Complete Summary

GUIDELINE TITLE

Guidelines for the interpretation of the neonatal electrocardiogram.

BIBLIOGRAPHIC SOURCE(S)

Schwartz PJ, Garson A Jr, Paul T, Stramba-Badiale M, Vetter VL, Wren C. Guidelines for the interpretation of the neonatal electrocardiogram. A task force of the European Society of Cardiology. Eur Heart J 2002 Sep;23(17):1329-44. [52 references] PubMed

GUIDELINE STATUS

This is the current release of the guideline.

COMPLETE SUMMARY CONTENT

SCOPE
METHODOLOGY - including Rating Scheme and Cost Analysis
RECOMMENDATIONS
EVIDENCE SUPPORTING THE RECOMMENDATIONS
BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS
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INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT
CATEGORIES
IDENTIFYING INFORMATION AND AVAILABILITY
DISCLAIMER

SCOPE

DISEASE/CONDITION(S)

Electrocardiogram (ECG) abnormalities

GUIDELINE CATEGORY

Diagnosis
Evaluation
Management
Risk Assessment
Screening
Treatment

CLINICAL SPECIALTY

Cardiology
Family Practice
Obstetrics and Gynecology
Pediatrics

INTENDED USERS

Allied Health Personnel
Physicians

GUIDELINE OBJECTIVE(S)

- To present adult cardiologists with a consensus document designed to provide guidelines for the interpretation of the neonatal electrocardiogram (ECG), focusing on the most clinically relevant abnormalities and on the ensuing management and referral options
- To provide paediatricians and neonatologists with updated information of clinical relevance that can be detected from a neonatal electrocardiogram

TARGET POPULATION

Newborns and infants having an electrocardiogram to rule out arrhythmogenic disorders, especially electrocardiograms conducted during the first month of life as part of a cardiovascular screening programme

INTERVENTIONS AND PRACTICES CONSIDERED

Diagnosis

1. Electrocardiogram (ECG): distinguishing normal from abnormal values; interpretation of abnormal values

Follow-up Management/Treatment of Electrocardiographic Abnormalities

1. 24-hour Holter monitoring
2. Echocardiogram (e.g., 2-dimensional)
3. Clinical history of autoimmune disease and plasma titres of maternal antibodies (e.g., antiRo/SSA and antiLa/SSB)
4. Evaluation of maternal drug use
5. Assessment of the conduction properties of the accessory pathway, i.e., the antegrade effective refractory period and the shortest RR-interval with preexcitation, by transesophageal programmed stimulation
6. Evaluation of family history/genetic screening
7. Permanent artificial pacing
8. Beta-blockers
9. Other drug therapy (e.g., atropine)
10. Left cardiac sympathetic denervation
11. Pacemakers
12. Implantable cardioverter defibrillator
13. Referral to specialist

MAJOR OUTCOMES CONSIDERED

Diagnosis

- Predictive/interpretative value of diagnostic tests and assessments
- Prevalence of electrocardiographic abnormalities and underlying diseases in the neonatal and paediatric population
- Morbidity and mortality related to arrhythmogenic disorders in the neonatal and paediatric population
- Side effects of maternal or fetal medication

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Weighting According to a Rating Scheme (Scheme Given)

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Strength of Evidence

A. Data derived from at least two randomized clinical trials or meta-analyses
B. Data derived from a single randomized trial and/or meta-analysis from non-randomized studies
C. Consensus opinion of the experts based on trials and clinical experience

METHODS USED TO ANALYZE THE EVIDENCE

Systematic Review

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

The procedure used for developing and issuing the guideline was in accordance with the companion document to this guideline, the European Society of Cardiology "Recommendations for Task Force Creation and Report Writing" (available from the European Society of Cardiology Web site).

