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Pediatric EKGs

A 3 year-old child is referred by his pediatrician to the emergency department for abnormal electrocardiogram findings. The child had presented for routine exam and mother reports the child had been complaining of chest pain for the last month. Child is developmentally normal, has no problems keeping up with other children in daycare and otherwise appears healthy and growing appropriately. Physical exam also was unremarkable. A repeat EKG was obtained in the emergency department. To understand what is abnormal, it is first important to determine how pediatric hearts (and therefore electrocardiograms) differ from that of an adult.

The pediatric heart rate is much faster in neonates and infants and decreases with age. The chart below helps outline average numbers for resting heart rate. One must keep in mind that in the busy emergency department, stimulation, crying and pain can all result in tachycardia in a child much like that expected in an adult. Arrhythmias in children are most commonly normal variant. Sinus arrhythmias are common. The **heart rate will increase with inspiration and slows with expiration. This variation is especially pronounced in young children** and is less pronounced in infants and adolescents.

Resting heart rate varies with age:

Newborn: 110 – 150 bpm
2 years: 85 – 125 bpm
4 years: 75 – 115 bpm
6 years+: 60 – 100 bpm

The pediatric heart is also much smaller than that of an adult and as a result, conduction intervals are shorter than in adults. Typical teaching in adult EKGs is that a PR interval greater than 200 milliseconds (one big box) is long and consistent with first degree AV block. Generally speaking, in infants and children, a **PR interval greater than 0.16 msec** (4 small boxes) would be considered long. Prolonged PR interval can be seen with myocarditis, congenital heart disease, digitalis toxicity, and hyperkalemia. On the other hand, a shortened PR interval can be normal if the QRS is narrow. However, a shortened PR interval can be consistent with pre-excitation if the QRS interval is wide, such as in Wolf-Parkinson-White (WPW). Specifically in this instance, a delta wave or upstroking of the QR segment can be seen. Pre-excitation occurs when a congenital bypass tract exists resulting in early excitation of the ventricle that bypasses the typical SA to AV node to ventricle pathway. Patients with this may present in SVT or on rare occasions with sudden death.

Likewise, the QRS interval is shortened in pediatrics. Whereas in the adult EKG, a QRS interval greater than 120 msec (3 small boxes) is abnormal, in the pediatric EKG, **QRS greater than 80 msec** (2 small boxes) is considered abnormal. Prolonged QRS can be concerning for bundle branch blocks, pre-excitation pathways (such as WPW), intraventricular block, and ventricular arrhythmias.

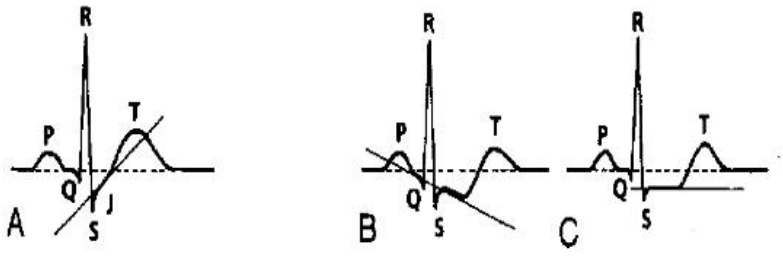
Normal values in paediatric electrocardiograms

Age	PR interval (ms)	QRS duration (ms)	R wave (S wave) amplitude (mm)	
			Lead V1	Lead V6
Birth	80-160	<75	5-26 (1-23)	0-12 (0-10)
6 months	70-150	<75	3-20 (1-17)	6-22 (0-10)
1 year	70-150	<75	2-20 (1-20)	6-23 (0-7)
5 years	80-160	<80	1-16 (2-22)	8-25 (0-5)
10 years	90-170	<85	1-12 (3-25)	9-26 (0-4)

The QTc corrects the QT interval for heart rate and generally speaking should be **less than 490 msec in infants less than 6 months and less than 440 msec in children older than 6 months**. Prolonged QTc can be worrisome for myocarditis, congenital QT syndrome, hypocalcemia, head injury, and drug-induced. Shortened QTc can be seen in hypercalcemia, digitalis, and congenital conditions.

