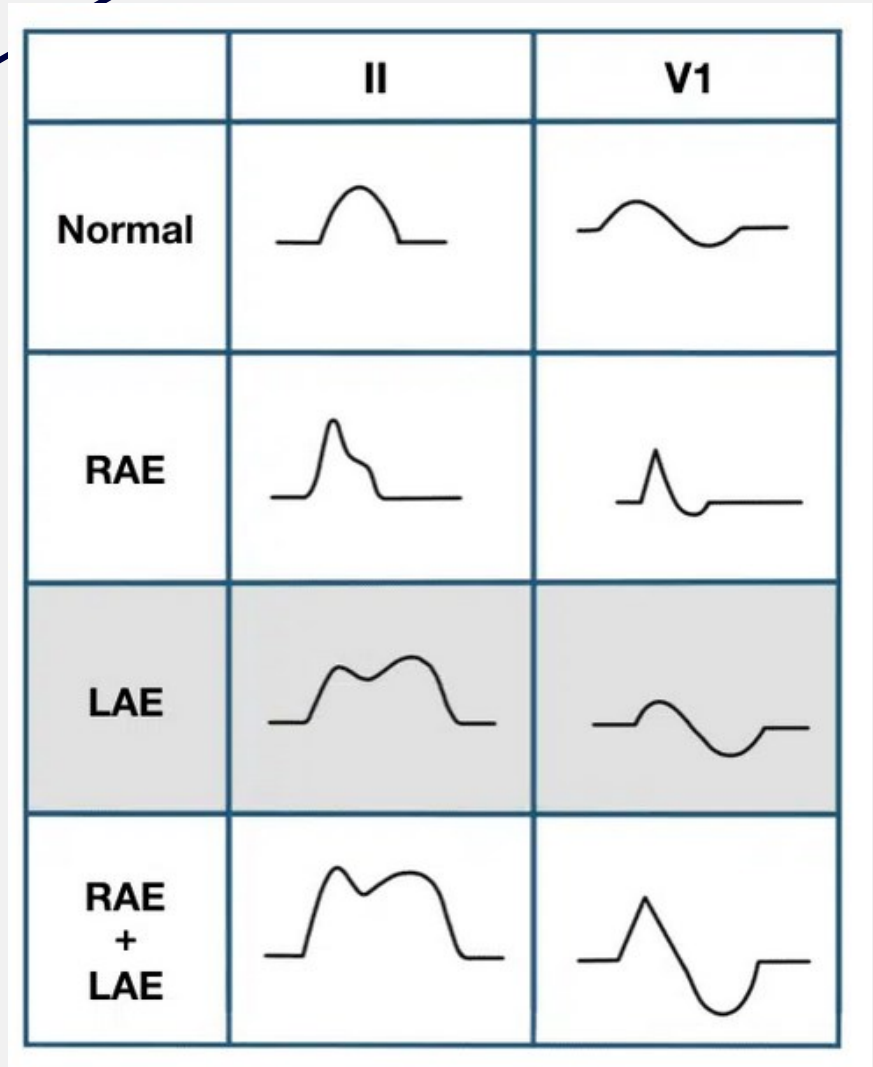
Katz-Wachtel phenomenon in child with isolated ventricular septal defect

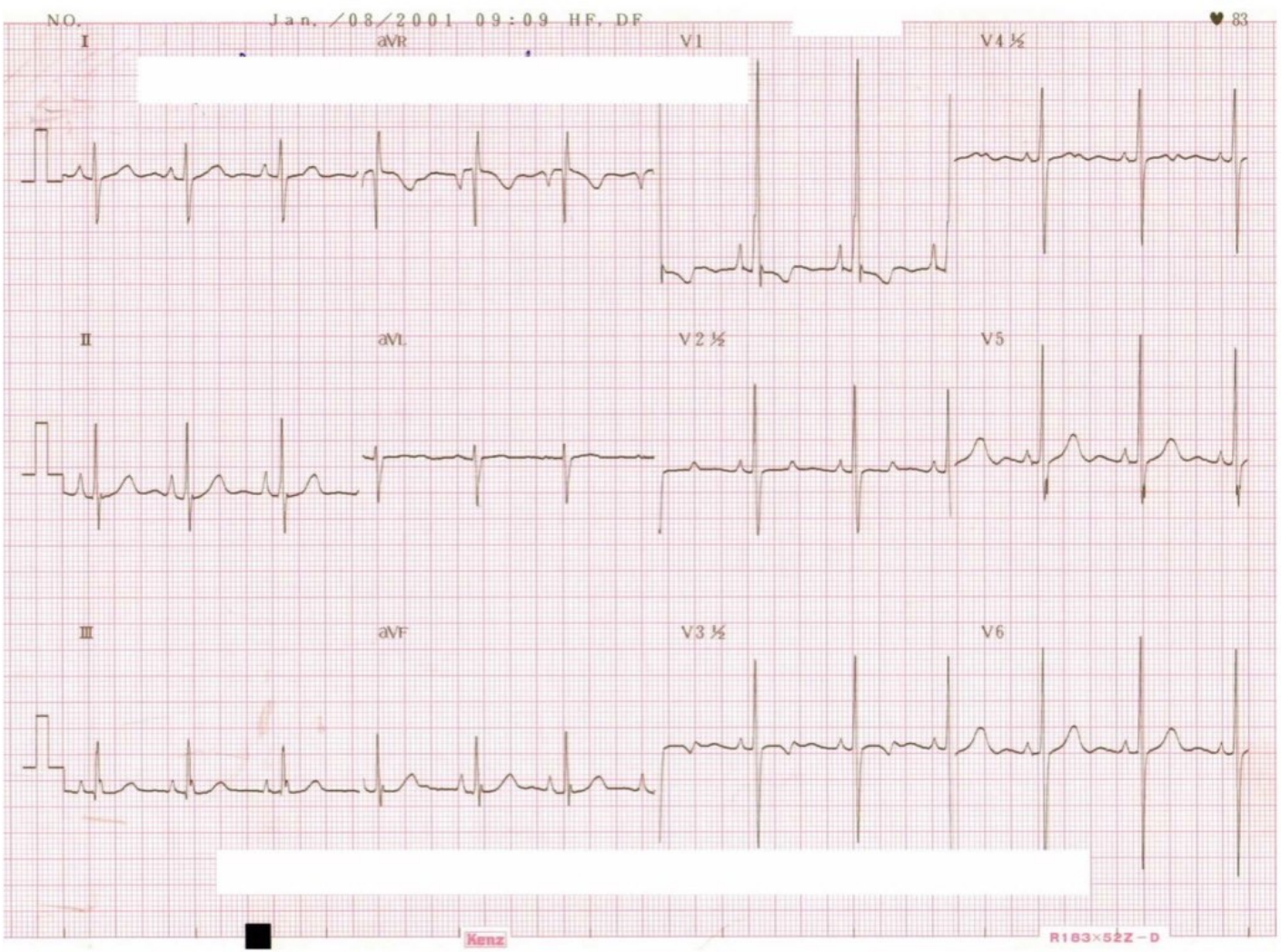
Chamber enlargement

Right atrial enlargement	มีผลต่อ Depolarization ในระยะ**ต้น**ของ P wave	P wave amplitude > 2.5 mm (มักพบที่ lead II หรือ V2) Peaked P wave
Left atrial enlargement	มีผลต่อ Depolarization ในระยะ**หลัง**ของ P wave	- Increased terminal posterior forces: P wave ส่วนท้ายหัวกลับลึกเกิน 1 mm และ กว้างเกิน 1 mm ใน V1-2 (Most reliable) - P wave duration > 2.5 mm at lead II, V1-2
Biatrial enlargement		Met both RAE + LAE criteria

P pulmonale

P mitrale





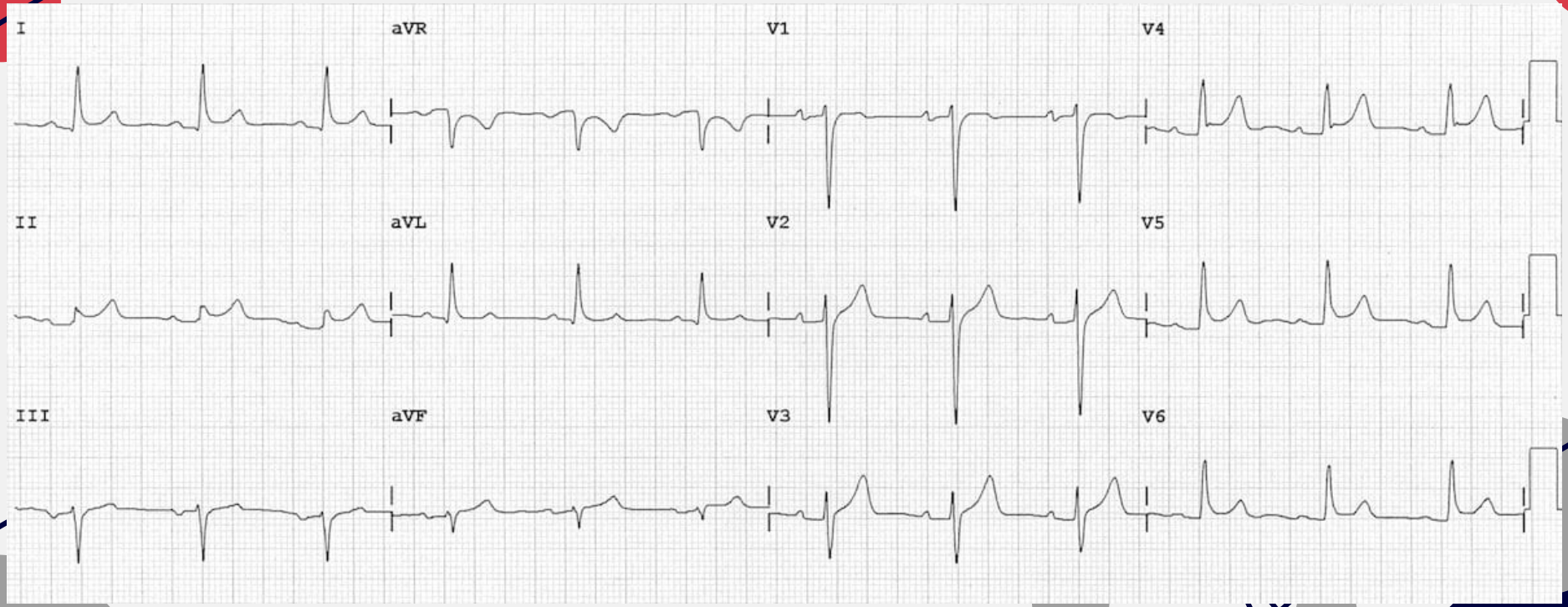
RAE
P amplitude > 3 mm
in II, V1

Pericarditis

Four stage

1) ST elevation (Diffuse), Upright T wave, PR segment elevation in aVR and V1, PR depression in STE leads
2) Normalized ST segment with flattening T wave
3) Inverted T wave in previous STE leads
4) Resolution

Pericarditis stage 1



ST-T segment

Myocardial Injury

Acute Infarction: ST elevation
Myocarditis: Flat or Inverted T wave (Common in left chest leads) and low voltage QRS

Myocardial Ischemia

- **Subendocardial**: Tall T wave
- **Subepicardial/Transmural**: Inverted T wave

Myocardial Infarction

Q wave with inverted T wave in infarct area (Several hours to days)

[In few min after onset: Hyperacute tall peaked T then ST elevation and reciprocal ST depression]

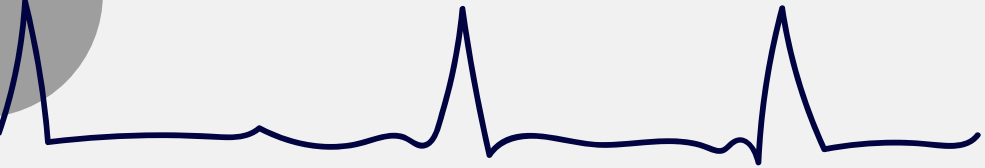


TABLE A-17. *Summary of Normal Values*

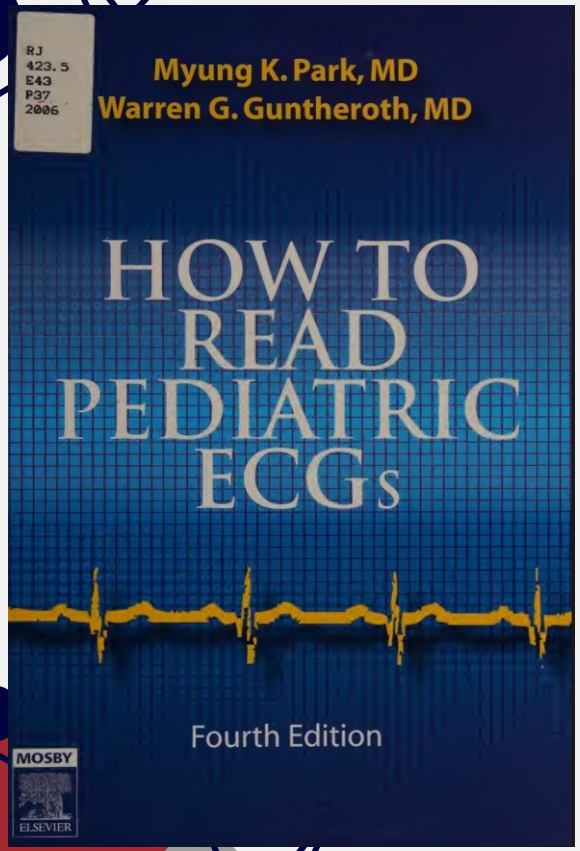
Age Group	*Heart Rate (BPM)	Frontal Plane QRS Vector (degrees)	PR Interval (sec)	**Q III (mm)§	**Q V_6 (mm)	RV_1 (mm)	SV_1 (mm)	R/S V_1	RV_6 (mm)	SV_6 (mm)	R/S V_6	**SV_1 + RV_6 (mm)	**R + S V_4 (mm)
Less than 1 day	93–154 (123)	+59 to −163 (137)	.08–.16 (.11)	4.5	2	5–26 (14)	0–23 (8)	.1–U (2.2)	0–11 (4)	0–9.5 (3)	.1–U (2.0)	28	52.5
1–2 days	91–159 (123)	+64 to −161 (134)	.08–.14 (.11)	6.5	2.5	5–27 (14)	0–21 (9)	.1–U (2.0)	0–12 (4.5)	0–9.5 (3)	.1–U (2.5)	29	52
3–6 days	91–166 (129)	+77 to −163 (132)	.07–.14 (.10)	5.5	3	3–24 (13)	0–17 (7)	.2–U (2.7)	.5–12 (5)	0–10 (3.5)	.1–U (2.2)	24.5	49
1–3 weeks	107–182 (148)	+65 to +161 (110)	.07–.14 (.10)	6	3	3–21 (11)	0–11 (4)	1.0–U (2.9)	2.5–16.5 (7.5)	0–10 (3.5)	.1–U (3.3)	21	49
1–2 months	121–179 (149)	+31 to +113 (74)	.07–.13 (.10)	7.5	3	3–18 (10)	0–12 (5)	.3–U (2.3)	5–21.5 (11.5)	0–6.5 (3)	.2–U (4.8)	29	53.5
3–5 months	106–186 (141)	+7 to +104 (60)	.07–.15 (.11)	6.5	3	3–20 (10)	0–17 (6)	.1–U (2.3)	6.5–22.5 (13)	0–10 (3)	.2–U (6.2)	32	61.5
6–11 months	109–169 (134)	+6 to +99 (56)	.07–.16 (.11)	8.5	3	1.5–20 (9.5)	.5–18 (4)	.1–3.9 (1.6)	6–22.5 (12.5)	0–7 (2)	.2–U (7.6)	32	53
1–2 years	89–151 (119)	+7 to +101 (55)	.08–.15 (.11)	6	3	2.5–17 (9)	.5–21 (8)	.05–4.3 (1.4)	6–22.5 (13)	0–6.5 (2)	.3–U (9.3)	39	49.5
3–4 years	73–137 (108)	+6 to +104 (55)	.09–.16 (.12)	5	3.5	1–18 (8)	.2–21 (10)	.03–2.8 (.9)	8–24.5 (15)	0–5 (1.5)	.6–U (10.8)	42	53.5
5–7 years	65–133 (100)	+11 to +143 (65)	.09–.16 (.12)	4	4.5	.5–14 (7)	.3–24 (12)	.02–2.0 (.7)	8.5–26.5 (16)	0–4 (1)	.9–U (11.5)	47	54
8–11 years	62–130 (91)	+9 to +114 (61)	.09–.17 (.13)	3	3	0–12 (5.5)	.3–25 (12)	0–1.8 (.5)	9–25.5 (16)	0–4 (1)	1.5–U (14.3)	45.5	53
12–15 years	60–119 (85)	+11 to +130 (59)	.09–.18 (.14)	3	3	0–10 (4)	.3–21 (11)	0–1.7 (.5)	6.5–23 (14)	0–4 (1)	1.4–U (14.7)	41	50

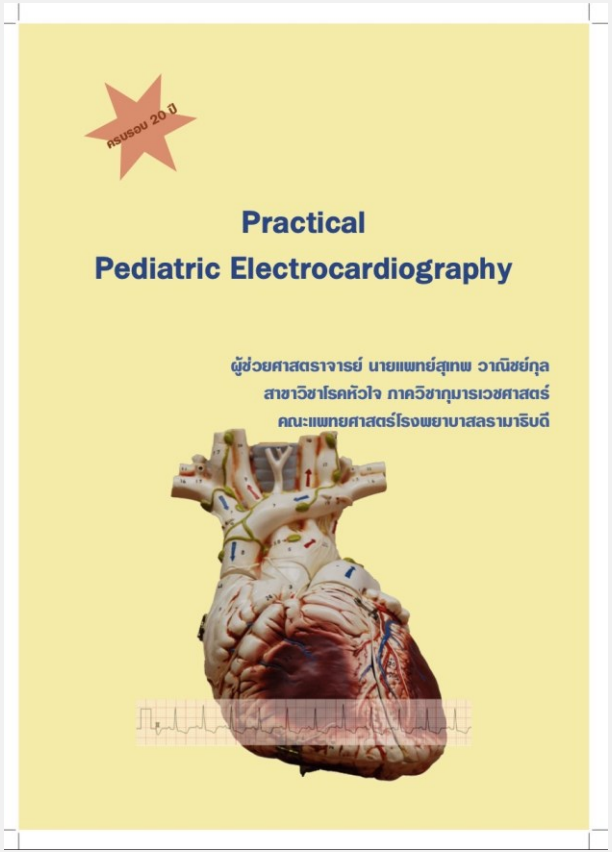
*2%–98% (mean)
**98th percentile
§mm at normal standardization
U undefined (S wave may equal zero)

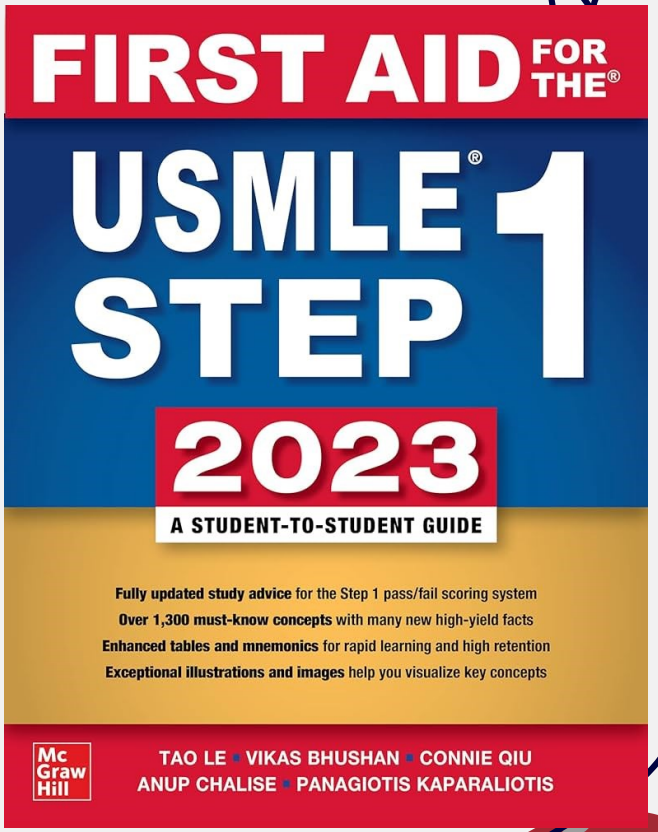
Take home messages

- Hexaxial reference system provides the frontal projection of the electromotive forces while horizontal reference system Provides the AP and the left-right relationship
- Components of ECG wave form: Wave, Interval and Segment
- Before routine measurement: Check paper speed and amplitude.
- Basic measurement: Rate, Rhythm, Axis, P wave, QRS wave, Intervals and Chamber hypertrophy/enlargement

Resources


RJ
423.5
E43
P37
2006
Myung K. Park, MD
Warren G. Guntheroth, MD
HOW TO READ PEDIATRIC ECGs
Fourth Edition
MOSBY
ELSEVIER


ครบรอบ 20 ปี
Practical
Pediatric Electrocardiography
ผู้ช่วยศาสตราจารย์ นายแพทย์สุเทพ วาณิชย์กุล
สาขาวิชาโรคหัวใจ ภาควิชากุมารเวชศาสตร์
คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี


FIRST AID FOR THE®
USMLE® STEP 1
2023
A STUDENT-TO-STUDENT GUIDE
Fully updated study advice for the Step 1 pass/fail scoring system
Over 1,300 must-know concepts with many new high-yield facts
Enhanced tables and mnemonics for rapid learning and high retention
Exceptional illustrations and images help you visualize key concepts
Mc Graw Hill
TAO LE • VIKAS BHUSHAN • CONNIE QIU
ANUP CHALISE • PANAGIOTIS KAPARALIOTIS

Thanks!