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Expert Consensus

DESCRIPTION OF METHODS USED TO FORMULATE THE RECOMMENDATIONS

Not stated

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Usefulness or Efficacy of a Recommended Treatment

Class I = Evidence and/or general agreement that a given treatment is beneficial, useful and effective

Class II = Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of the treatment

> IIa: weight of evidence/opinion is in favour of usefulness/efficacy
>
> IIb: usefulness/efficacy is less well established by evidence/opinion

Class III* = Evidence or general agreement that the treatment is not useful/effective and in some cases may be harmful.

* Use of Class III is discouraged by the ESC

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

External Peer Review
Internal Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

This document was reviewed and approved by the European Society of Cardiology (ESC) Committee for Practice Guidelines and Policy Conferences (W. Klein [Chairman], V. Dean, D. Jumeau, M.A. Alonso, C. Blomström-Lundqvist, G. De Backer, M. Flather, J. Hradec, K. H. McGregor, A. Oto, A. Parkhomenko, S. Silber, A. Torbicki, G. Mazzotta, J. Deckers, H. Dargie, H-J. Trappe). The guideline was endorsed by the Board of the European Society of Cardiology.

RECOMMENDATIONS

MAJOR RECOMMENDATIONS

There are important differences between neonatal and adult electrocardiograms (ECGs). When a cardiologist examines the ECG of an apparently normal and healthy infant the focus has to be on distinguishing between patterns that should cause no alarm and those that require action or additional investigations. To provide clues for this distinction is what the members of the Task Force have attempted to do and, whenever possible or appropriate, steps in management have also been suggested.

Normal Electrocardiogram in the Newborn

Normal values

- Normal electrocardiographic values in the paediatric population traditionally derive from those published in 1979 by Davignon et al; thus, the percentile tables published by Davignon are recommended for use in clinical practice (see Table 1 in the original guideline document).

Technology

- The normal newborn ECG should include 12 leads. Other leads, V_{3R}, V_{4R} and V_7, may provide additional information to evaluate possible congenital heart lesions.
- The current use of computerized digital ECG systems affects newborn ECGs to a greater extent than those of older children or adults. The newborn ECG may have a higher voltage and shorter duration QRS complexes resulting in a higher percentage of high frequency components. The recommendations of a number of groups vary as to the best bandwidth cutoffs and sampling frequency to reduce error. Higher bandwidth cutoffs may alter amplitude of signals by as much as 46%. This would make standards determined from analogue signals or digitized signals at lower sampling rates and lower frequency cutoffs different from those at higher settings. The current American Heart Association recommendation for paediatric ECGs is 150 Hz as a minimum bandwidth cutoff and 500 Hz as a minimum sampling rate. The Rijnbeek study reported normals using a higher sampling rate of 1200 Hz. Compared to Davignon's study, which used a sampling rate of 333 Hz, the newborn upper limits in Rijnbeek´s study were 12-25% higher than in Davignon´s.

Artefacts

- Artefacts are common in newborn ECGs and include limb lead reversal and incorrect chest lead positioning. In addition, electrical interference, usually 60 cycles, can occur in hospital settings from bedside monitors, warmers or other equipment. Other artefacts occur because of various types of patient movement common in neonates. These artefacts may be random as with hiccoughs or limb movement. Normal complexes are seen along with the artefacts, and the intrinsic rhythm of the patient is not affected. Other common artefacts include a fine, often irregular undulation of the baseline from muscle tremors or jitteriness. Again, the intrinsic rhythm is not affected. The size of the QRS complex and the baseline may wander in a cyclic fashion with respirations. It should be noted that the neonate breathes from 30-60 times per min.

- The main clue in determining the presence of an artefact is to evaluate whether it affects the intrinsic rhythm and if it is timed such that it could be a true depolarization. A signal within 80 ms from a true QRS complex could not occur from an electrophysiologic point of view.

Electrocardiographic measurements

- Because of the current limitations of electronic measurements in newborn ECGs, intervals should be hand measured as the computerized systems are often inaccurate in the newborn.
- Intervals in children increase with increasing age, reaching most of the adult normal values by 7-8 years of age.

