Practical EKG tips in children

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Interpretation:

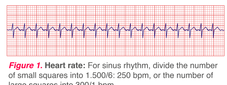


Figure 1. **Heart rate:** For sinus rhythm, divide the number of small squares into 1.500/6: 250 bpm, or the number of large squares into 300/1 bpm.

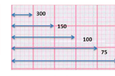


Figure 2. If QRS coincides with the large squares.

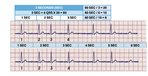


Figure 3. Heart rate evaluation in a non-sinus or irregular rhythm

- **Sinus rhythm:** QRS preceded by P, positive P in lead II and negative in aVR with a constant PR
- **P-wave axis:** (Axis 0 and +90° in leads I, II and aVF)
- **QRS axis:** note QRS direction in leads I and aVF.
- **QRS complex:** Q waves = IVS depolarization.
  < 3 years: an amplitude of 8 mm is normal
  >3 years: depth no > 5 mm in leads I, II, III, aVF, V5 and V6. Left ventricular dominance (-30° to +90°).
  Newborn: R is dominant in V1 and S is dominant in V6.
  Duration: 0-8 years: 0.05-0.075 ms. 8-16 years: 0.05-0.08 ms.
- **ST segment:** isoelectric. >2 mm depression/elevation: myocarditis, pericarditis, myocardial ischemia and ALCAPA; myocardial tumors and mucopolysaccharidoses.
- **T wave**
  Peaked in hyperkalemia: LVH (fluid overload) and thrombotic cerebrovascular accident (CVA).
  Flattened: Newborn, hypothyroidism, hypokalemia, carditis, myocarditis, pericarditis, myocardial ischemia, hyperglycemia or hypoglycemia.
- **U wave:** papillary muscle disorders.
- **ALCAPA:** Pathological Q and inverted T waves on aVL
- **TGA:** Q in V1-V3.

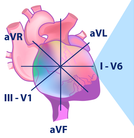
PR interval

- **Long:** rheumatic fever, myocarditis, digitalis or quinidine toxicity, hyperkalemia, AV septal defect or Ebstein anomaly and increased vagal tone.
- **Short PR:** WPW preexcitation, Lown-Ganong-Levine, Duchenne muscular dystrophy, Friedreich's ataxia, pheochromocytoma and/or glycogenosis.

QT interval

- **Short QTc:** Syncope, channelopathies (malignant arrhythmias or VF), hyperkalemia, hypercalcemia, digitalis and/or tachycardia.
- **Prolonged:** "Sudden death."
- **Congenital:** Romano-Ward and Jervell-Lange-Nielsen syndromes (associated with deafness).
- **Acquired:** hypokalemia, hypomagnesemia and hypocalcemia, brief resolved unexplained events (BRUE), myocarditis, hypertrophic or dilated cardiomyopathy, severe malnutrition, TBI and medications: amiodarone, fluconazole, quinidine, haloperidol, metoclopramide, chlorpromazine, 5-HT3 antagonists, tricyclics, arsenic, organophosphates, TMP/SMX, azithromycin, erythromycin, amantadine and anthracyclines.

$$QTc = \frac{QT}{\sqrt{R\text{-}R}}$$



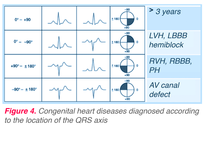


Figure 4. *Congenital heart diseases diagnosed according to the location of the QRS axis*

Table 1. *Pediatric electrocardiogram reference values by age. Adapted with permission from Sanches M., et al. (2014) Electrocardiograma en edad pediátrica. Semergen. 40 (6): 334-340. dx.doi.org/10.1016/j.semerg.2013.10.007.*