CREDITS: This presentation template was created by **Slidesgo**, including icons by **Flaticon**, and infographics & images by **Freepik**

Please keep this slide for attribution

Basic science:

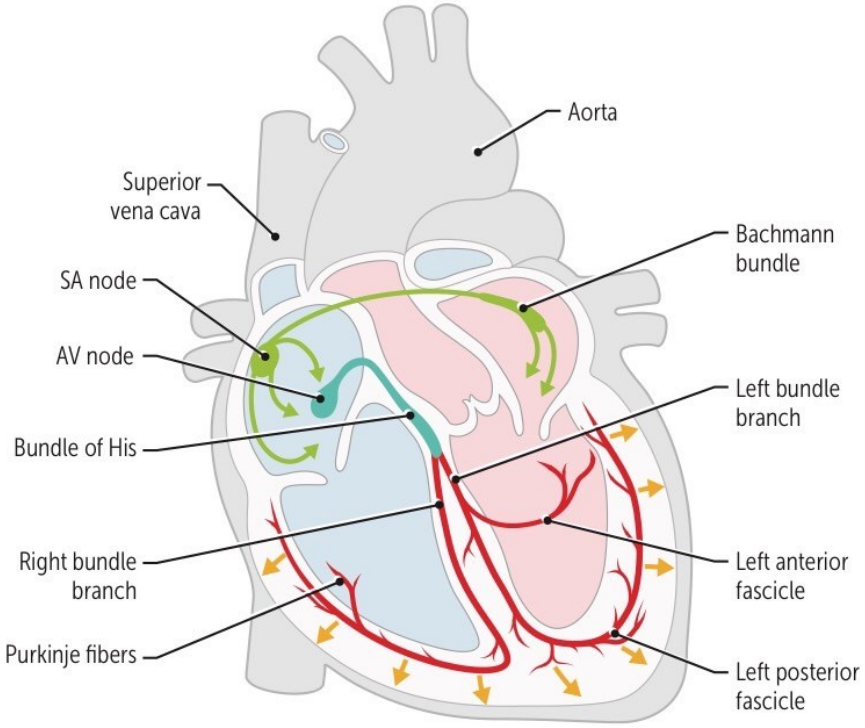
Pediatric Electrocardiogram

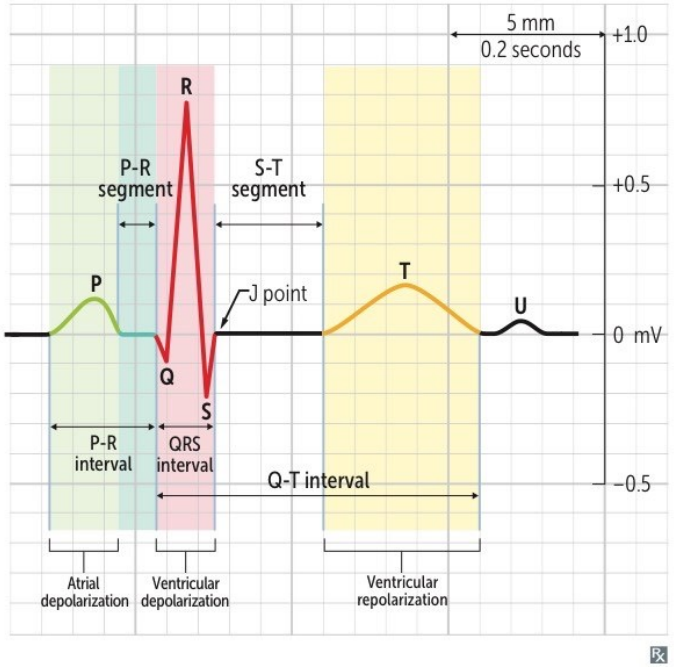
Resident 2 Worawit/Aj. Orakan

Table of contents

01

Cardiac cycle


Aorta
Superior vena cava
SA node
AV node
Bundle of His
Right bundle branch
Purkinje fibers
Bachmann bundle
Left bundle branch
Left anterior fascicle
Left posterior fascicle


5 mm
0.2 seconds
+1.0
+0.5
0 mV
−0.5
R
P-R segment
S-T segment
P
J point
T
U
Q
S
P-R interval
QRS interval
Q-T interval
Atrial depolarization
Ventricular depolarization
Ventricular repolarization

Cardiac cycle

1
Isovolumic contraction

Mitral valve closing to Aortic valve opening

2
Systolic ejection

Aortic valve opening to closing

3
Isovolumetric relaxation

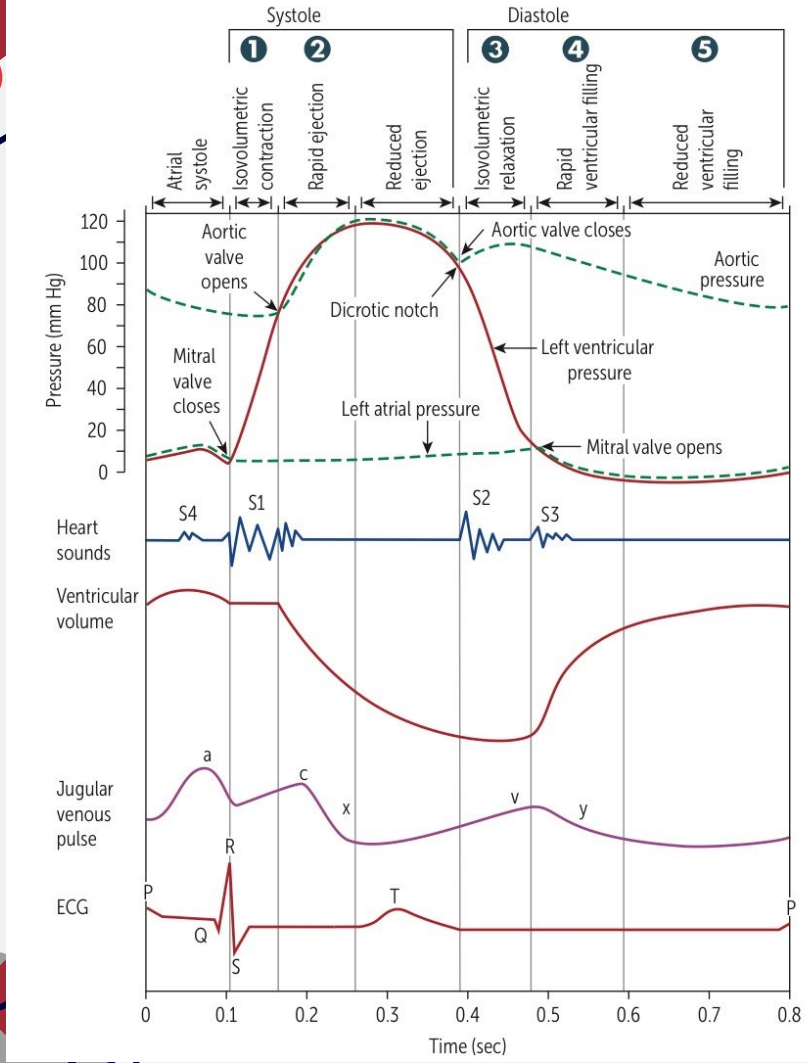
Aortic valve closing to mitral valve opening

4
Rapid filling

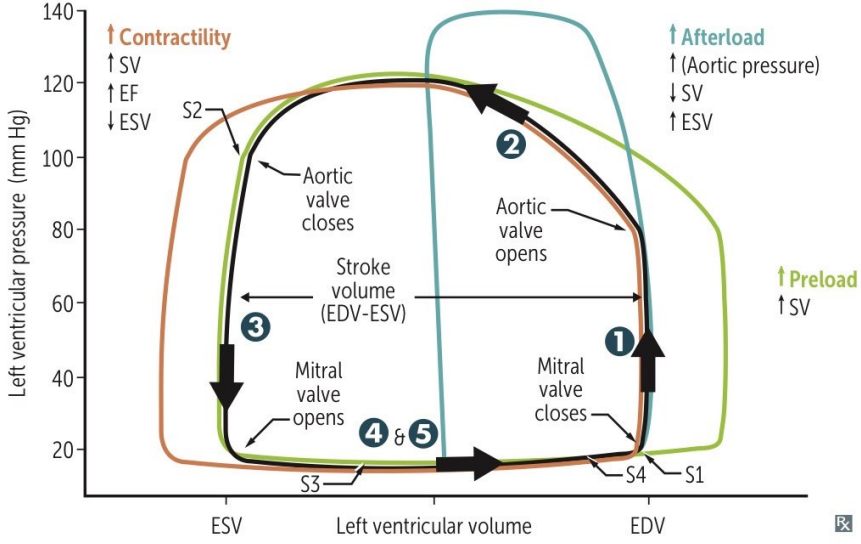
Just after mitral valve opening

5
Reduced filling

Just before mitral valve closing



Pressure-volume loops and cardiac cycle



02

Vectorial Approach

VCG and ECG

- **The Vectorcardiogram (VCG)** = The registration of the direction and magnitude of the moment to moment electromotive forces of heart during one complete cycle.
- **A scalar ECG** = ECG obtained in clinical practice, show only magnitude of multiple consecutive cardiac cycles against time (two or more scalar leads can infer the direction)

Vector

- **Vector** = Quantity with magnitude and direction
- Magnitude = height or depth of the wave form of ECG
- Direction of the forces determined by a combination of the leads which represent the **frontal projection** and the **horizontal projection** of the VCG

Vectorcardiogram

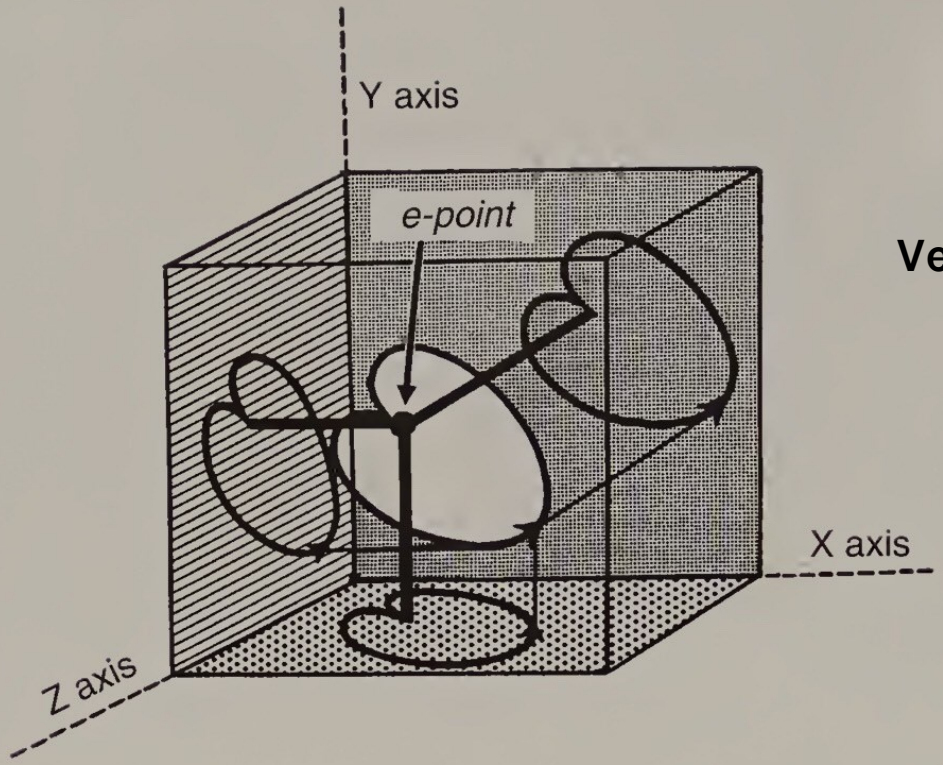
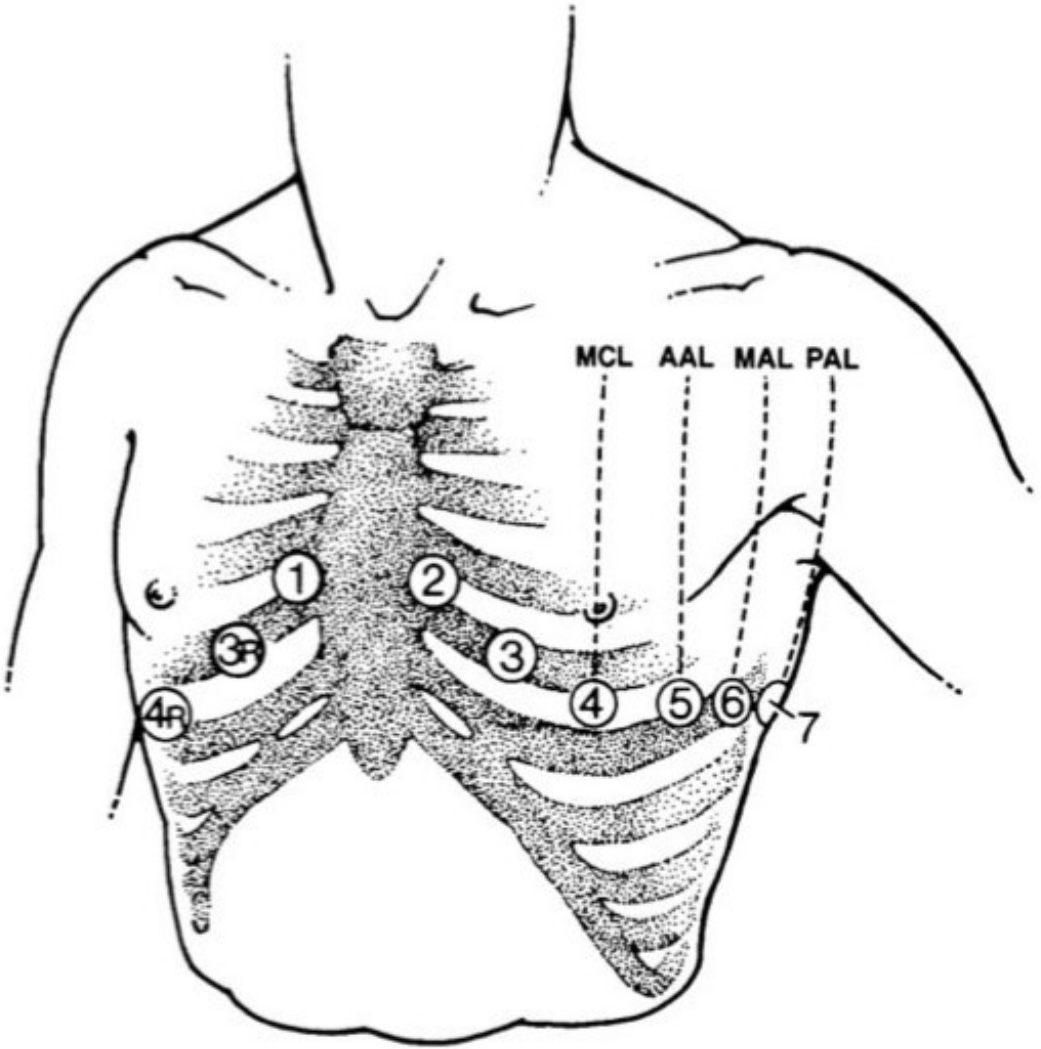
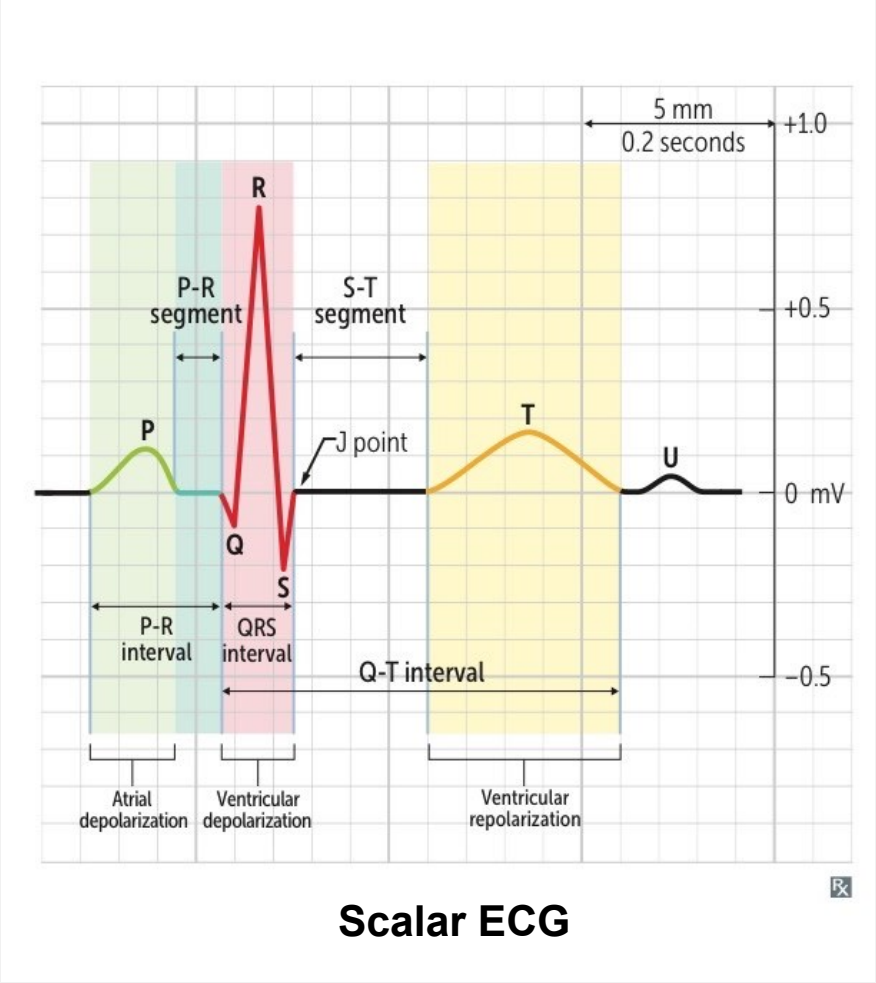


FIG 1-1.
Diagrammatic representation of a three-dimensional QRS vector loop (*solid unshaded*) on the frontal, horizontal, and sagittal planes. Frontal and horizontal planes are important in the understanding of the vectorial approach (modified from Nadas AN. *Pediatric Cardiology*, 2nd ed., Philadelphia: WB Saunders; 1964, with permission).