Heart rate

- Heart rate can be determined by a variety of methods. Normal neonates may have heart rates between 150-230 beats. min^{-1}, especially if they are crying or agitated. Over 200 beats. min^{-1}, one-half small box can make an appreciable difference in heart rates.
- Heart rates between the 2nd and 98th percentile in the first year of life are shown in Table 1 of the original guideline document. The normal heart rate increases from the first day of life, it reaches a peak between the first and second month and then declines returning to the values recorded at birth by the sixth month. During the following six months, it remains rather stable and then slowly declines after one year due to maturation of vagal innervation of the sinus node.
- Clinically significant gender differences in heart rate are not seen in the neonatal period.

P wave

- The P wave axis is a vector indicating the direction of activation, which is away from the site of origin. By identifying the quadrant location of the P wave axis one can determine the site of origin of the rhythm. For example, sinus rhythm originates in the high right atrium transcribing a P wave with an axis in the quadrant bordered by 0 and +90 degrees.
- Measurements are available in Table 1 of the original guideline document for P wave amplitude. The P wave is generally pointed in lead II and aVF and more rounded in other leads. Lead V$_1$ may be diphasic.
- The PR interval is measured from the onset of the P wave to the Q or R wave if no Q wave is present. The PR interval, measured in lead II, increases with age and decreases with heart rate. The normal neonatal PR interval ranges from a minimum of 70 ms to a maximum of 140 ms, with a mean of 100 ms.

QRS complex

- The normal full-term neonate has an axis between 55 degrees and 200 degrees but by one month, the normal upper limit has fallen to 160 degrees or less. Although one might identify an axis of 120 degrees as right axis deviation in an adult, it is a normal finding in a newborn.
- The QRS axis in the premature newborn ECG ranges between 65 degrees and 174 degrees.

- The duration of the QRS complex is measured from the beginning to the end of the ventricular depolarization complex and it should be measured in a lead with an initial Q wave. QRS duration in the newborn and infant is narrow (<80 ms). Normal QRS duration increases with age. Normal values for QRS complex duration in lead V_5 are shown in Table 1 of the original guideline document.
- QRS morphology in the newborn may have more notches and direction changes than seen in older children or adults. The direction of the Q wave in the precordial or horizontal plane indicates the direction of septal depolarization. Normally, there is a Q wave in leads V_5-V_6 indicating depolarization from left to right. Normal values of Q wave amplitudes vary with the lead and with age. Q wave amplitudes may be as high as 0Â·55 mV in lead III or 0Â·33 mV in aVF at 1 month. Q wave duration >30 ms is abnormal. The appearance of secondary r waves (r´ or R´) in the right chest leads is frequent in normal neonates.
- Davignon et al. provided â ˜normal´ values in infants. The use of 2nd and 98th percentiles to define normality implies that 4% of the population are â ˜abnormal´ for any given single measurement, so â ˜normal´ ranges have to be interpreted with caution (see Table 1 of the original guideline document).

QT interval

- The QT interval is the interval between the beginning of the QRS complex and the end of the T wave. The QT measurement should be made in leads II, V_5, and V_6 with the longest value being used. The main difficulty lies in identifying correctly the point where the descending limb of the T wave intersects the isoelectric line. Due to the fast heart rate of infants the P wave may be superimposed on the T wave, particularly when the QT interval is prolonged. In this case, the end of the T wave should be extrapolated by drawing a tangent to the downslope of the T wave and considering its intersection with the isoelectric line.
- The QT interval duration changes with rate and it is usually corrected (QTc) by using Bazett´s formula. Correction of the QT interval requires a stable sinus rhythm without sudden changes in the RR interval. QTc is equal to QT interval in seconds divided by the square root of the preceding RR interval in seconds. To avoid time-consuming calculations, a simple chart (see Figure 1 of the original guideline document) where the value of QTc is easily obtained by matching QT and RR interval in millimetres (given the paper speed 25 mm . s^{-1}) has been produced. When heart rate is particularly slow or fast the Bazett´s formula may not be accurate in the correction but it remains the standard for clinical use.
- The mean QTc on the 4th day of life is 400 plus or minus 20 ms and, at variance with the adult, no gender differences are present. Therefore, the upper normal limit of QTc standard deviations above the mean, corresponding to the 97Â·5 percentile) is 440 ms. By definition, 2Â·5% of normal newborns are expected to have a QTc greater than 440 ms. In healthy infants there is a physiological prolongation of QTc by the second month (mean 410 ms) followed by a progressive decline, so that by the sixth month QTc returns to the values recorded in the first week.
- Pitfalls with QT measurement. Despite its apparent simplicity the measurement of the QT interval is fraught with errors. The simple fact that a