Q waves can be normal in children if they are narrow (less than 30 msec) and less than 5 mm deep in left precordial leads and aVF. A **q wave as deep as 8 mm in lead III is considered normal in children younger than three years**. Q waves in children would be concerning if they appeared in the right precordial leads (V1, as in severe RVH), are absent in the left precordial leads (concerning for LBBB), are abnormally deep (ventricular hypertrophy due to volume overload) or are abnormally deep and wide (in the case of myocardial infarction or fibrosis).

The ST segment is normally isoelectric. However, some ST segment changes can be normal. Limb lead ST depression or elevation less than 1 mm (up to 2 mm in the left precordial leads) can be seen in the normal EKG. Additionally, J point (junction between QRS and ST segment) depression without sustained ST depression resulting in an upsloping ST depression is normal. Early repolarization can be seen in adolescents where the ST segment is elevated and concave in leads with an upright T wave. Abnormal ST segments would include downward slope of ST segment followed by biphasic inverted T wave or a sustained horizontal depression of 80 msec or longer. Pathologic ST segment changes are typically associated with T wave changes and would suggest pathologies including pericarditis, myocardial ischemia or infarction, severe ventricular hypertrophy, or digitalis effect. Below, some examples of normal and abnormal ST segments are shown.



A = upsloping ST depression / J-point depression (normal variant)
B = downsloping ST depression (usually abnormal)
C = horizontal ST depression (usually abnormal)

While U waves can be seen in hypokalemia, they can also be a normal finding at slower heart rates, such as in the setting of an adolescent with sinus bradycardia.

The **right ventricle at birth is much larger and thicker than the left due to the increased resistance of the pulmonary vasculature in utero**. Changes in systemic vascular resistance result in the left ventricle increasing in size until it is larger than the right. As a result, a child's EKG can resemble that of an adult with right ventricular hypertrophy with rightward axis, dominant R wave in V1 (precordial) and T wave inversions in septal leads. The **left ventricle becomes larger than the right by age 1 month and by age 6 months, the ratio of the right ventricle to the left is similar to that of an adult**. While the age varies depending on the source, the right side dominance is typically replaced **by left side dominance by ages three to four years at which time a pediatric EKG resembles more that of an adult**. T waves are upright in precordial leads in the neonate. However, the **T wave in lead V1 inverts by seven days of age and typically remains inverted until at least age seven years**. This is referred to as the "juvenile T wave pattern." Therefore, an upright T wave in V1 to V3 between ages 7 days and 7 years would actually be abnormal and indicate right ventricular hypertrophy. In determining left ventricular hypertrophy, the midprecordial leads can be unreliable in children since their chest walls are so thin. As a result, V1 and V6 should be used for evaluating LVH.

Armed with this knowledge, we are now ready to evaluate the repeat EKG obtained in our case study. The EKG showed a heart rate of 110, inverted T waves in V1 and V2, sinus arrhythmia with respiratory variation, and Q waves in inferior leads. Therefore, this was a normal EKG. Chest pain in children is rarely cardiac in origin and is often associated with tenderness in the chest wall. Electrocardiography is not usually helpful in making a diagnosis, although a normal trace can be very reassuring to the family. Pediatric EKGs can be helpful in the setting of syncope, exertional symptoms, drug ingestion, hypothermia, cyanotic episodes, tachy- or brady-arrhythmias, and electrolyte abnormalities. Less common pathologies in which an EKG can be useful include heart failure, myocarditis, pericarditis, rheumatic fever, Kawasaki disease, myocardial contusion, congenital heart defects, and post-cardiac surgery.

Paediatric electrocardiographic findings that may be normal

- Heart rate >100 beats/min
- QRS axis >90°
- Right precordial T wave inversion
- Dominant right precordial R waves
- Short PR and QT intervals
- Short P wave and short duration of QRS complexes
- Inferior and lateral Q waves

Resources/Further Reading

1. Burns, Edward. "Paediatric ECG Interpretation." Life in the Fast Lane <http://lifeinthefastlane.com/ecg-library/paediatric-ecg-interpretation/>
2. Goodacre, Steve and McLeod, Karen. "Paediatric electrocardiography." BMJ 2002;324:1382
3. Evans WN et al. "Simplified Pediatric Electrocardiogram Interpretation." Clinical Pediatrics 2009; Volume XX, Number X, Month XXXX

4. Dickinson DF. “The normal ECG in childhood and adolescence.” Heart. 2005 Dec; 91(12): 1626–1630.