MCL
AAL
MAL
PAL
1
2
3
3R
4
4R
5
6
7


5 mm
0.2 seconds
+1.0
+0.5
0 mV
−0.5
R
P-R
segment
S-T
segment
P
J point
T
U
Q
S
P-R
interval
QRS
interval
Q-T interval
Atrial
depolarization
Ventricular
depolarization
Ventricular
repolarization

Scalar ECG

Reference system

Hexaxial reference system
- Lead I, II, III, aVR, aVL, aVF
- Provides the frontal projection of the electromotive forces

Horizontal reference system
- All precordial leads
- Provides the anteroposterior and the left-right relationship

Hexaxial reference system

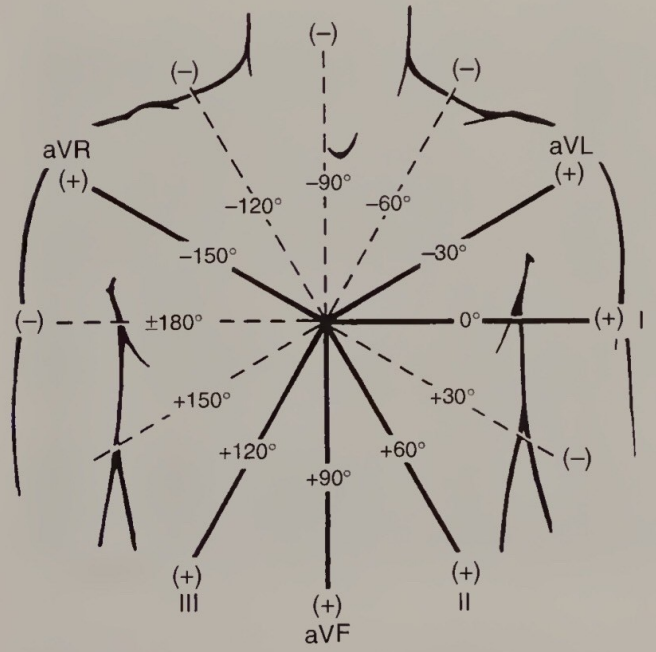


FIG 1-3.
Hexaxial reference system (viewed from the patient's front). Positive pole of each lead is indicated by (+) sign. The angle between two adjacent limb leads is 30 degrees.

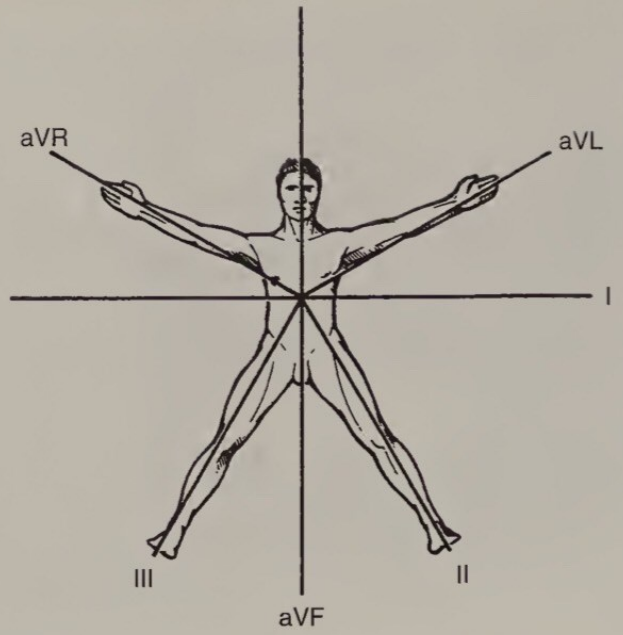
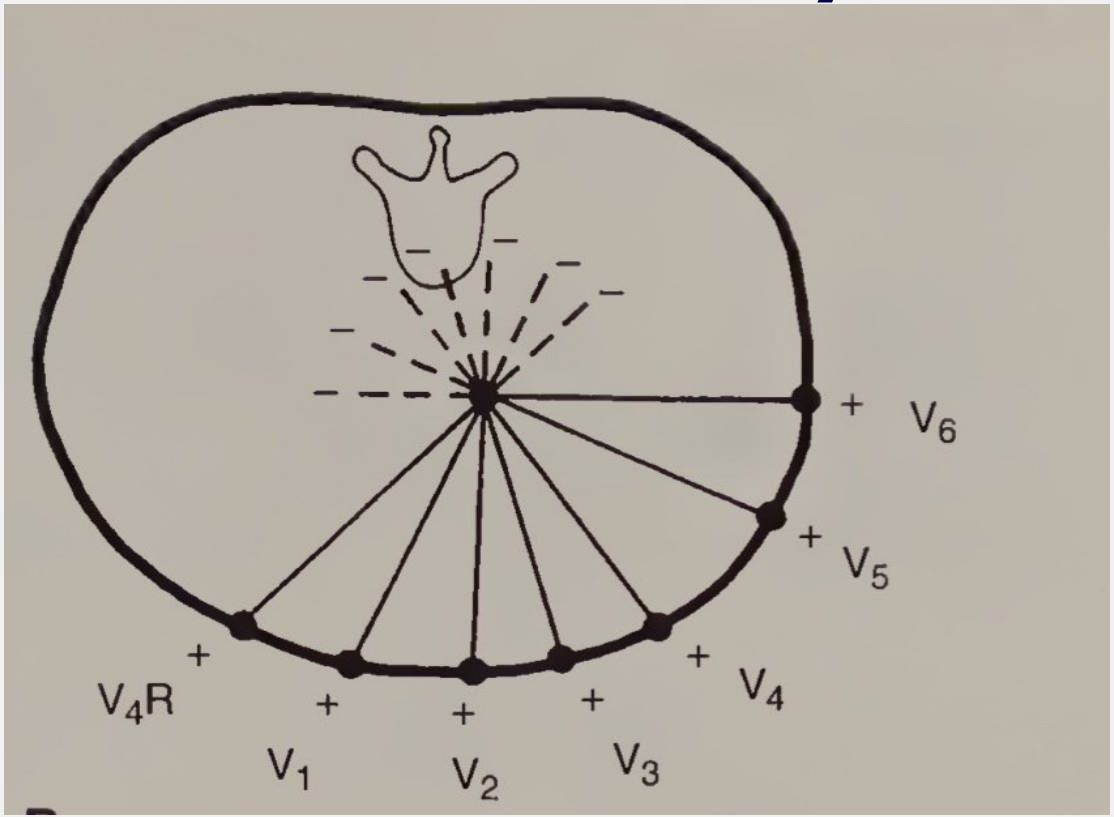


FIG 1-4.
Easy way to memorize the hexaxial reference system (see text).

Horizontal reference system

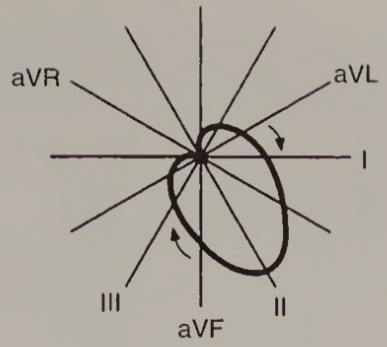


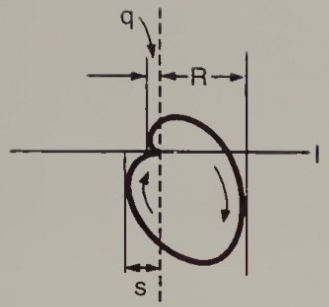
Left-Right

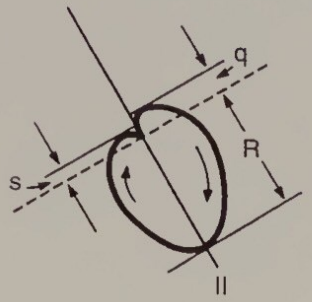
AP

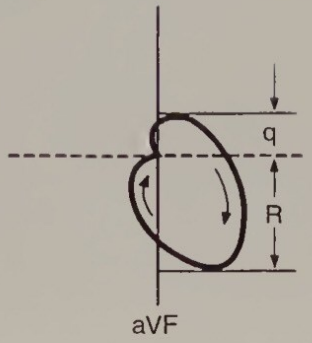
Correlation of the VCG and scalar ECG

- VCG and Scalar ECG are two different ways of looking at the same electrical activity in the heart
- When the depolarization current moves toward positive electrode, an upward deflection is recorded on ECG paper
- When the depolarization current moves away from the positive pole, a negative deflection is recorded.

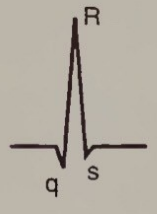

aVR
aVL
I
III
II
aVF


q
R
I
s

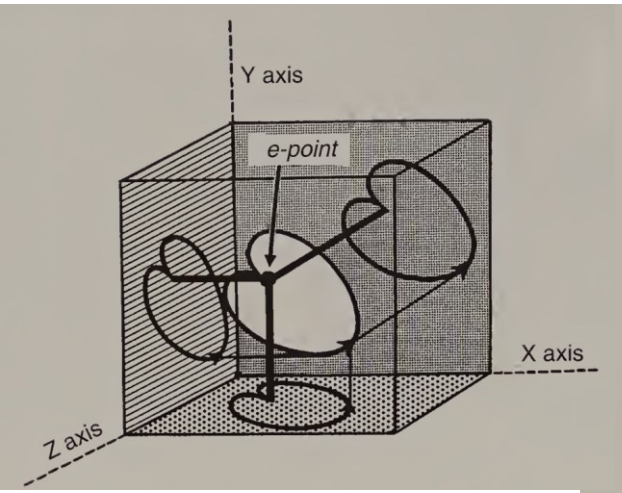

q
R
s
II


q
R
aVF

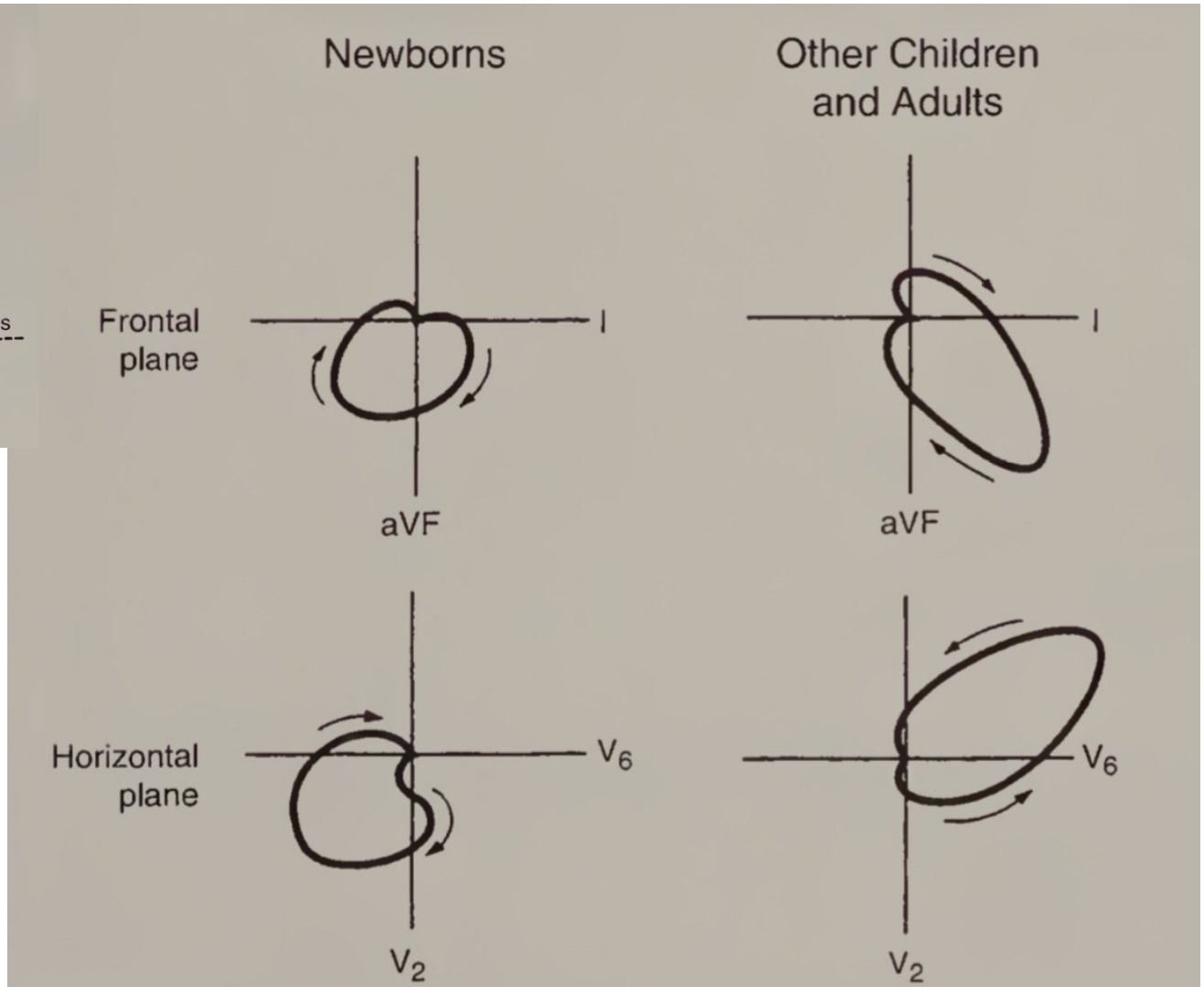

R
q
s
I


R
q
s
II


R
q
aVF



Normal newborn
In the frontal plane, the major QRS vector is to the subject's right and inferior



03

Basic measurements

Before routine measurements

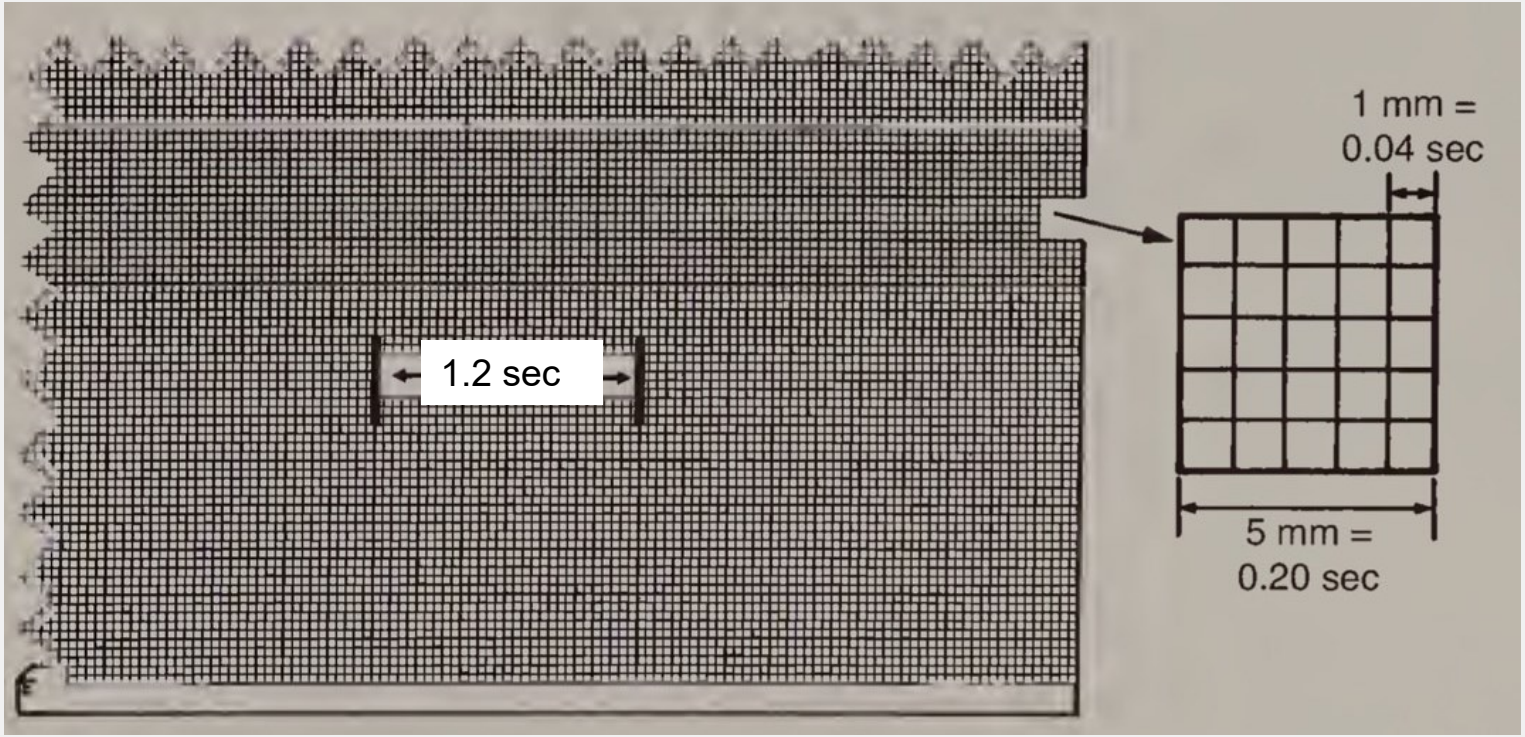
Standard!

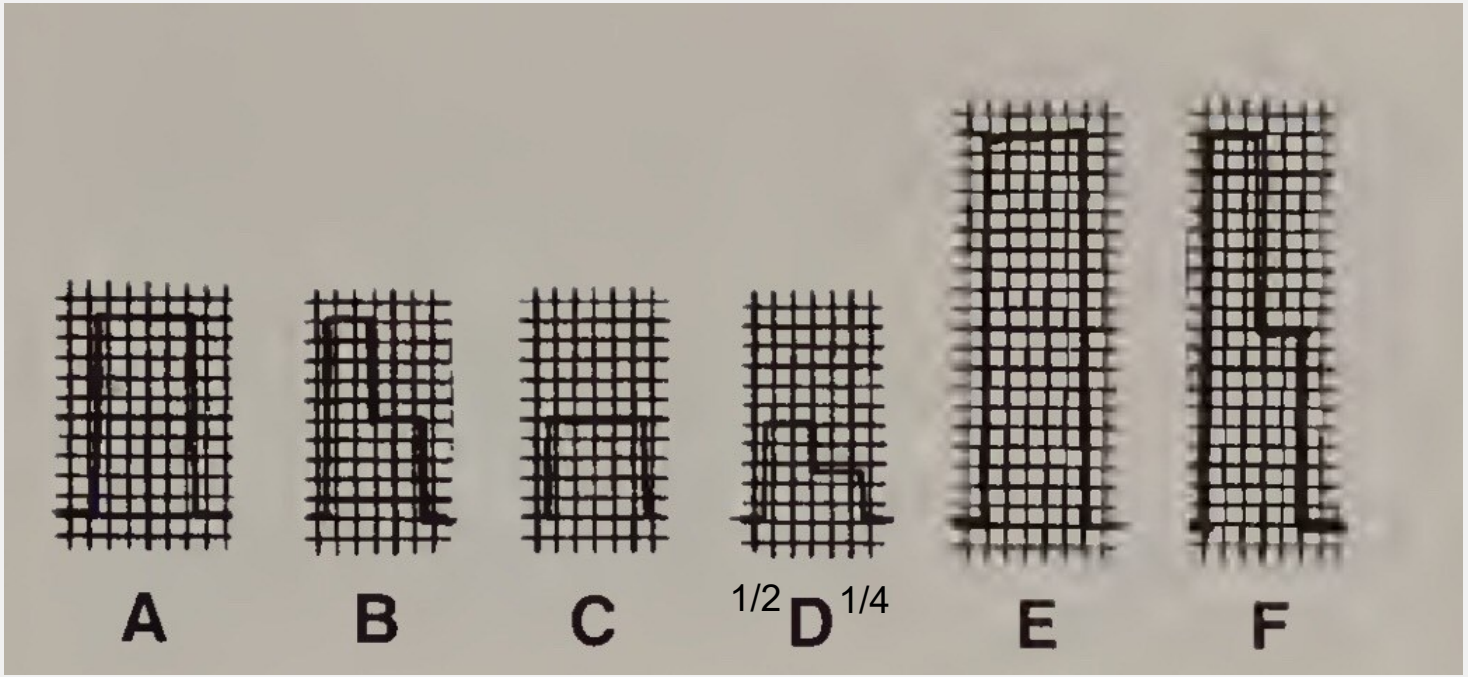
Recording speed of paper = 25 mm/sec

1 mm = 0.04 sec (one small box)
5 mm = 0.20 sec (one large box)
30 mm = 1.2 sec (six large divisions)