small square on the ECG paper is equivalent to 40 ms explains why healthy scepticism should accompany claims of clinical importance attached to very small degrees of â ˜QT prolongation´. An attempt should be made to measure with 10 ms (1/4 of a mm) while one recognizes that this may be within measurement error.

ST segment and T wave

- ST segment elevations >1 mm above the isoelectric line are uncommon in the newborn. In neonates and infants it is better to consider as the isoelectric line the TP segment instead of the PQ segment. T waves are normally quite variable in the first week of life. After 1 week, the T wave is negative in lead V_1 and positive in $V_{5\text{-}}V_6$.

Abnormal Electrocardiogram in the Newborn

Heart rate

Sinus arrhythmia

- Since sinus arrhythmia is less pronounced at fast heart rate, neonates show a more regular rhythm than young children and adolescents, particularly in the first week of life. Sinus arrhythmia should be differentiated from wandering pacemaker, which manifests itself with a gradual change of P wave axis and morphology and that is due to a shift of the pacemaker from the sinus node to the atrium and the atrioventricular (AV) junction. Although wandering pacemaker may accompany other types of bradyarrhythmia, it has no pathologic meaning.
- Work up: No work-up should be necessary unless significant bradycardia coexists.

Sinus tachycardia

- Sinus tachycardia is a sinus rhythm with a heart rate above the normal limit for age. In the newborn the upper normal limit (98th percentile) is 166 beats. min^{-1} in the first week and 179 beats. min^{-1} in the first month. After the sixth month the upper normal limit declines to approximately 160 beats . min-1 and at 1 year is 151 beats . min^{-1}. These values have been measured from ECGs recorded when infants were awake and quiet. It has to be noted that newborn infants may transiently reach a heart rate up to 230 beats . min^{-1}.
- Work-up: The evaluation of these patients should be performed according to the underlying condition. If myocarditis is suspected an echocardiogram should be performed. Appropriate acute treatment of causes of tachycardia may be considered. Persistence of elevated rates should be further evaluated.

Sinus bradycardia

- Sinus bradycardia is defined as a sinus rhythm with a heart rate below the normal limit. In the neonatal period the lower normal limit (2nd percentile) is 91 beats . min^{-1} during the first week and 107 beats . min^{-1} in the first month of life. At the first month the lower limit increases to 121 beats . min^{-1} and

declines to approximately 100 beats . min^{-1} in the following months. At 1 year the lower normal limit is 89 beats . min^{-1}. These values apply to an ECG recorded in the awake state when heart rate is measured over two respiratory cycles.

- Work-up: 24-hour Holter monitoring may be helpful for further evaluation when a heart rate below 80-90 beats . min^{-1} is present on surface ECG during infancy. Evaluation for underlying conditions should be performed.

Other bradycardias

- Sinus pauses in newborns may last from 800 to 1000 ms. Pauses >2 s are abnormal. Sinus pauses may be followed by escape beats which arise from the atria or from the AV-junction. It has to be noted that even healthy neonates may show periods of junctional rhythm, i.e. a sequence of narrow QRS complexes in the absence of preceding P waves.
- Work-up: 24-hour Holter monitoring may be useful for the assessment of significant bradycardia. Long pauses secondary to excessive vagal tone may be eliminated by the use of atropine, and rarely require pacemakers. Treatment of other underlying diseases should be undertaken.