	0-7 days	8-30 days	1-6 months	6-12 months	1-5 years	5-10 years	10-15 years	> 15 years
HR (bpm)	90 to 160	100 to 175	110 to 180	70 to 160	65 to 140	65 to 140	60 to 130	60 to 100
PR (ms)	80 to 150	80 to 150	80 to 150	50 to 150	80 to 150	80 to 150	90 to 180	100 to 200
QRS axis(°)	70 to 180	45 to 160	10 to 120	10 to 110	5 to 110	5 to 110	5 to 110	5 to 110
QRS (ms)	40 to 70	40 to 70	40 to 70	40 to 70	45 to 80	45 to 80	50 to 90	60 to 90
QRS V1								
Q (mV)	0	0	0	0	0	0	0	0
R (mV)	0.5 to 2.5	0.3 to 2.2	0.3 to 2.0	0.2 to 2.0	0.2 to 1.8	0.1 to 1.5	0.1 to 1.2	0.1 to 0.6
S (mV)	0 to 2,2	0 to 1.6	0 to 1.5	0.1 to 2.0	0.1 to 2.0	0.3 to 2.1	0.3 to 2.2	0.3 to 1.3
QRS V6								
Q (mV)	0 to 0.2	0 to 0.2	0 to 0.2	0 to 0.3	0 to 0.4	0 to 0.4	0 to 0.3	0 to 0.2
R (mV)	0.1 to 1.2	0.1 to 1.7	0.3 to 2.0	0.5 to 2.2	0.6 to 2.2	0.8 to 2.5	0.8 to 2.4	0.5 to 1.8
S (mV)	0 to 0.9	0 to 0.9	0 a 0.9	0 to 0.7	0 to 0.6	0 to 0.4	0 to 0.4	0 to 0.2
T V1 (mV)	−0.3 to 0.3	−0.6 to −0.1	−0.6 to −0.1	−0.6 to −0.1	−0.6 to −0.1	−0.6 to −0.1	−0.6 to 0.2	−0.4 to 0.3	−0.2 to0.2

Electrolyte disorders

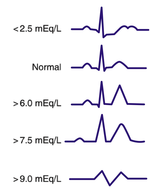
Hypercalcemia:
- ST shortening (without affecting T)
- Shortening QT.

- Normal

Hypocalcemia:
- Prolonged ST.
- Prolonged QT.

Hypokalemia: 2.5 meq/L. Prominent U wave (apparent QTc prolongation), flattened or biphasic T wave, ST depression and even prolonged PR with heart block.

Hyperkalemia: peaked T, prolonged QRS and prolonged PR, absent P, biphasic and/or bizarre QRS or potential asystole.



Electrocardiographic considerations in isomerisms

Situs Inversus: mirror image. The sinus node and atrioventricular node are RA structures. The P wave and QRS complex are negative in V5 and V6, negative in aVL and positive in a VR.

Isomerisms: these refer to the duplication of one side or absence of the other (see Figures 4 and 5).

Left isomerism: P axis -30 and -90. Second and third-degree AV block.

Right isomerism: reentry supraventricular tachycardia due to the presence of two AV nodes (twin nodes).

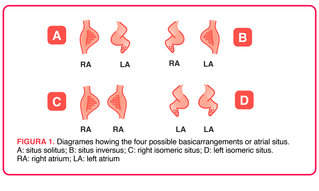


FIGURA 1. Diagrames howing the four possible basicarrangements or atrial situs.
A: situs solitus; B: situs inversus; C: right isomeric situs; D: left isomeric situs.
RA: right atrium; LA: left atrium

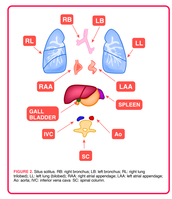


FIGURE 2. Situs solitus. RB: right bronchus, LB: left bronchus, RL: right lung (trilobed), LL: left lung (bilobed), RAA: right atrial appendage, LAA: left atrial appendage, Ao: aorta, IVC: inferior vena cava. SC: spinal column.

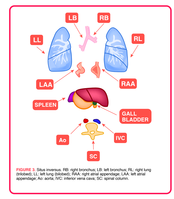


FIGURE 3. Situs inversus. RB: right bronchus, LB: left bronchus, RL: right lung (bilobed), LL: left lung (trilobed), RAA: right atrial appendage, LAA: left atrial appendage, Ao: aorta, IVC: inferior vena cava. SC: spinal column.

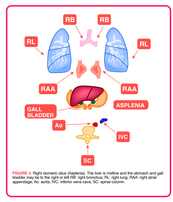


FIGURE 4. Right isomeric situs (Asplenia). The liver is midline and the stomach and gall bladder may be to the right or left RB: right bronchus, RL: right lung, RAA: right atrial appendage, Ao: aorta, IVC: inferior vena cava, SC: spinal column.