Amplitude 1 mV = 10 mm

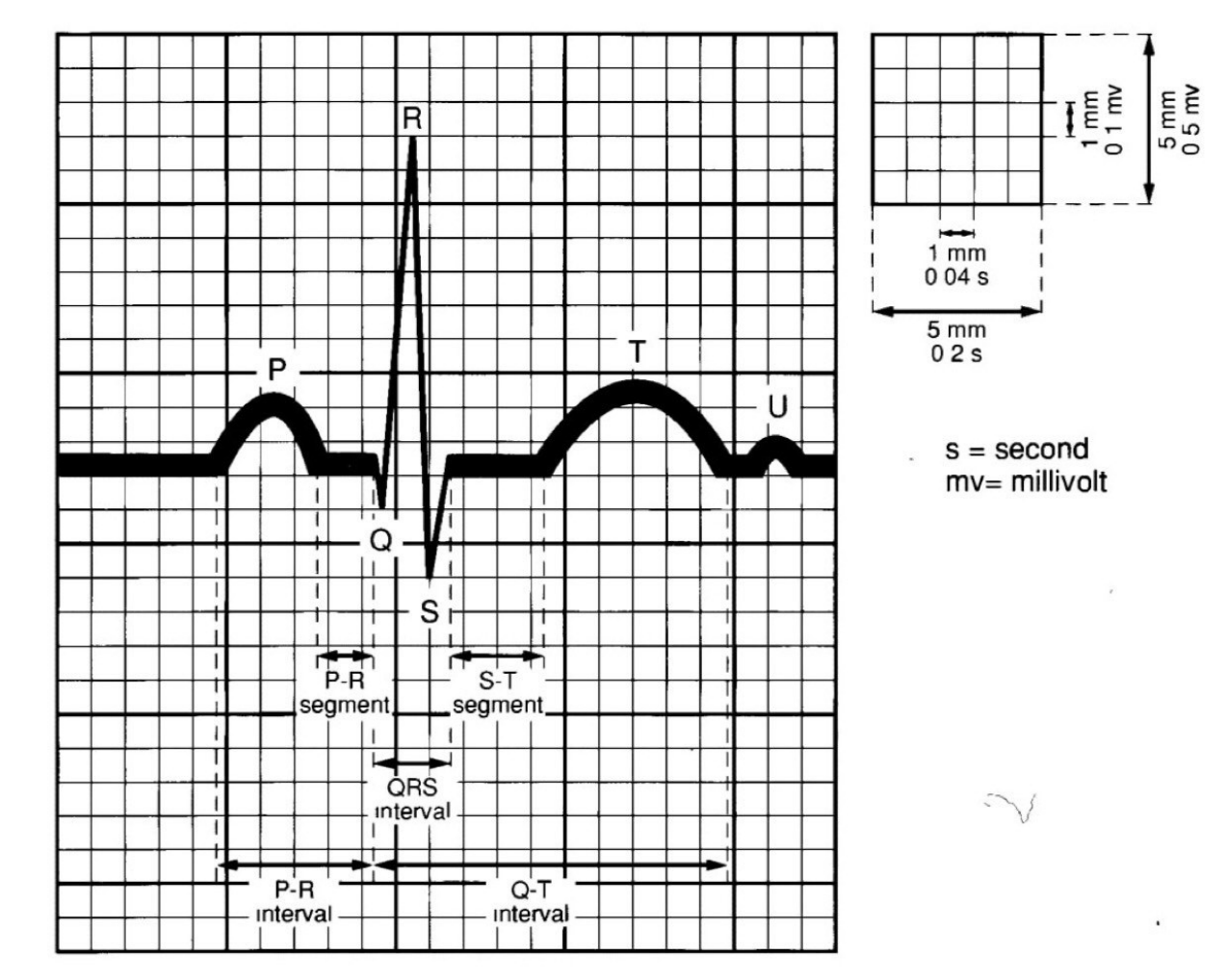
1 mV = 10 mm = ten small boxes


1 mm =
0.04 sec
1.2 sec
5 mm =
0.20 sec



1 mV = 20 mm

Components of ECG wave form



Basic measurements

Rhythm

Rate

Axis

P wave

PR interval

QRS axis

QRS interval

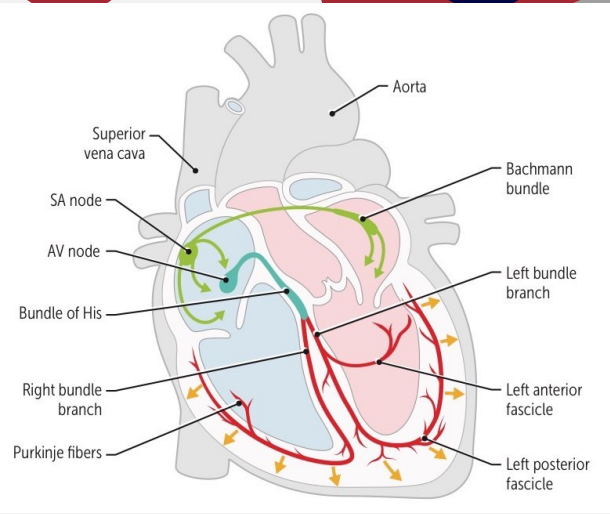
QTc interval

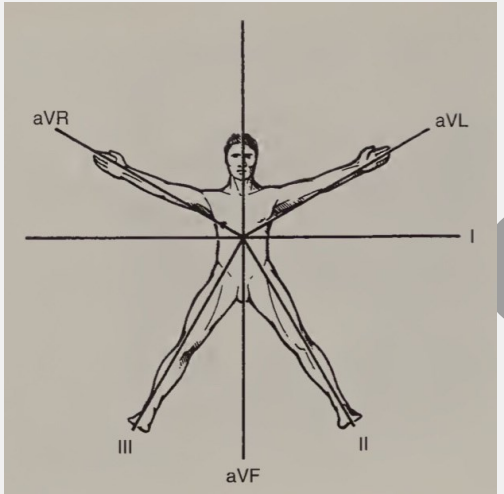
ST-T segment

Chamber enlargement and hypertrophy

Rhythm

- Sinus rhythm = ต้นกำเนิดมาจาก SA node
  - Upright P waves in leads I, II and aVF
- Normal sinus rhythm (NSR)
  - SA node เป็นต้นกำเนิดของกระแสไฟฟ้า
  - Normal and Monomorphic P wave
  - P wave นำหน้า QRS complex ทุกตัว
  - PR interval ปกติและคงที่
  - QRS complex ปกติทั้งรูปร่างและความกว้าง
  - Normal rate ตามอายุ





Rhythm

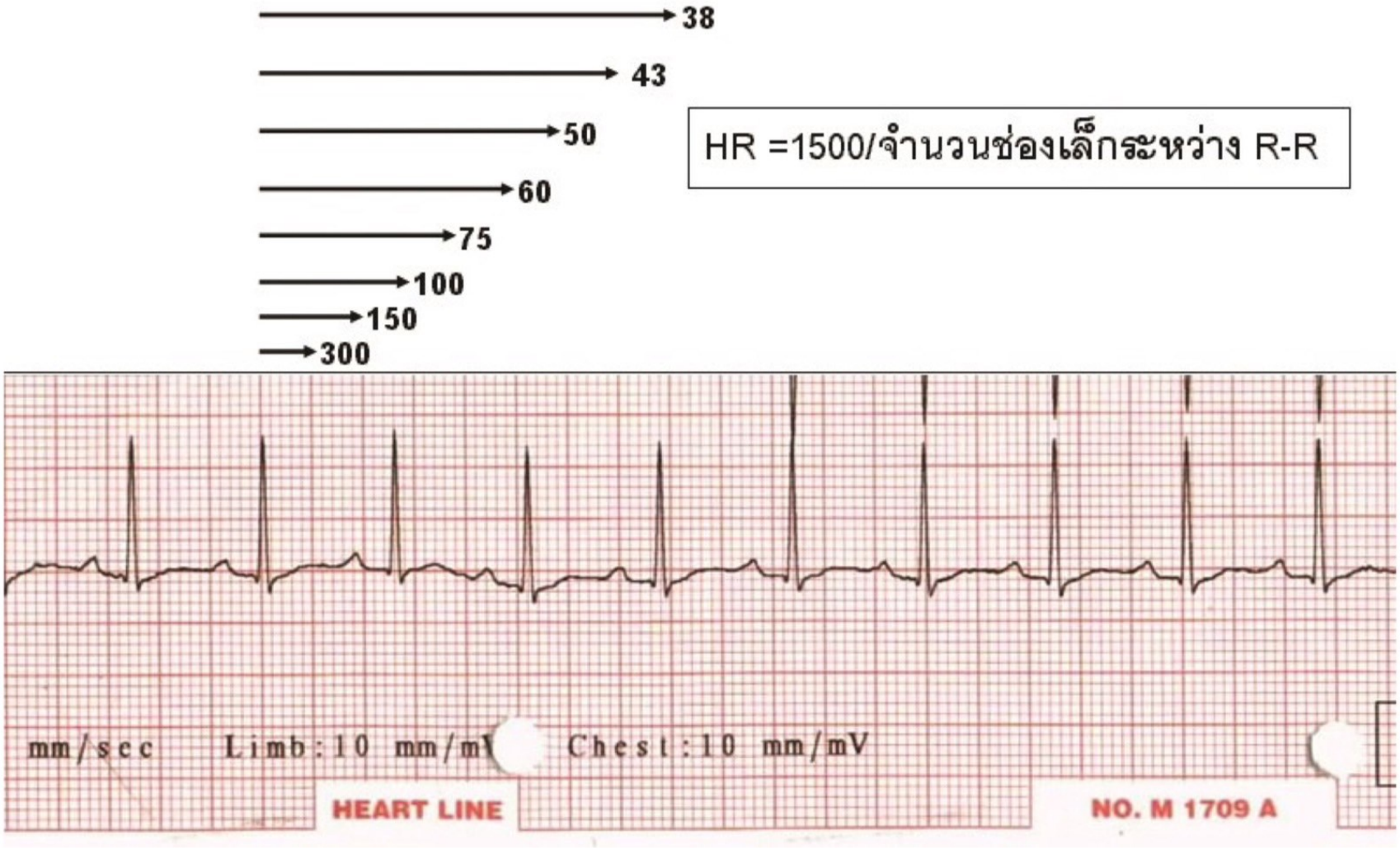
Sinus arrhythmia

- P-P interval ที่เปลี่ยนแปลงทำให้ R-R interval ไม่สม่ำเสมอ
- คุณลักษณะอื่นเป็นไปตาม NSR
- พบได้ปกติในเด็ก (Increased vagal tone)

Rate

$$\text{Rate} = \frac{\mathbf{1500}}{\boldsymbol{n}} = \frac{300}{N}$$

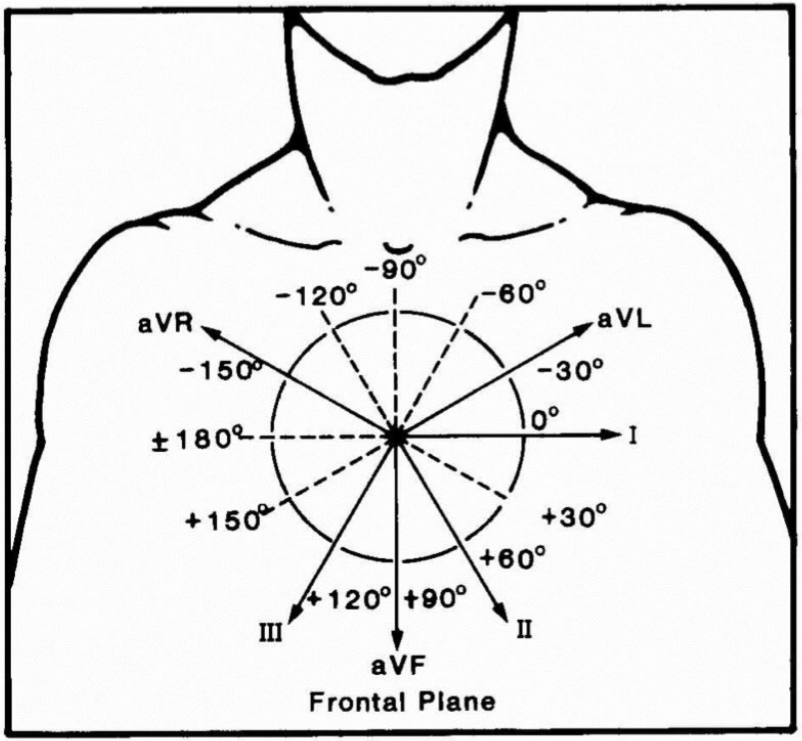
n = จำนวนช่องเล็กที่อยู่ระหว่าง R wave ของ beat ที่อยู่ติดกัน
N = จำนวนช่องใหญ่ที่อยู่ระหว่าง R wave ของ beat ที่อยู่ติดกัน


38
43
50
60
75
100
150
300
HR =1500/จำนวนช่องเล็กระหว่าง R-R
mm/sec
Limb:10 mm/mV
Chest:10 mm/mV
HEART LINE
NO. M 1709 A

Axis

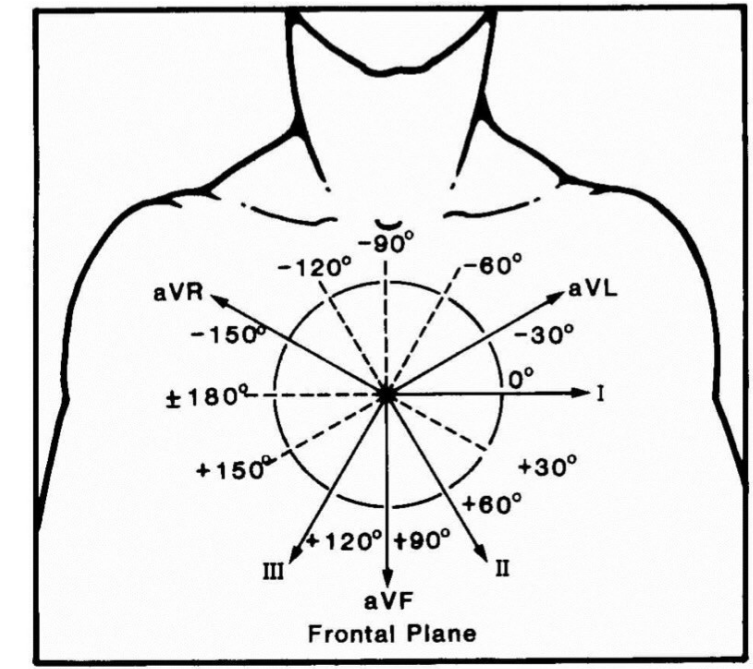
= Vector of frontal plane
Evaluation of P, QRS, and T axis

6 Limb leads



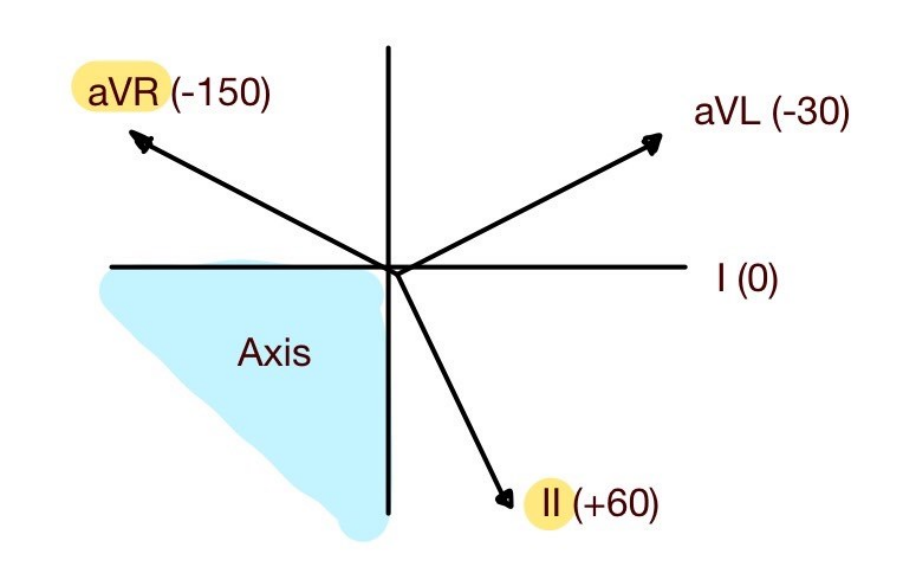
Step 1

กำหนดว่า **axis** อยู่ใน **Quadrant** ใดอย่างหยาบๆพิจารณาที่ **Lead I** และ **aVF**
รวม **Vector** ของ **QRS complex** โดยค่าที่อยู่เหนือ **Isoelectric line** เป็นบวก อยู่ใต้ **Isoelectric line** มีค่าเป็นลบ



Step 2: Fine tuning

หลักการคือ Axis จะตั้งฉากกับ Lead ที่เป็น isoelectric (magnitude ของ wave QRS รวมกันเป็น 0) จึงต้องมองหา Lead ที่เป็น isoelectric ที่อยู่ใน Quadrant ที่ตั้งฉากกับ Axis ใน Step 1



ตัวอย่าง

หาก Axis ตกอยู่ช่วง +90 ถึง +180 องศา มองหา Lead ที่มีโอกาสเป็น Isoelectric คือ aVR และ II

- หาก aVR เป็น isoelectric

Axis จะตั้งฉากกับ aVR = +120

- หาก II เป็น isoelectric

Axis จะตั้งฉากกับ II = +150

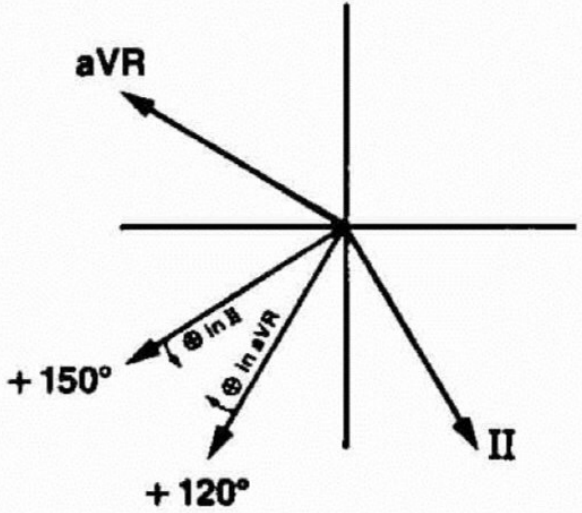
Step 2: Fine tuning

- หากทั้ง aVR และ II ไม่เป็น isoelectric ทั้งคู่ ให้คิดผลรวมของ Magnitude
- หากเป็นค่าบวก Axis จะเขยิบเข้าหา Lead นั้นจากตำแหน่งที่ตั้งฉากกัน ตรงกันข้าม หากค่าเป็นลบ Axis จะเขยิบไปไกลกว่า Lead นั้นจากตำแหน่งที่ตั้งฉากกัน
- นำตำแหน่งที่เป็นไปได้มาคิดค่าเฉลี่ยตรงกลาง จะเท่ากับค่าของ Axis

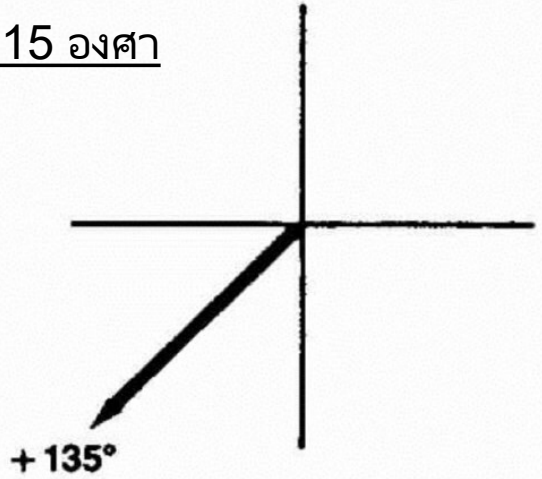
ตัวอย่าง

a. II slightly positive (Q (−2mm) + R (+8mm) + S (−4mm) = +2mm)
∴ slightly towards II from +150°