P wave

- Abnormal P waves may be seen in infants with atrial enlargement or non-sinus origin of the P wave. Ectopic atrial rhythms originate most commonly from the low right atrium (0 to -90 degrees), high left atrium (+90 to +180 degrees) or the low left atrium (+180 to +270 degrees).
- Right atrial enlargement and/or hypertrophy typically produces increased P wave amplitude with a normal P wave duration. The P wave axis usually remains normal so the effect is usually best seen in lead II.
- Left atrial enlargement and/or hypertrophy typically produces an increased and prolonged negative terminal deflection of the P wave in lead V$_1$ (generally accepted as >40 ms in duration and 0·1 mV in amplitude). Left atrial enlargement also causes exaggerated notching of the P wave in lead II although this is not a specific sign.
- Work-up: An echocardiogram should be performed when clinically indicated.

Atrioventricular (AV) conduction

- During atrial tachycardia, it is possible to observe 1/1 conduction through the atrioventricular node at rates over 300 beats . min^{-1}.

Complete (third degree) atrioventricular (AV) block

- Complete atrioventricular (AV) block implies complete absence of conduction from atrium to ventricle. ECG shows normal atrial activation and slower dissociated regular QRS complexes. Congenital complete block is observed in complex congenital heart malformations.

First and second degree atrioventricular (AV) block

- Neonates may present with first or second degree atrioventricular (AV) block and rare reports exist demonstrating progression to complete AV block after birth in children with and without antibody mediated conduction disorders.
- Long QT syndrome (LQTS) is occasionally complicated by impaired atrioventricular conduction, mostly 2:1 AV block. Functional AV block can be observed in neonates because they have a fast atrial rate and the P wave falls within the very prolonged T wave. Cases of infra-Hisian block location at the His-Purkinje level have been demonstrated.
- Work-up: In neonates and infants with AV conduction abnormalities clinical history of autoimmune disease and plasma titres of maternal antibodies (anti Ro/SSA and antiLa/SSB) should be performed. When neonates have abnormal AV nodal conduction without maternal antibodies, an ECG should also be performed on the parents and siblings (see intraventricular abnormalities). Neonates with first degree AV block should be followed with additional ECGs in the following months. Neonates and infants with second or third degree AV block need a complete paediatric cardiologic work-up, including an echocardiogram. The only effective treatment of congenital complete AV block in neonates with symptoms or a low ventricular escape rhythm is permanent artificial pacing.

Intraventricular conduction

Bundle branch block

- Congenital isolated complete right bundle branch block (RBBB) and left bundle branch block are very rare in neonates. The classical ECG in Ebstein´s anomaly of the tricuspid valve displays a prolonged PR interval and wide RBBB.
- Left anterior fascicular block is found in association with congenital heart malformations such as atrioventricular canal defects and tricuspid atresia. In severe cardiomyopathy, interruption of the left bundle, which results from the involvement of the left ventricle and/or its conduction system, has been reported and carries a poor prognosis.
- Hereditary bundle branch block is an autosomal dominant genetic disease that was mapped in some families to the long arm of chromosome 19. Affected individuals have various combinations of conduction defects such as RBBB, left or right QRS axis deviation or AV block; the r´ pattern may as well be the prelude to a conduction block. Abnormalities have been described in patients as young as 15 days.
- Non-specific intraventricular conduction abnormalities are very rare in neonates and infants with normal heart structures. They may be a manifestation of inflammation in myocarditis or endocarditis.
- Work-up: Neonates and infants with intraventricular conduction abnormalities need a complete paediatric cardiologic work-up. Evaluation of possible underlying causes should be performed. An ECG should also be performed on the parents and siblings.