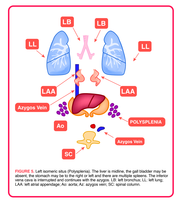


FIGURE 5. Left isomeric situs (Polysplenia). The liver is midline, the gall bladder may be absent, the stomach may be to the right or left and there are multiple spleens. The inferior vena cava is interrupted with azygos continuation. LB: left bronchus, LL: left lung, LAA: left atrial appendage, Ao: aorta, Az: azygos vein, SC: spinal column.

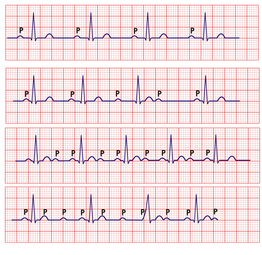
Atrial enlargement criteria:

- **LAH:** Mitral P > 2.5 mm or biphasic in V1 (at least 0.10 sec in children and > 0.08 sec in infants).
- **RAH:** Pulmonary P > 3 mm (< 6 months) and > 2.5 mm (> 6 months).

Ventricular enlargement criteria:

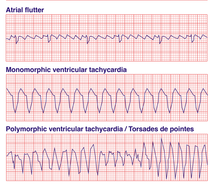
- **RVH:** right QRS axis and QRS lead voltage toward the RV (R > voltage in aVR, III, V4R, V1 and V2, and deep S in leads I and V6). Positive T in V1 after adolescence. qR in V1 and R/S ratio < 1 en V6.
- **LVH:** left QRS axis and QRS lead voltage toward the LV. (R > voltage in I, II, aVL, V5, V6 and sometimes III in small infants and deep S in V4R, V1 and V2). R/S ratio <1 in V1 and V2. Deep Q waves (> 5 mm) in V5 and V6 and/or tall T-waves in V5 and V6 (volume overload such as VSD). Inverted T in leads I and aVL.

Rhythm disorders Heart blocks



First degree	Healthy, increased vagal tone, myocarditis, hyperkalemia, hypoxemia, AMI, heart surgery, calcium channel blockers, beta blockers, digoxin, acute rheumatic fever and AV node disease	Prolonged PR **(REGULAR PR)**	Asymtomatic
Mobitz I Second degree	Healthy, increased vagal tone, AMI, calcium channel blockers, beta blockers and digoxin.	Progressive PR prolongation until P does not conduct **(IRREGULAR PR)**	Presyncope and lightheadedness
Mobitz II Second degree	Intrinsic conduction disorders, rarely due to increased vagal tone or drugs, AMI and heart surgery.	Some, but no all, P waves are blocked prior to reaching the ventricle. Constant **(REGULAR PR)**	Heartbeat irregularities, presyncope and syncope
Third degree	Cardiac conduction disease, myocarditis, heart surgery, congenital complete AV block, AMI, increased parasympathetic tone, pharmacotoxicological agents, or severe hypoxia/acidosis	P-QRS dissociation Ventricular rhythm: lower pacemaker **(IRREGULAR RR)**	Fatigue, lightheadedness and syncope

Tachyarrhythmias



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Bibliography

1. Matiz-Mejía S. & Carvajal-Barrios G. (2022) Electrocardiografía pediátrica. En: Ramos N. Et al., compilador. Pediatría Práctica, 3er Ed. Bogotá: Universidad El Bosque. ISBN: 978-958-739-235-7

2. Lambrechts L. & Fourie B. (2020) How to interpret an electrocardiogram in children. BJA Educ. 20(8):266-277. doi: 10.1016/j.bjae.2020.03.009.

3. Sanches M., et al cols. (2014) Electrocardiograma en edad pediátrica. Semergen. 40 (6): 334-340. dx.doi.org/10.1016/j.semerg.2013.10.007.

4. Matiz-Camacho H. & Vallejo C. ATLAS COLOMBIANO DE ELECTROCARDIOGRAFÍA. 1ra Ed. Bogotá: Universidad El Bosque. SOCIEDAD COLOMBIANA DE CARDIOLOGÍA & CIRUGÍA CARDIOVASCULAR.
ISBN: 978-958-49-5073-8

5. Bartram U., et al cols. (2005). Heterotaxy Syndrome - Asplenia and Polysplenia as Indicators of Visceral Malposition and Complex Congenital Heart Disease.

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