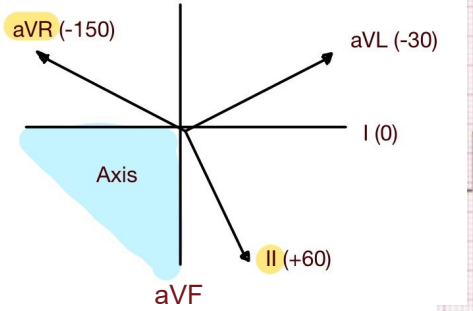
b. aVR slightly positive (R (+1mm) + S (−4mm) + R' (+6mm) = +3mm)
∴ slightly towards aVR from + 120°



อ่านละเอียดถึงระดับ 15 องศา

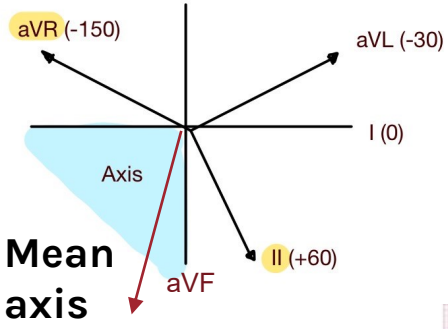


4. Conclusion = Mean vector between +120° and +150° = +135°



ลบ

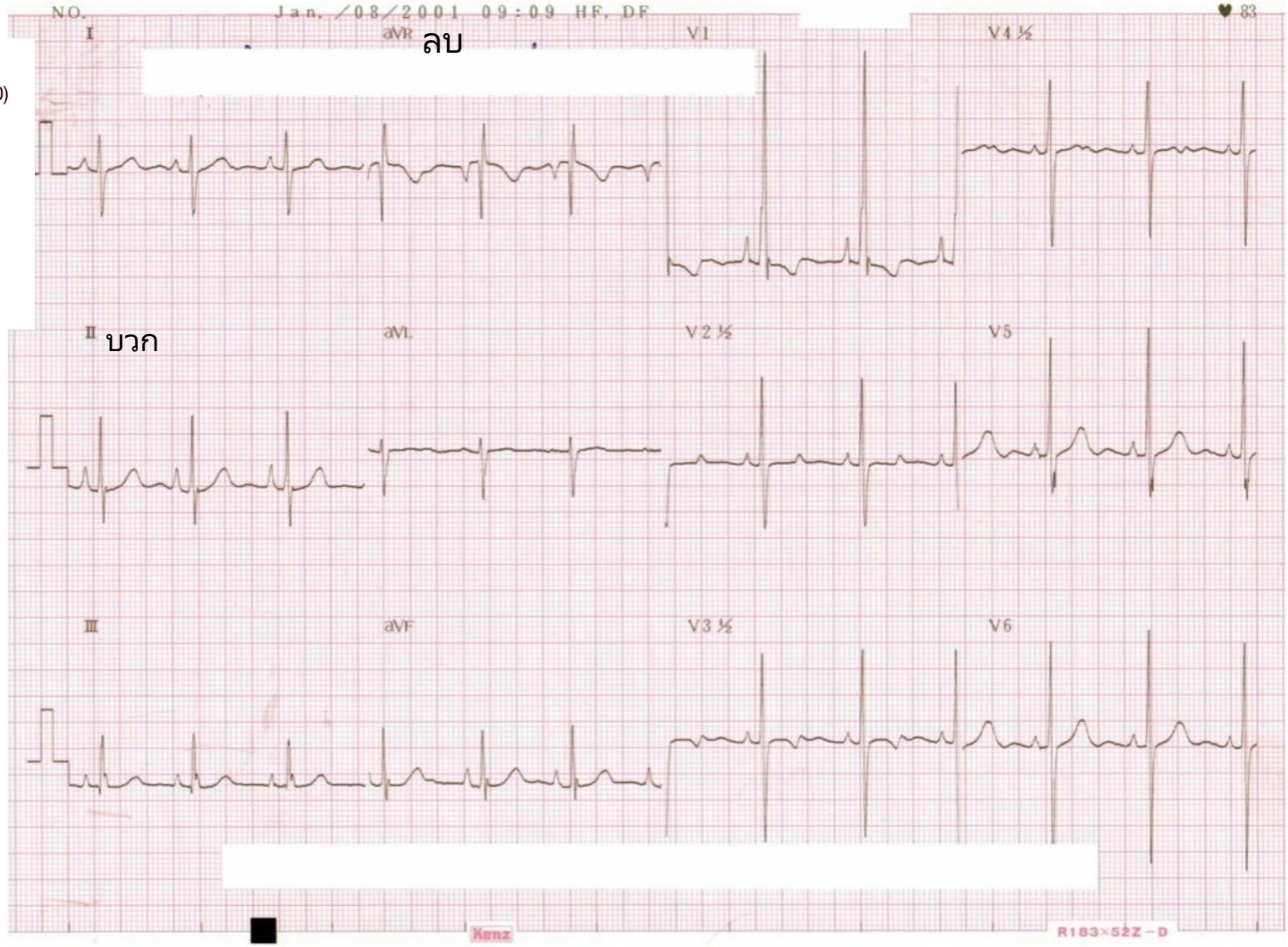
บวก



Lead II เป็นบวก
Axis อยู่ช่วง +150 ถึง + 90

Lead aVR เป็นลบ
Axis อยู่ช่วง +120 ถึง +90

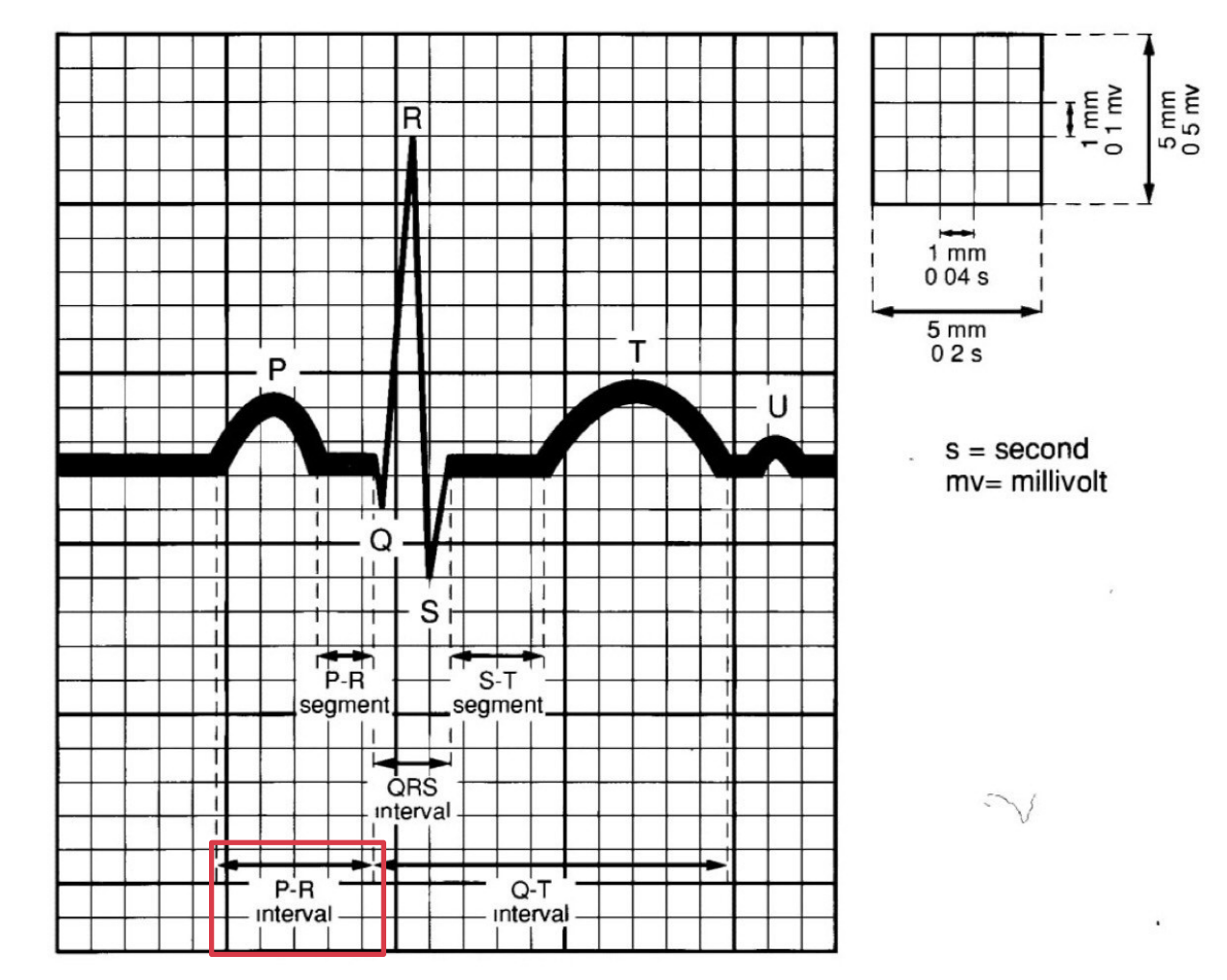
เพราะฉะนั้น
Mean vector axis
= (+120 + 90)/2
= +105 องศา



P wave

- P wave axis = Vector ที่ชี้ทิศทางของการกระตุ้นไฟฟ้าจากจุดกำเนิด
- Sinus rhythm ต้องมีจุดกำเนิดมาจาก Right Atrium ส่วนบน-> P axis 0 ถึง +90 องศา
- P wave axis abnormal = Ectopic foci

PR interval


R
P
T
U
Q
S
P-R segment
S-T segment
QRS interval
P-R interval
Q-T interval
1 mm 0 1 mv
5 mm 0 5 mv
1 mm 0 04 s
5 mm 0 2 s
s = second
mv= millivolt

PR interval

- จุดเริ่มต้น P wave ถึง เริ่มต้น Q wave/R wave (No Q wave)
- มักเลือกวัดที่ Lead II

Prolonged PR interval:
> 160 msec

- 1st degree AV block
- Complete AVSD
- Ebstein's anomaly
- Rheumatic fever
- Digitalis effects

Short PR interval: PR interval ≤ 100 msec

- Preexcitation syndrome (WPW)
- Glycogen storage disease:

Increased AV nodal size and conduction

QRS axis

Normal axis = อยู่ระหว่าง 0 องศาถึงค่าปกติที่ขึ้นกับอายุ

Right axis deviation:
> 98th percentile สำหรับค่าปกติตามช่วงอายุ

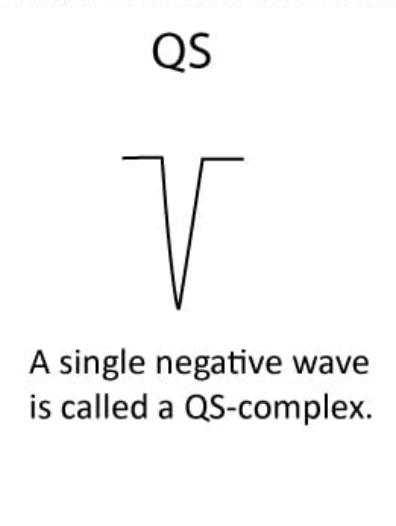
Left axis deviation = 0 ถึง -90 องศาพบใน

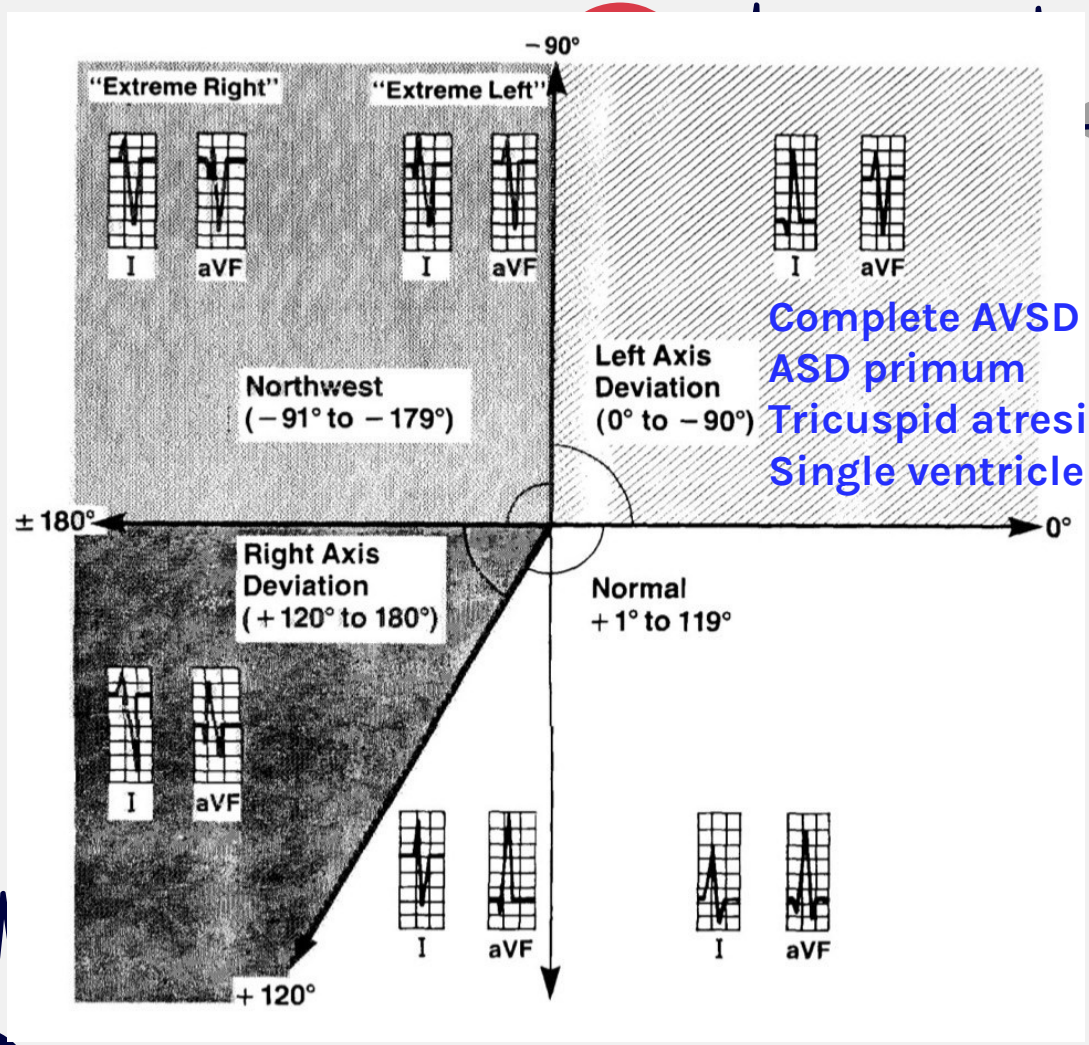
- **Complete AVSD**
- **ASD primum**
- **Tricuspid atresia**
- **Single ventricle**

QRS axis

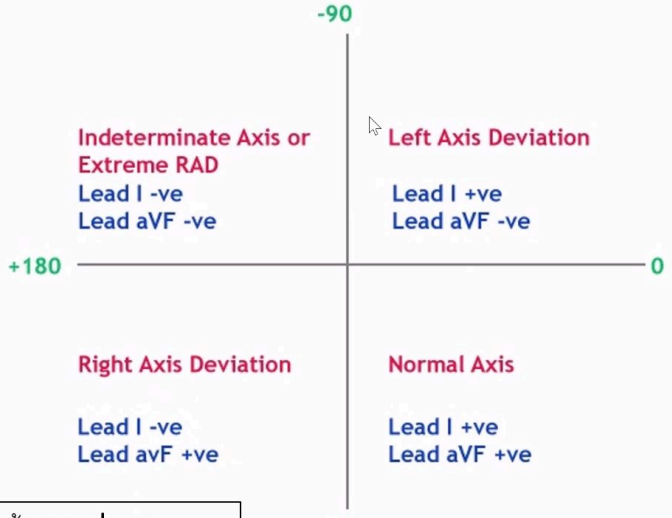
Northwest axis = ระหว่าง -90 องศา ถึง -180 องศา

- Q wave in lead I or aVL = **extreme left axis deviation**
- Q wave or QS pattern in lead II, III or aVF = **extreme right axis deviation**



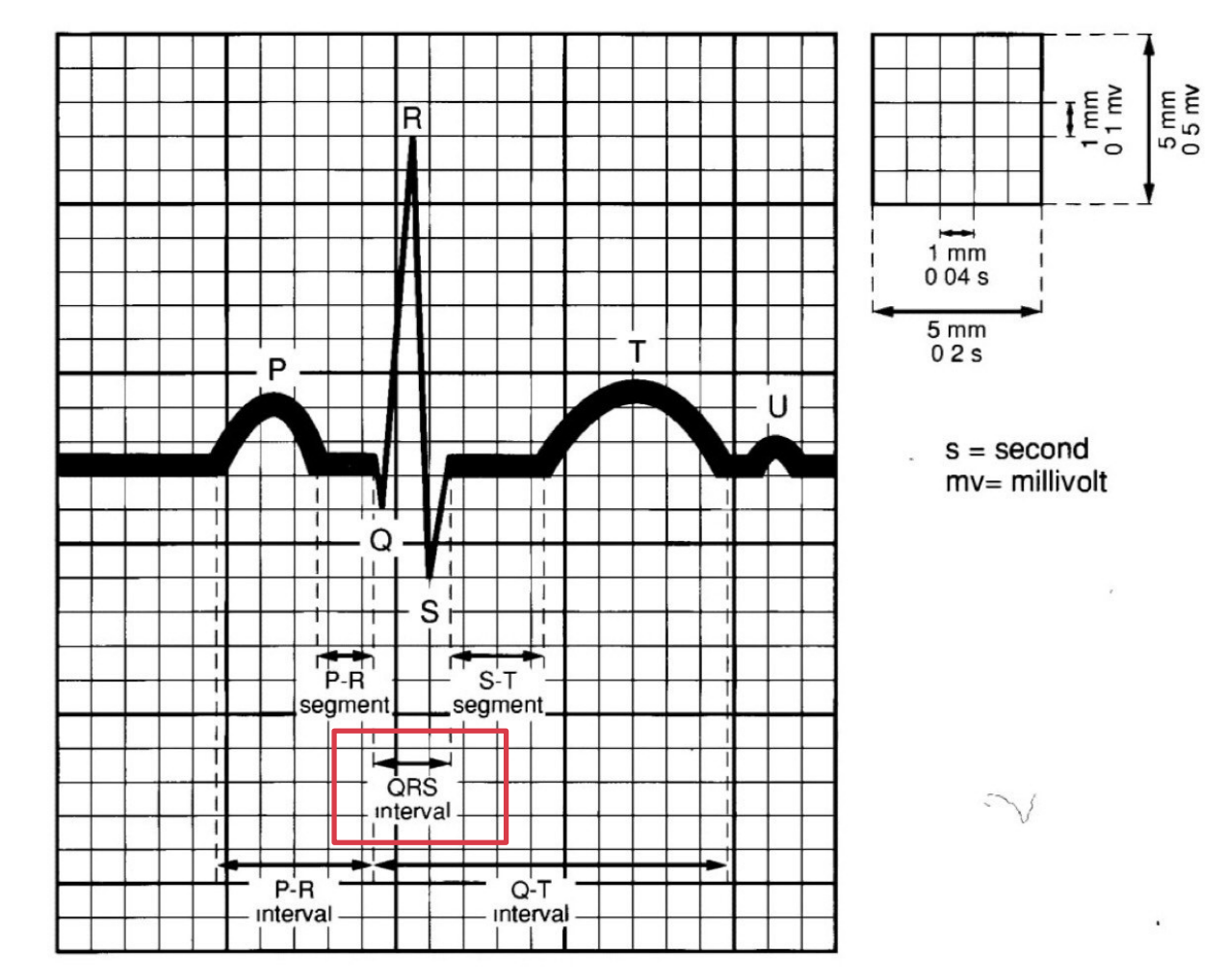

−90°
"Extreme Right"
"Extreme Left"
I
aVF
I
aVF
I
aVF
Northwest
(−91° to −179°)
Left Axis
Deviation
(0° to −90°)
Complete AVSD
ASD primum
Tricuspid atresia
Single ventricle
±180°
0°
Right Axis
Deviation
(+120° to 180°)
Normal
+1° to 119°
I
aVF
I
aVF
I
aVF
+120°

EKG interpret(4)