Wolff-Parkinson-White syndrome (WPW)

- The anatomical substrate of preexcitation in Wolf-Parkinson-White (WPW) syndrome is a direct muscular connection between the atria and ventricles. Since accessory pathways rarely show decremental conduction, the electrical

impulse is conducted prematurely to the ventricles resulting in a short PR interval. Conduction through the atrioventricular node and the accessory pathway results in collision of two electrical wavefronts at the ventricular level causing a delta wave and a fusion QRS complex with prolonged duration.

- The diagnosis of preexcitation is solely based on the findings of the surface ECG (see Figure 2 of the original guideline document). Intermittent preexcitation is not uncommon in newborns and infants. Depending on the location of the accessory pathway as well as the conduction properties of the atrioventricular node, even continuous preexcitation may be subtle and only detected in the mid-precordial leads.
- Clinical counterparts: In WPW syndrome the typical form of paroxysmal supraventricular tachycardia (orthodromic) results from reentry antegradely through the atrioventricular node and retrogradely through the accessory pathway. As digoxin shortens the antegrade effective refractory period of the accessory pathway and promotes rapid atrioventricular conduction during atrial flutter or atrial fibrillation over the pathway, the use of digoxin is contraindicated at any age. Verapamil should also be avoided as it may increase the ventricular response rate during atrial fibrillation in those patients, and may cause cardiovascular collapse in infants and young children.
- Work-up: Congenital heart disease is more common in infants and young children with preexcitation, with a prevalence as high as 45% for infants with an ECG pattern consistent with a right-sided accessory pathway. Thus, in every young patient with a preexcitation pattern on surface ECG, a complete 2-dimensional echocardiographic work-up is recommended to rule out any intracardiac abnormality.

  Assessment of the conduction properties of the accessory pathway, i.e., the antegrade effective refractory period and the shortest RR-interval with preexcitation, by transesophageal programmed stimulation may be useful in selected patients for risk stratification and mode of therapy.

QRS axis and amplitude

- Abnormal axis implies a mean frontal plane QRS vector outside the normal range and must take into account the relative right axis deviation seen in normal neonates. Left axis deviation is seen in a variety of abnormalities including atrioventricular septal defect, ventricular septal defect, tricuspid atresia, and Wolff-Parkinson-White (WPW) syndrome, but may be occasionally observed in otherwise normal infants.

Right ventricular hypertrophy

- Right ventricular hypertrophy may be suspected from a QR complex in V_1, an upright T wave in V_1 (normal in the first week of life), increased R wave amplitude in V_1, and increased S wave amplitude in V_6 (according to the Davignon criteria). Sensitivity and specificity has not been tested in the neonate. QR patterns are commonly seen with pressure overload congenital lesions, rSR´ patterns are seen in volume overload lesions.

Left ventricular hypertrophy

- The performance of the ECG in recognition of left ventricular hypertrophy is poorer than generally recognized and has not been specifically tested in neonates. Left ventricular hypertrophy is expected to produce increased left sided voltages. Garson described the most helpful ECG signs in children as being T wave abnormalities in leads V_5 and V_6, increased R wave amplitude in V_6, increased S wave amplitude in V_1 (according to the Davignon criteria), and a combination of these last two variables. Left to right shunt lesions may result in left ventricular hypertrophy, but this may be in association with right ventricular hypertrophy and manifested as biventricular hypertrophy. Left ventricular hypertrophy in the newborn may be attenuated by the normal right-sided predominance of the newborn. The normal premature heart may not have developed the right-sided predominance, especially if <28 weeks gestation, and left ventricular predominance may be present.

Low QRS voltage

- In the limb leads the total amplitude of R+S in each lead $\leq 0Â·5$ mV may be indicative of myocarditis or cardiomyopathy.
- Work-up: Evaluation of the underlying causes should be performed. An echocardiogram should be performed when clinically indicated.