ยกเว้น newborn
Quadrant นี้ ถือว่า normal

QRS complex

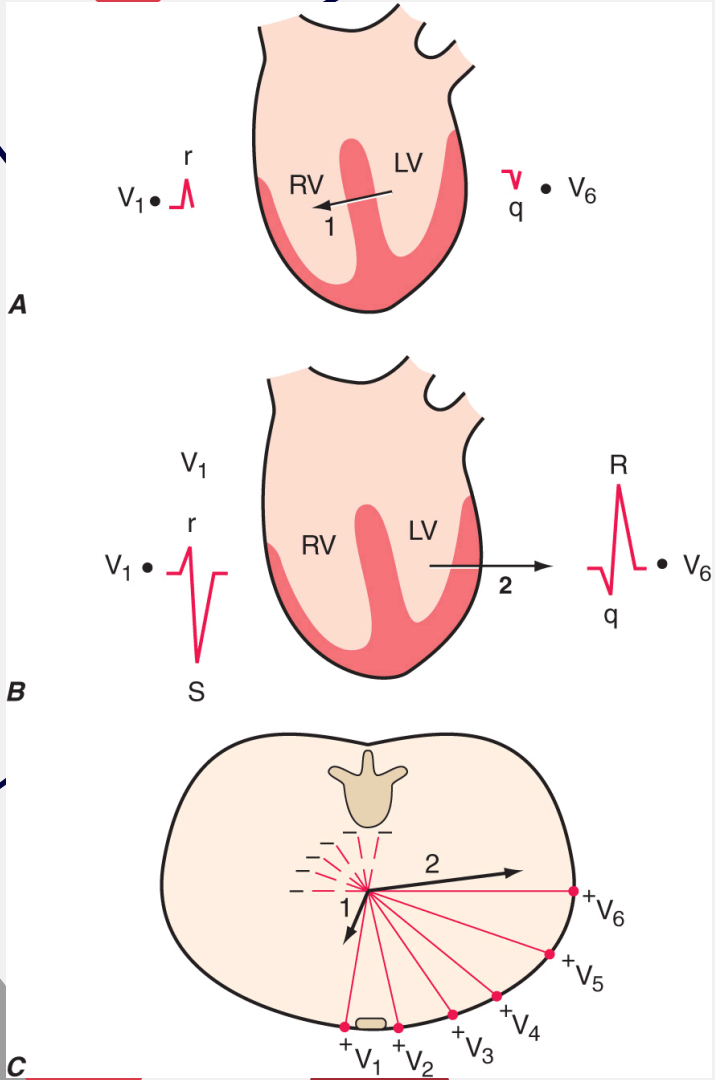

R
P
T
U
Q
S
P-R segment
S-T segment
QRS interval
P-R interval
Q-T interval
1 mm 0 1 mv
5 mm 0 5 mv
1 mm 0 04 s
5 mm 0 2 s
s = second
mv= millivolt

QRS complex

- ควรเลือกวัดใน lead ที่มี initial Q wave
- ทิศทางของ Q wave ใน precordial lead บ่งบอกทิศทางของ septal depolarization; ปกติควรมีใน lead V5 – V6

Abnormal Q wave

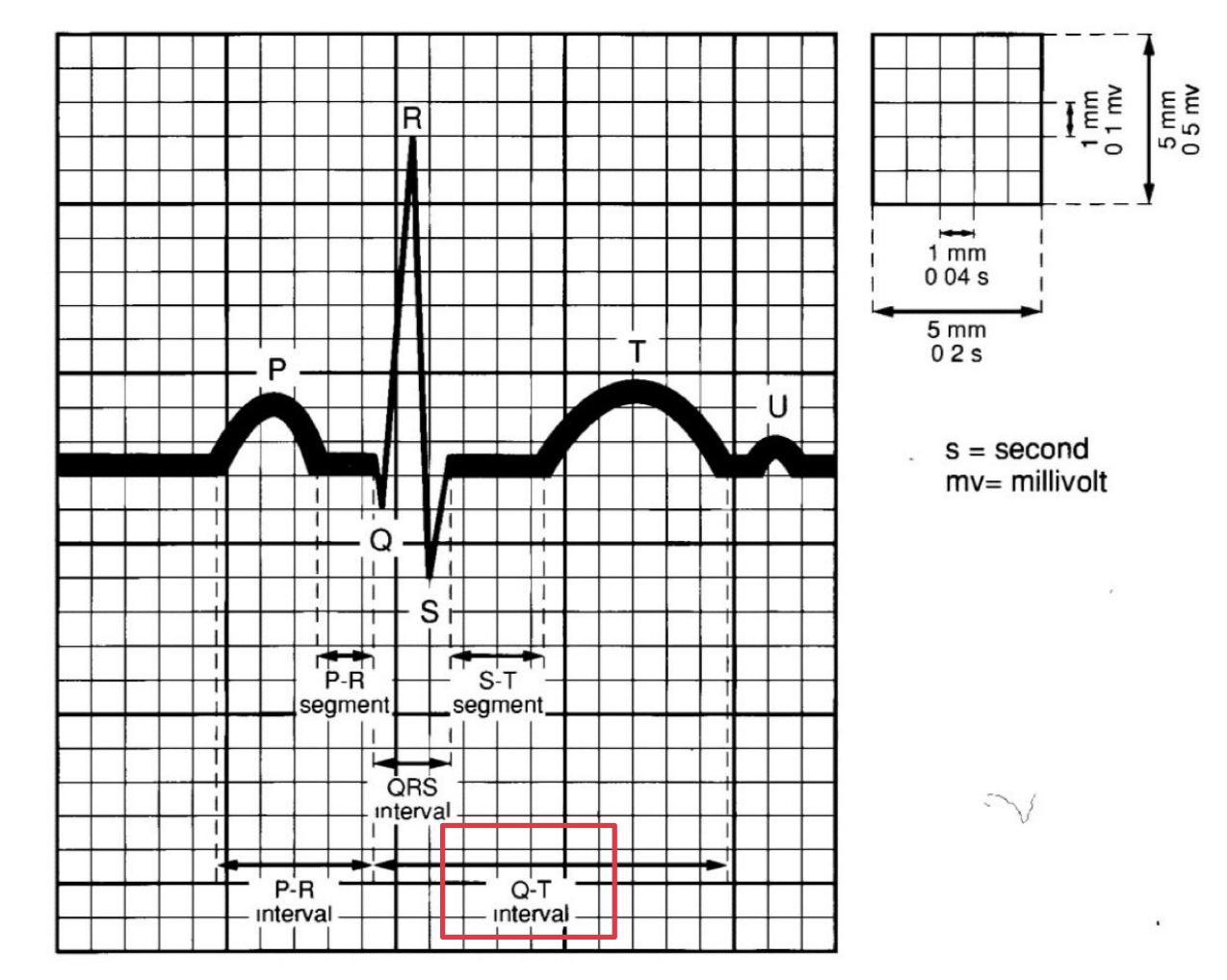
- **Pathologic Q wave** = กว้างเกิน 30 msec หรือ ลึกเกิน 4 mm (Myocardial infarction)
- **Low voltage QRS** = R+S wave < 5 mm in limb leads or R+S < 8 mm in chest leads (Myocardial edema)
- **Wide QRS** = > 2.5 mm



- The first phase is depolarization of the interventricular septum from the left to the right and anteriorly (vector 1).
- The second results from the simultaneous depolarization of the right and left ventricles; it normally is dominated by the more massive left ventricle, so that vector 2 points leftward and posteriorly.

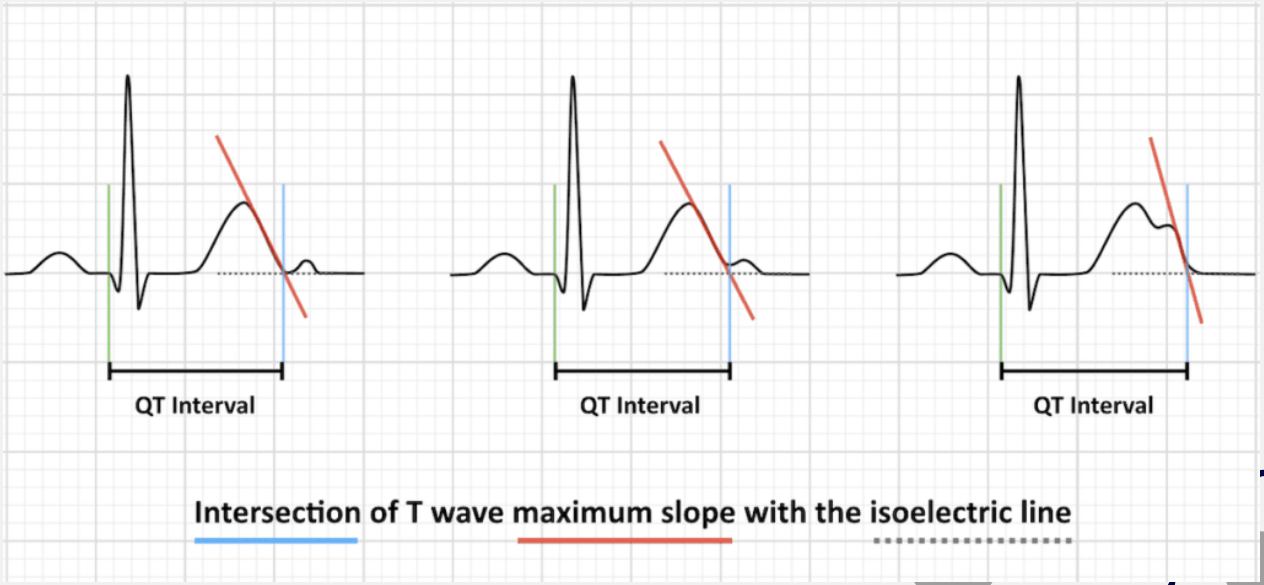
https://thoracickey.com/electrocardiography-5/

QRS complex


R
P
T
U
Q
S
P-R segment
S-T segment
QRS interval
P-R interval
Q-T interval
1 mm 0 1 mv
5 mm 0 5 mv
1 mm 0 04 s
5 mm 0 2 s
s = second
mv= millivolt

QT interval

- เริ่มต้น QRS complex ไปจนสิ้นสุด T wave
- ควรวัดที่ Lead II, V5 และ V6 โดยเลือกอ่านค่าที่ยาวที่สุด



https://litfl.com/qt-interval-ecg-library/

Corrected QT interval (QTc)

- **Corrected with heart rate**
- **Bazett formula**

$$\text{QTc} = \frac{QT\ (sec)}{\sqrt{RR}(sec)}$$

Age < 6 months old: < 450 msec

Age > 6 months old: < 440 msec

Corrected QT interval (QTc)

Long QTc: Risk for VT/VF

- Hypocalcemia
- Hypokalemia
- Hypomagnesemia
- Amiodarone effects
- Macrolide/ Trimethoprim
- Infant of autoimmune mother, Anti-Ro antibodies positive

Short QTc

- Hypercalcemia
- Hypermagnesemia
- Digitalis effects

Chamber enlargement and hypertrophy

RVH

- QR pattern in right chest lead
- T wave change
- R wave amplitude in V1
- S wave amplitude in V6
- R/S ratio in V1
- RSR’ in V1
- RAD

LVH

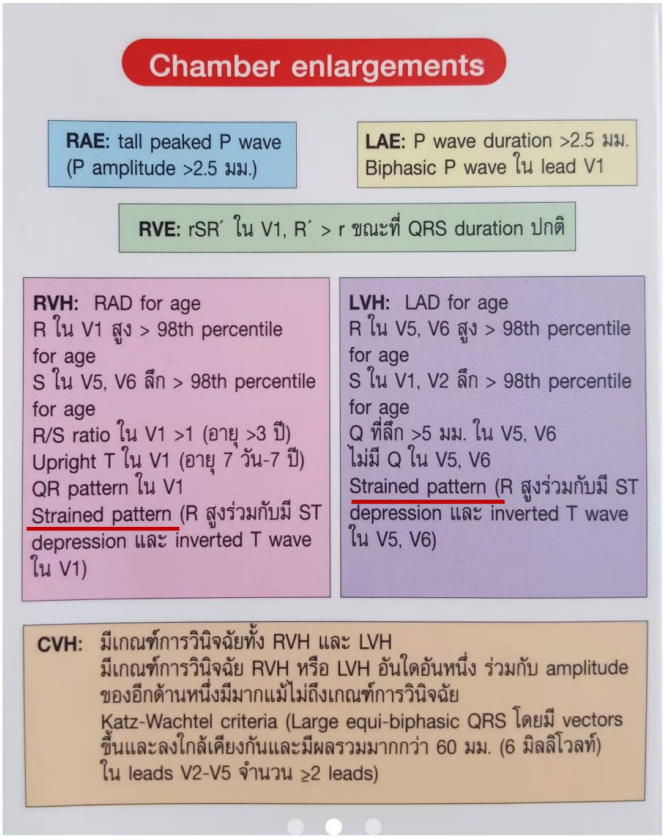
- T wave change
- R wave amplitude in V6 or S wave amplitude in V1
- Amplitude of R wave in V6 + Amplitude of S wave in V1
- Q wave abnomalities

Biventricular hypertrophy

- Abnormal voltage in both the right and left chest leads
- Katz-Wachtel criterion

เรียงลำดับความ
significant
ของ RVH criteria
ที่สำคัญ

1. RV strain
2. Upright T in V1
3. QR pattern in V1

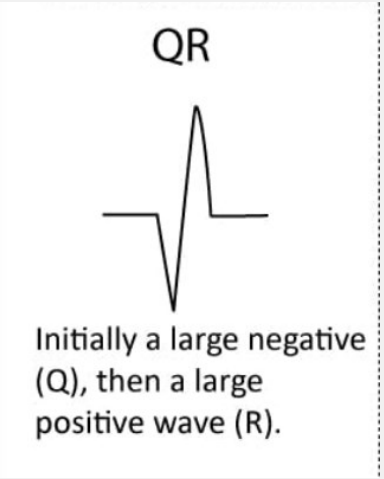


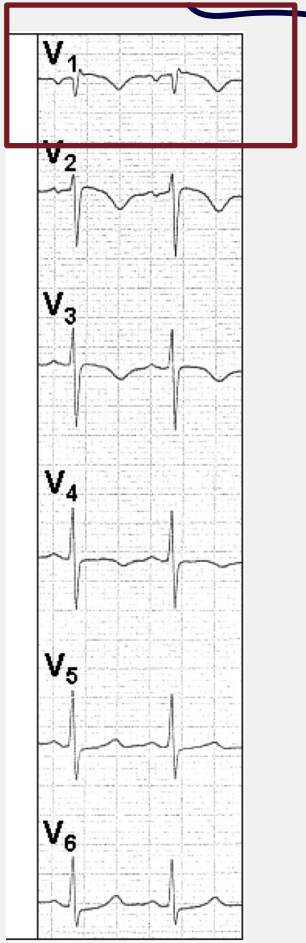
เรียงลำดับความ
significant
ของ LVH criteria
ที่สำคัญ

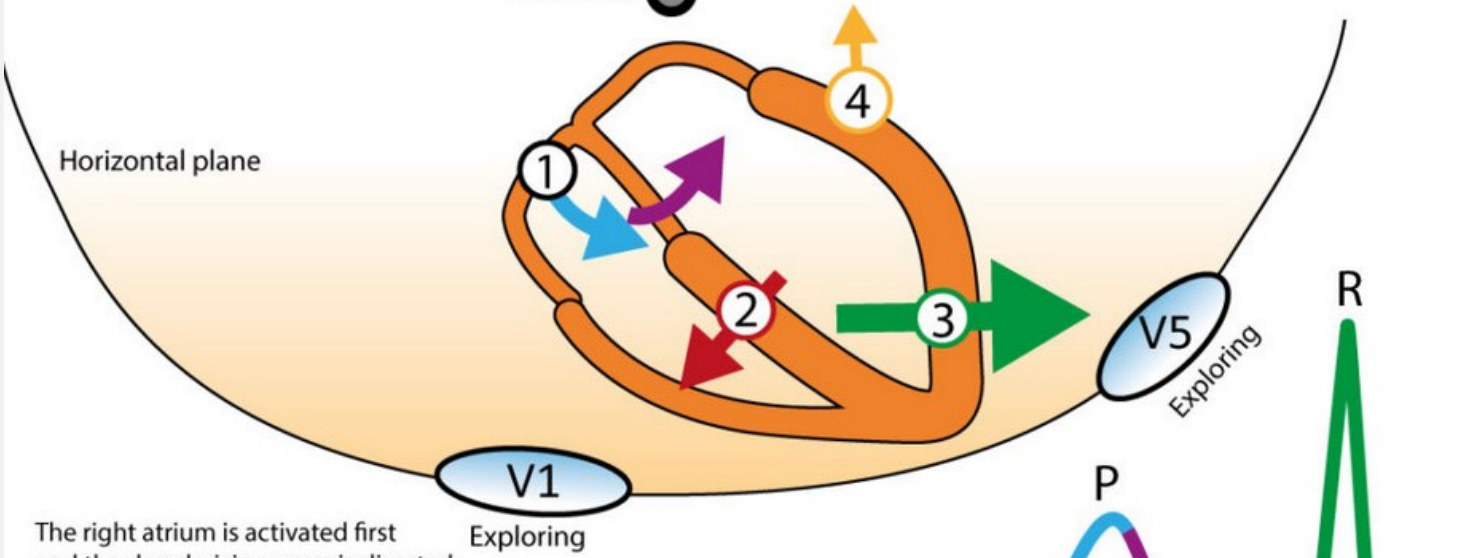
1. LV strain
2. Deep Q in V5,V6
3. Absent Q in V5,V6

QR pattern in the right chest leads (RVH)

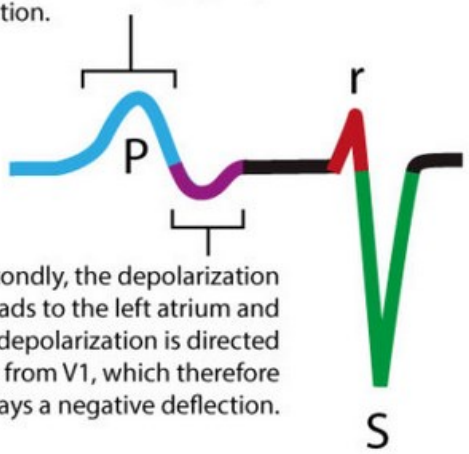
QR pattern:
- Most reliable sign of RVH
- Systolic pressure of right ventricle > 70 mmHg







The right atrium is activated first and the depolarizing wave is directed towards V1, which displays a positive deflection.



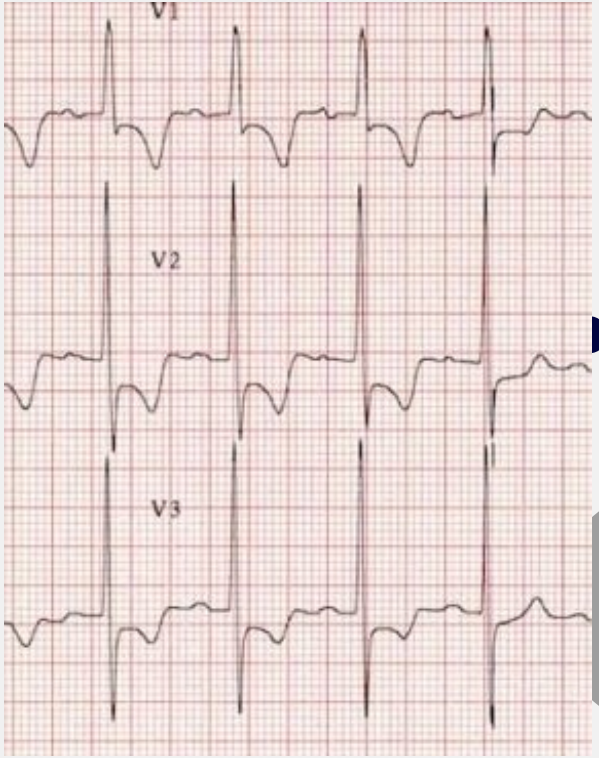
Secondly, the depolarization spreads to the left atrium and the depolarization is directed away from V1, which therefore displays a negative deflection.

Note the successive transition of the QRS-komplex from V1 to V6.

T wave changes (RVH)

Normal T wave in V1-3
- Upright in age < 7 days
- Inverted T in age > 7 days to adolescent

RVH: ความดันหัวใจห้องล่างขวาสูงขึ้น
- Upright T in V1 (ต้องไม่มี LV strain หรือ inverted T in V5-6)
- Tall R with asymmetrically inverted T in V1-4 (Right ventricular strain)
  = ความดันในหัวใจล่างขวาเท่ากับหรือสูงกว่าความดันเลือด
- Invert T in aVF



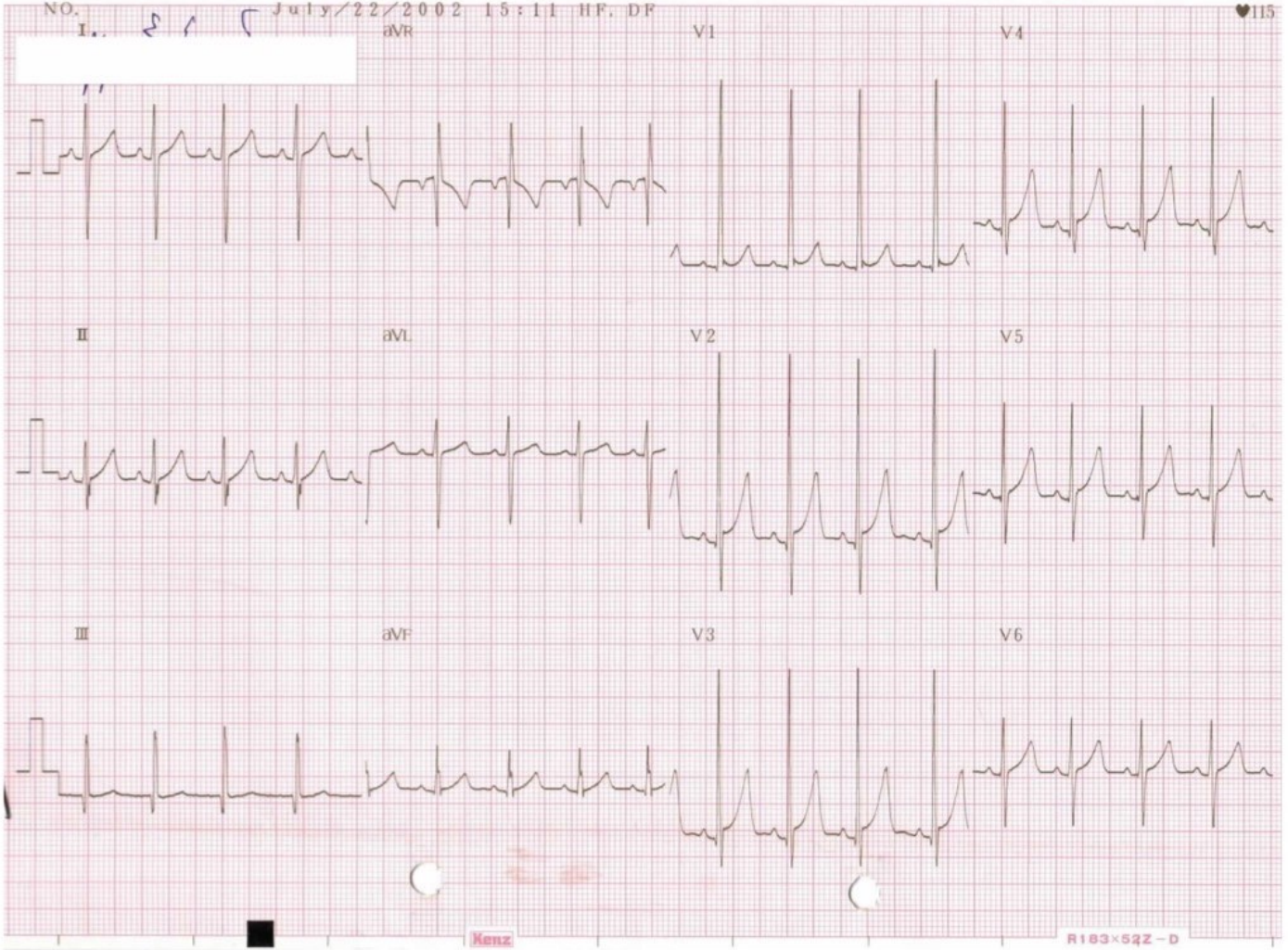
RV strain pattern

R wave amplitude in lead V1 (RVH)

Amplitude of R wave in V1 > 98th percentile
(High specificity, low sensitivity)
If amplitude > 20 mm = ความดันในหัวใจห้องล่างขวาสูงเท่ากับ หรือ มากกว่าความดันเลือด

S wave amplitude in lead V6 (RVH)

Deep amplitude of S wave in V6 > 98th percentile



Right axis deviation
Upright T V1
R in V1 34 mm
Deep S in V6

RVH

R/S ratio >1 in lead V1	ไม่ค่อยแม่นยำ ต้องอาศัยเกณฑ์ประกอบอื่นๆ
rSR’ in V1 (normal QRS duration)	With low S wave and tall R’ (> 15 mm if age < 1 year, > 10 mm if age > 1 year) Mild RVH แต่พบในเด็กปกติได้ถึง 7% และใน incomplete RBBB
Right axis deviation	ใช้สนับสนุนการวินิจฉัย RVH

Chamber enlargement and hypertrophy

RVH

- QR pattern in right chest lead
- T wave change
- R wave amplitude in V1
- S wave amplitude in V6
- R/S ratio in V1
- RSR’ in V1
- RAD

LVH

- T wave change
- R wave amplitude in V6 or S wave amplitude in V1
- Amplitude of R wave in V6 + Amplitude of S wave in V1
- Q wave abnomalities

Biventricular hypertrophy

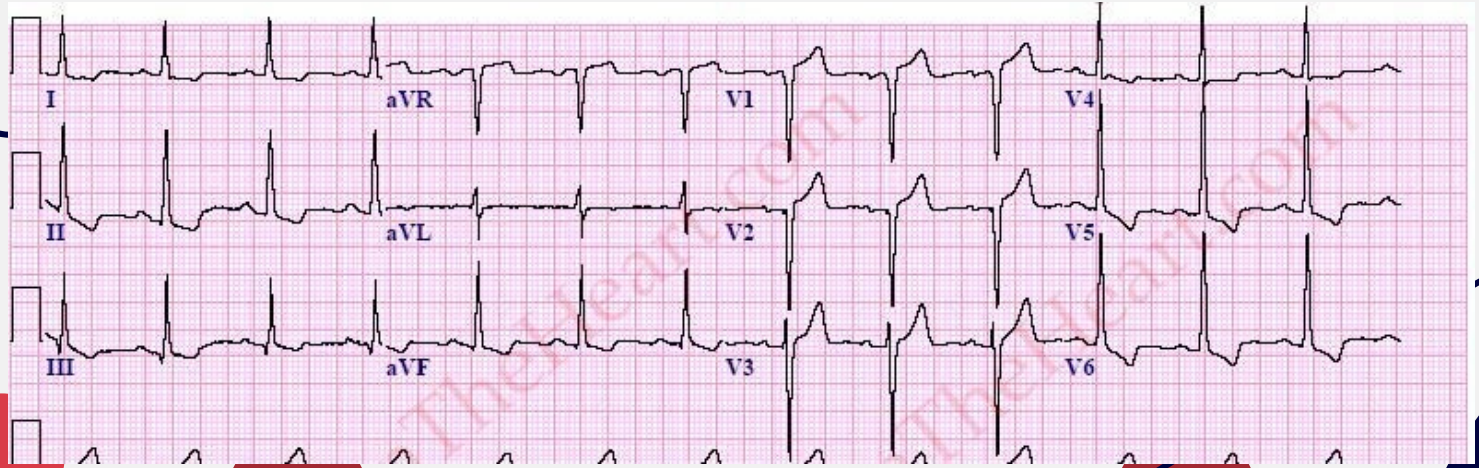
- Abnormal voltage in both the right and left chest leads
- Katz-Wachtel criterion

T wave changes (LVH)

Normal T wave in V5-6
- Upright T

LVH
- Asymmetrically inverted T in V5-6 (LV strain pattern)

(Most reliable sign of LVH)
- Inverted T in aVF
- Inverted T in inferior/Lateral lead without evidence of ischemia



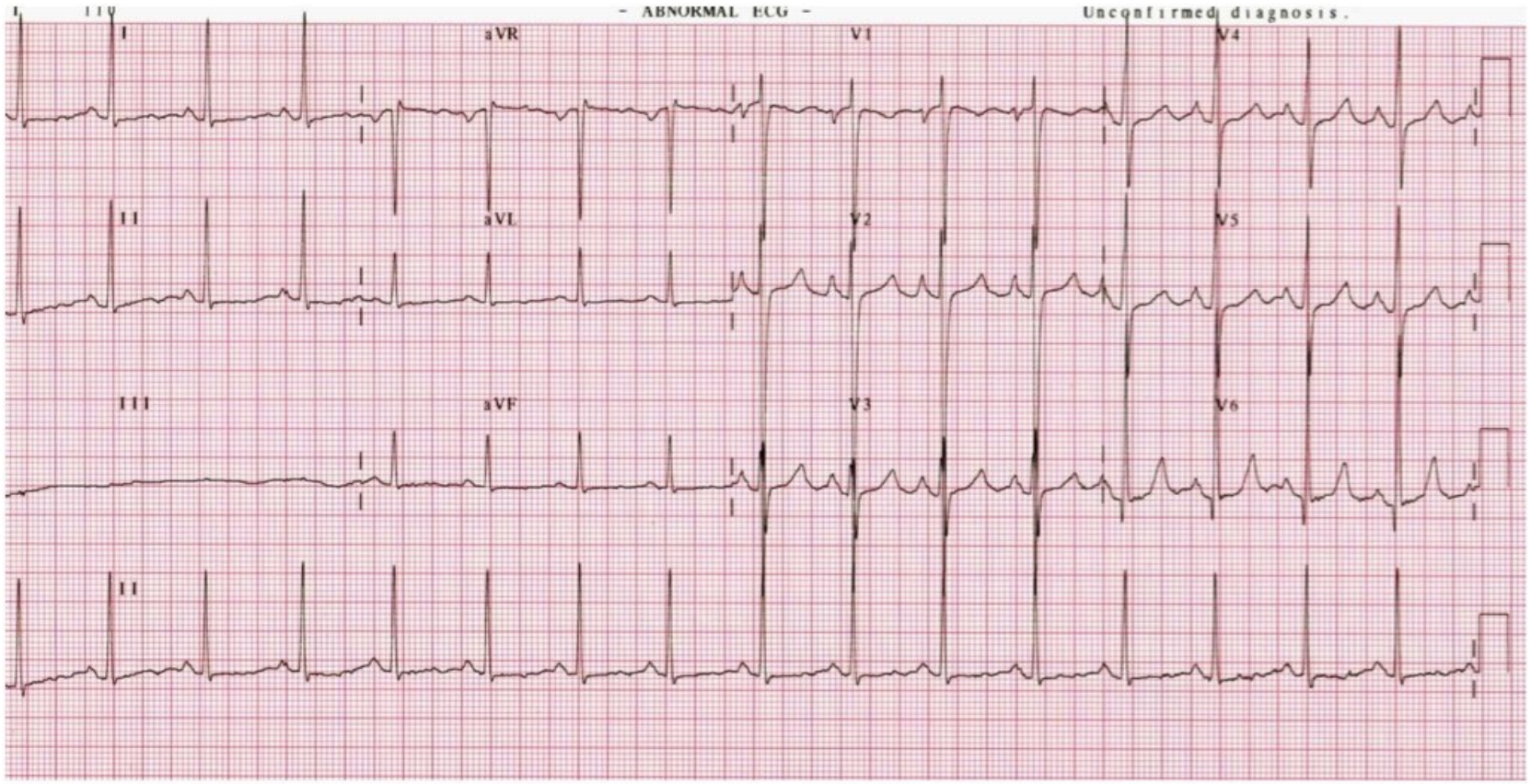
LVH

R wave amplitude in lead V6 or S wave amplitude in V1

- 98th percentile
- Voltage criteria for LVH

Amplitude of R wave in lead V6 plus amplitude of S wave in lead V1

- 98th percentile
- Voltage criteria for LVH



Deep S in V1, Dominant R in V6

Q wave abnormalities

- Deep Q wave more than normal in inferior and lateral leads (II, III, aVF, V5-6) (Volume overload)
- Absent Q wave in V6 (Pressure overload)

Chamber enlargement and hypertrophy

RVH

- QR pattern in right chest lead
- T wave change
- R wave amplitude in V1
- S wave amplitude in V6
- R/S ratio in V1
- RSR’ in V1
- RAD

LVH

- T wave change
- R wave amplitude in V6 or S wave amplitude in V1
- Amplitude of R wave in V6 + Amplitude of S wave in V1
- Q wave abnomalities

Biventricular hypertrophy

- Abnormal voltage in both the right and left chest leads
- Katz-Wachtel criterion

Abnormal voltage in both the right and left chest leads

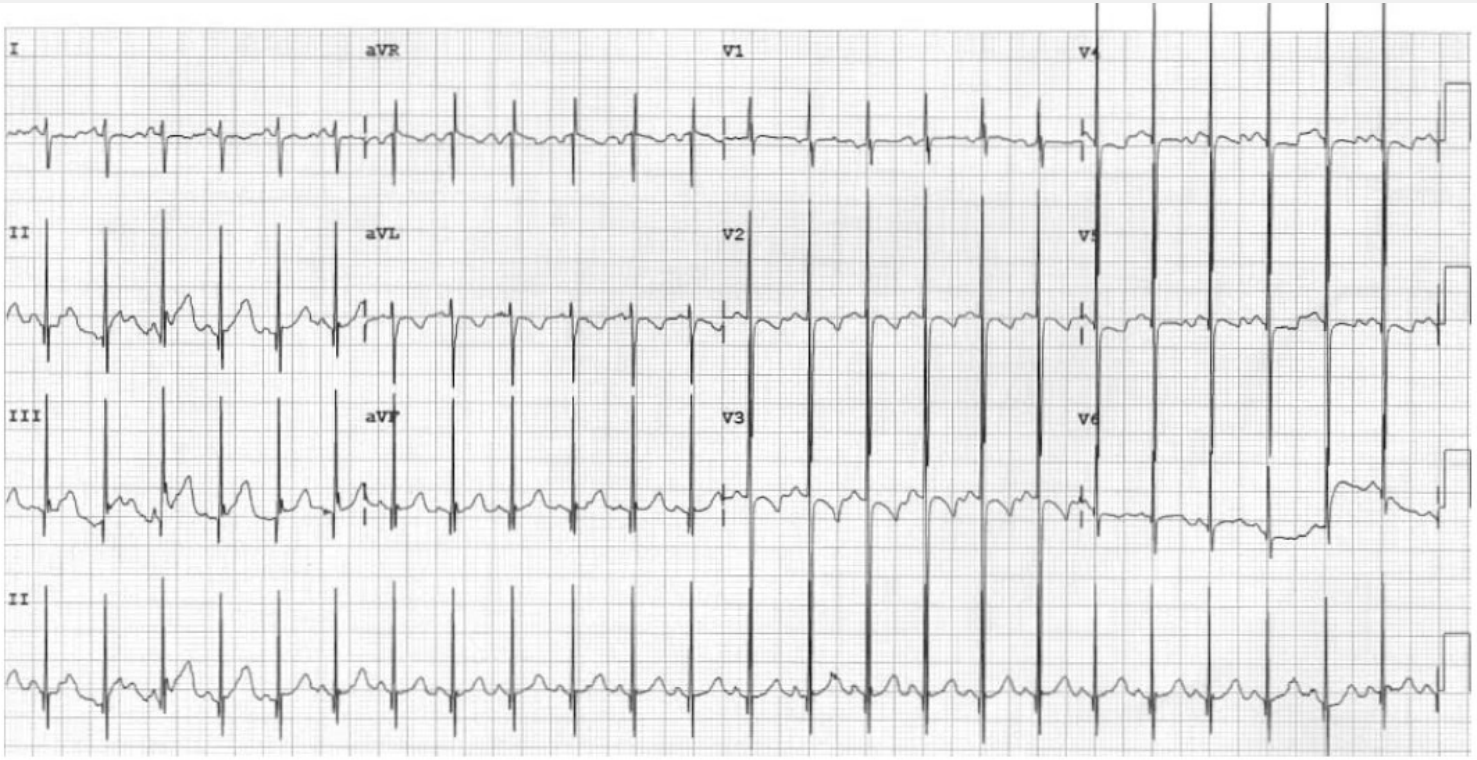
- Tall R in V1 or deep S in V6 (RVH) **plus** S wave in V1 or R wave in V6
- Tall R in V6 or deep S in V1 (LVH) **plus** S wave in V6 or R wave in V1

*Amplitude above normal limit compared to age

Katz-Wachtel criterion

Abnormal voltage in the midprecordial leads

- Amplitude of R wave plus Depth of S wave in V3-4 > 98th percentile (> 60 mm)



Katz-Wachtel phenomenon in child with isolated ventricular septal defect

Chamber enlargement

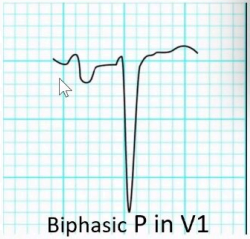
Right atrial enlargement	มีผลต่อ Depolarization ในระยะ**ต้น**ของ P wave	P wave amplitude > 2.5 mm (มักพบที่ lead II หรือ V2) Peaked P wave
Left atrial enlargement	มีผลต่อ Depolarization ในระยะ**หลัง**ของ P wave	- Increased terminal posterior forces: P wave ส่วนท้ายหัวกลับลึกเกิน 1 mm และ กว้างเกิน 1 mm ใน V1-2 (Most reliable) - P wave duration > 2.5 mm at lead II, V1-2
Biatrial enlargement		Met both RAE + LAE criteria

EKG interpret(5)

5. P wave (สูง > 2.5 ช่อง = RAE)

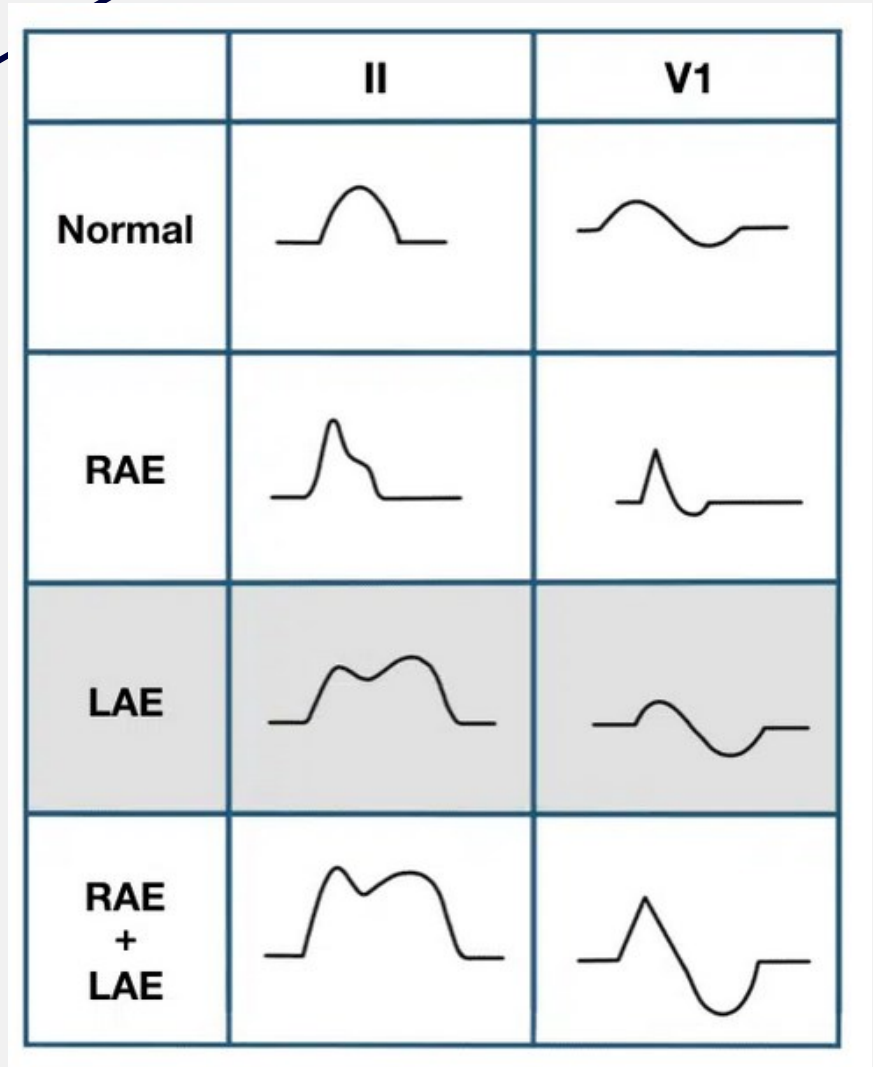
(กว้าง > 2.5 ช่อง หรือ หัวแตก = LAE)

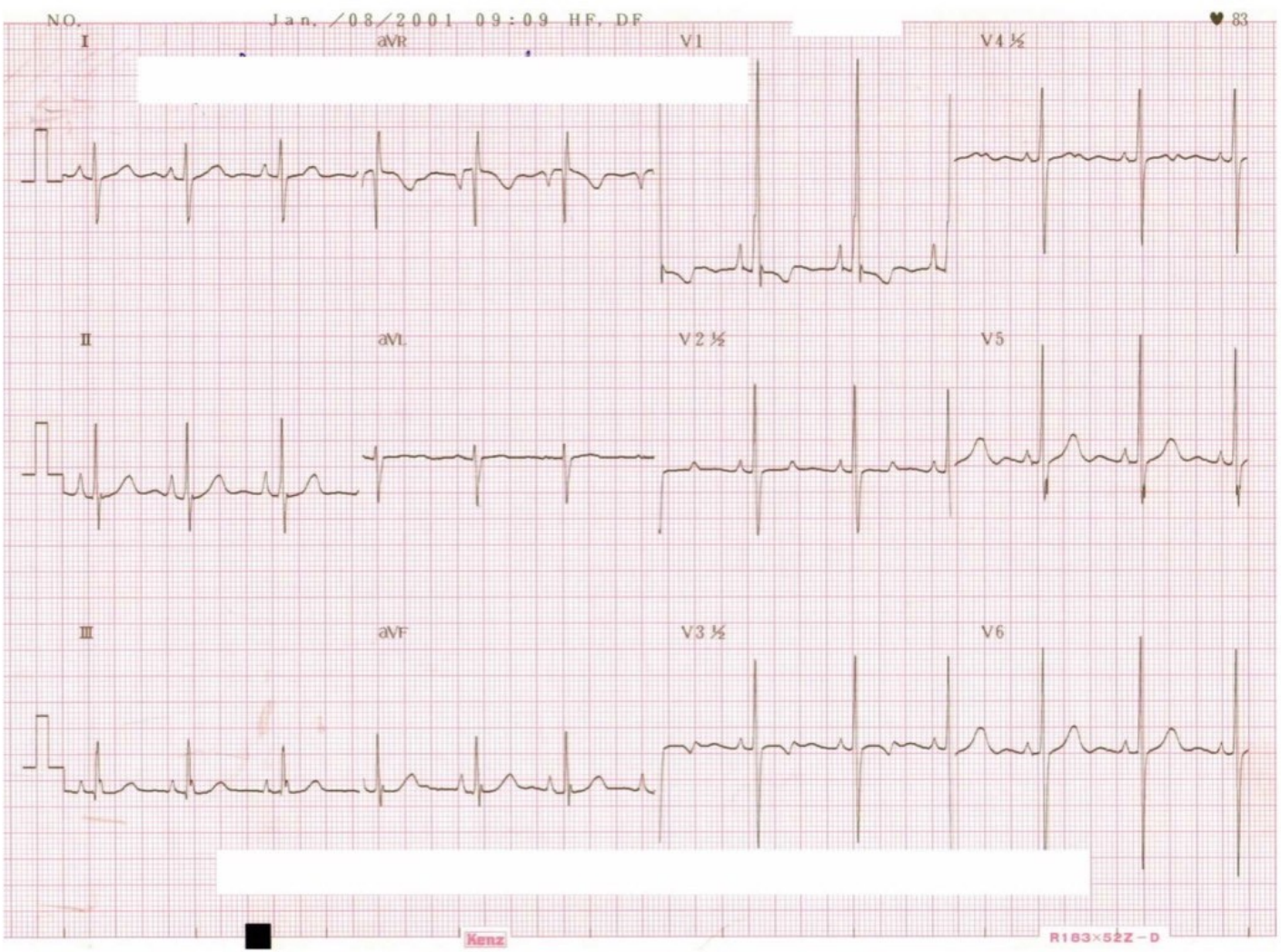
(Biphasic P in V1 = LAE)



P pulmonale

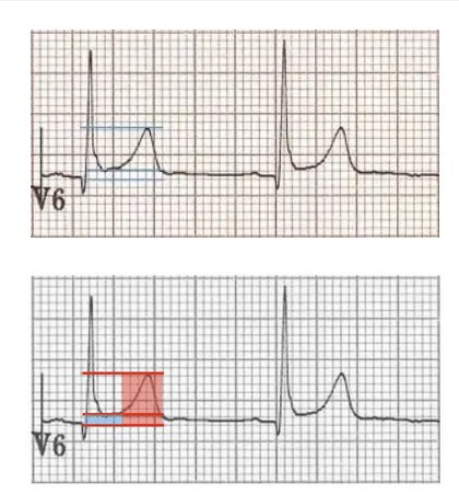
P mitrale





RAE
P amplitude > 3 mm
in II, V1

ST-T segment



Early repolarization

Functional T wave changes

- Sympathetic activity (Frightening, Anxiety): Inverted T wave

Early repolarization syndrome

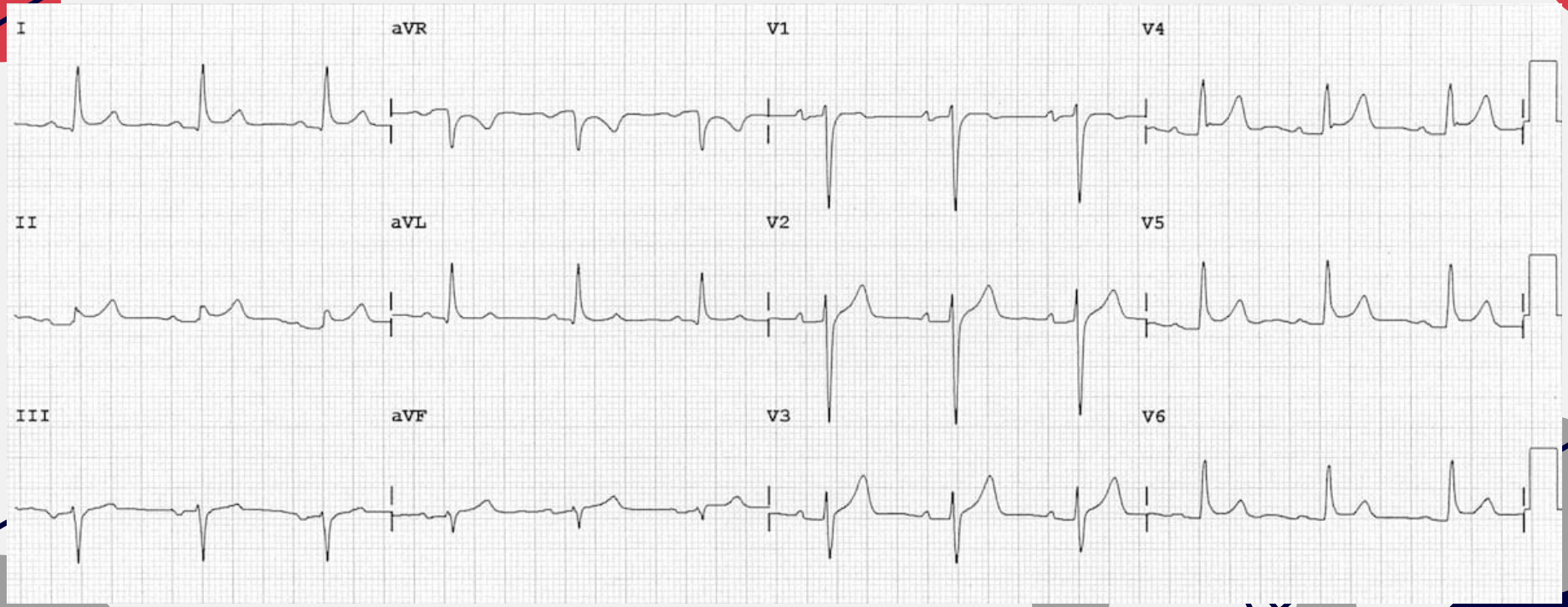
- In adolescent
- J point elevation (mimic ST elevation)
- เกิดจาก T wave ปรากฏเร็วกว่าธรรมดา ในขณะที่ Ventricles ยัง Depolarization อยู่
- Differential with pericarditis (Multi-stage, ST/T ratio > 0.25)

Pericarditis

Four stage

1) ST elevation (Diffuse), Upright T wave, PR segment elevation in aVR and V1, PR depression in STE leads
2) Normalized ST segment with flattening T wave
3) Inverted T wave in previous STE leads
4) Resolution

Pericarditis stage 1



ST-T segment

Myocardial Injury

Acute Infarction: ST elevation
Myocarditis: Flat or Inverted T wave (Common in left chest leads) and low voltage QRS

Myocardial Ischemia

- **Subendocardial**: Tall T wave
- **Subepicardial/Transmural**: Inverted T wave

Myocardial Infarction

Q wave with inverted T wave in infarct area (Several hours to days)

[In few min after onset: Hyperacute tall peaked T then ST elevation and reciprocal ST depression]

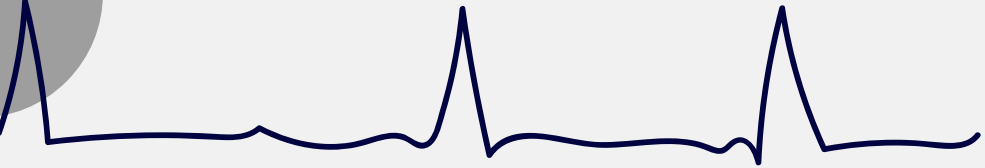


TABLE A-17. *Summary of Normal Values*

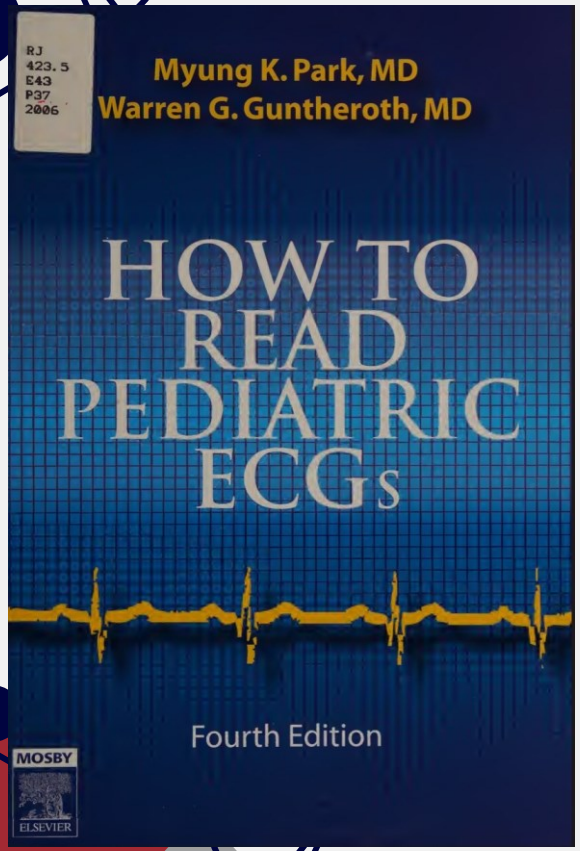
Age Group	*Heart Rate (BPM)	Frontal Plane QRS Vector (degrees)	PR Interval (sec)	**Q III (mm)§	**Q V_6 (mm)	RV_1 (mm)	SV_1 (mm)	R/S V_1	RV_6 (mm)	SV_6 (mm)	R/S V_6	**SV_1 + RV_6 (mm)	**R + S V_4 (mm)
Less than 1 day	93–154 (123)	+59 to −163 (137)	.08–.16 (.11)	4.5	2	5–26 (14)	0–23 (8)	.1–U (2.2)	0–11 (4)	0–9.5 (3)	.1–U (2.0)	28	52.5
1–2 days	91–159 (123)	+64 to −161 (134)	.08–.14 (.11)	6.5	2.5	5–27 (14)	0–21 (9)	.1–U (2.0)	0–12 (4.5)	0–9.5 (3)	.1–U (2.5)	29	52
3–6 days	91–166 (129)	+77 to −163 (132)	.07–.14 (.10)	5.5	3	3–24 (13)	0–17 (7)	.2–U (2.7)	.5–12 (5)	0–10 (3.5)	.1–U (2.2)	24.5	49
1–3 weeks	107–182 (148)	+65 to +161 (110)	.07–.14 (.10)	6	3	3–21 (11)	0–11 (4)	1.0–U (2.9)	2.5–16.5 (7.5)	0–10 (3.5)	.1–U (3.3)	21	49
1–2 months	121–179 (149)	+31 to +113 (74)	.07–.13 (.10)	7.5	3	3–18 (10)	0–12 (5)	.3–U (2.3)	5–21.5 (11.5)	0–6.5 (3)	.2–U (4.8)	29	53.5
3–5 months	106–186 (141)	+7 to +104 (60)	.07–.15 (.11)	6.5	3	3–20 (10)	0–17 (6)	.1–U (2.3)	6.5–22.5 (13)	0–10 (3)	.2–U (6.2)	32	61.5
6–11 months	109–169 (134)	+6 to +99 (56)	.07–.16 (.11)	8.5	3	1.5–20 (9.5)	.5–18 (4)	.1–3.9 (1.6)	6–22.5 (12.5)	0–7 (2)	.2–U (7.6)	32	53
1–2 years	89–151 (119)	+7 to +101 (55)	.08–.15 (.11)	6	3	2.5–17 (9)	.5–21 (8)	.05–4.3 (1.4)	6–22.5 (13)	0–6.5 (2)	.3–U (9.3)	39	49.5
3–4 years	73–137 (108)	+6 to +104 (55)	.09–.16 (.12)	5	3.5	1–18 (8)	.2–21 (10)	.03–2.8 (.9)	8–24.5 (15)	0–5 (1.5)	.6–U (10.8)	42	53.5
5–7 years	65–133 (100)	+11 to +143 (65)	.09–.16 (.12)	4	4.5	.5–14 (7)	.3–24 (12)	.02–2.0 (.7)	8.5–26.5 (16)	0–4 (1)	.9–U (11.5)	47	54
8–11 years	62–130 (91)	+9 to +114 (61)	.09–.17 (.13)	3	3	0–12 (5.5)	.3–25 (12)	0–1.8 (.5)	9–25.5 (16)	0–4 (1)	1.5–U (14.3)	45.5	53
12–15 years	60–119 (85)	+11 to +130 (59)	.09–.18 (.14)	3	3	0–10 (4)	.3–21 (11)	0–1.7 (.5)	6.5–23 (14)	0–4 (1)	1.4–U (14.7)	41	50

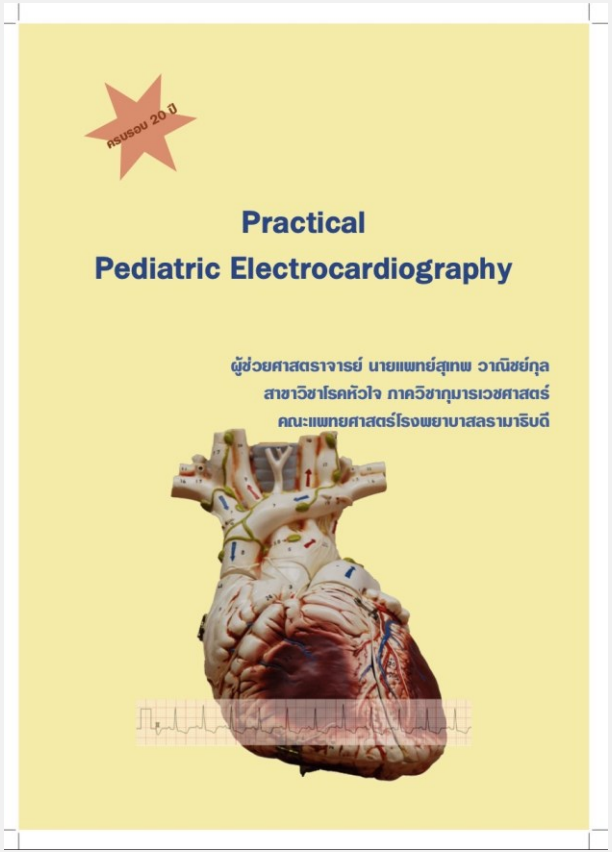
*2%–98% (mean)
**98th percentile
§mm at normal standardization
U undefined (S wave may equal zero)

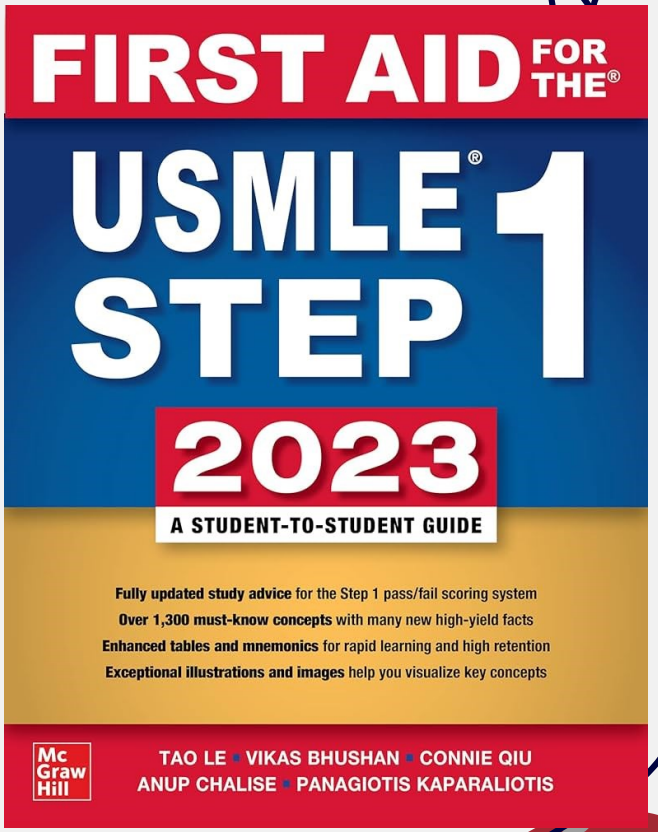
Take home messages

- Remember the 2 reference systems:
  - Hexaxial reference system provides the frontal projection of the electromotive forces while horizontal reference system provides the AP and the left-right relationship
- Components of ECG wave form: Wave, Interval and Segment
- Before routine measurement: Check paper speed and amplitude.
- Basic measurement: Rate, Rhythm, Axis, P wave, QRS wave, Intervals and Chamber hypertrophy/enlargement criteria

Resources


RJ
423.5
E43
P37
2006
Myung K. Park, MD
Warren G. Guntheroth, MD
HOW TO READ PEDIATRIC ECGs
Fourth Edition
MOSBY
ELSEVIER


ครบรอบ 20 ปี
Practical
Pediatric Electrocardiography
ผู้ช่วยศาสตราจารย์ นายแพทย์สุเทพ วาณิชย์กุล
สาขาวิชาโรคหัวใจ ภาควิชากุมารเวชศาสตร์
คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี


FIRST AID FOR THE®
USMLE® STEP 1
2023
A STUDENT-TO-STUDENT GUIDE
Fully updated study advice for the Step 1 pass/fail scoring system
Over 1,300 must-know concepts with many new high-yield facts
Enhanced tables and mnemonics for rapid learning and high retention
Exceptional illustrations and images help you visualize key concepts
Mc Graw Hill
TAO LE • VIKAS BHUSHAN • CONNIE QIU
ANUP CHALISE • PANAGIOTIS KAPARALIOTIS

Thanks!

CREDITS: This presentation template was created by **Slidesgo**, including icons by **Flaticon**, and infographics & images by **Freepik**

Please keep this slide for attribution