Ventricular repolarization

- There is a simple reason that makes clinically important the analysis of ventricular repolarization abnormalities: their presence could be the harbinger of a significant risk for life-threatening arrhythmia. It is established that newborns found to have a prolonged QTc (>440 ms) on the fourth day of life have an increased risk for sudden death. Some of these sudden deaths have previously been labeled as Sudden Infant Death Syndrome.
- On the other hand, the presence of confounding factors--above all the ambiguities in their quantification--calls for caution before making hasty diagnoses associated with need for therapy and with considerable parental anxiety.
- Ventricular repolarization can be evaluated on the surface ECG by measuring the QT interval duration and by analysing the morphology of the ST segment and of the T wave. Measurements of the QT interval should be performed by hand.
- It is important to remember that QT duration may change over time. Accordingly, it is recommended repeating the ECG in those infants found to have a prolonged QTc on the first ECG. While exceptions do exist, the more prolonged the QTc interval, the greater the likelihood of its clinical significance. A QTc close to 500 ms implies a clear abnormality even taking into account potential measurement errors.

QT interval prolongation: differential diagnosis

- Electrolyte disturbances are fairly common and may cause QT prolongation. Among them, hypocalcaemia (less than $7Â·5$ mg . dL^{-1}) usually produces a distinctive lengthening of the ST segment. Hypokalaemia and hypomagnesaemia, often encountered in infants who have had vomiting or diarrhoea, usually decrease T wave amplitude and increase U wave

amplitude. Central nervous system abnormalities can produce QT prolongation and T wave inversion.

- Several drugs commonly used in the neonatal period and during infancy may induce QT interval prolongation; among them are macrolide antibiotics such as spyramycin, erythromycin, clarithromycin and also trimethoprim. Prokinetics such as cisapride have been positively linked to QT interval prolongation. All these drugs share one action: they block I_{Kr}, one of the ionic currents involved in the control of ventricular repolarization.
- Neonates born from mothers with autoimmune diseases and positive for the anti-Ro/SSA antibodies may also show QT interval prolongation, sometimes with QTc values exceeding 500 ms, which tends to be transient and to disappear by the sixth month of life, concomitantly with the disappearance of the anti Ro/SSA antibodies.
- Some of the neonates with QT interval prolongation may be affected by the congenital LQTS. This possibility has to be carefully evaluated because of its implications for management.

Long QT syndrome (LQTS)

- Long QT syndrome (LQTS) is characterized by the occurrence of syncopal episodes due to torsades de pointes ventricular tachycardia (VT) and by a high risk for sudden cardiac death among untreated patients. Importantly, in 12% of patients with LQTS, sudden death was the first manifestation of the disease and in 4% this happened in the first year of life. This point alone mandates the treatment of all those diagnosed as affected, even if there are no symptoms. Long QT syndrome is a genetic disease due to mutations of several genes all encoding ionic (potassium or sodium) currents involved in the control of ventricular repolarization. In most cases, several members of the same family are gene-carriers. Low penetrance exists in LQTS, which means that gene-carriers may not show the clinical phenotype and may have a normal QT interval. Therefore a normal QT in the parents does not rule out familial LQTS. In addition, approximately 30% of cases are due to 'de novo' mutations which imply unaffected parents and no family history. 'De novo' LQTS mutations have been demonstrated in infant victims of cardiac arrest and sudden death diagnosed as Sudden Infant Death Syndrome.
- Even though relatively few LQTS patients have cardiac events during the first year of life, the vast majority become symptomatic later on, either during childhood or adolescence according to genetic subgroups. Therefore treatment must continue. Beta-blockers are the first choice therapy in LQTS and are effective in preventing recurrences in 80% of already symptomatic patients; different degrees of protection exist according to genetic subgroups. If beta-blockers are unable to prevent new cardiac events, additional drug therapy, left cardiac sympathetic denervation, pacemakers or the implantable cardioverter defibrillator should be considered based on evidence, with due consideration for body size.
- ECG tracings of newborns with LQTS are shown in Figure 3 of the original guideline document.
- Work-up: It is well understood that the likelihood of having LQTS increases with increasing QTc; however, since a small percentage of LQTS patients has a QTc <440 ms, the correlation between QT prolongation and the presence of the syndrome is not absolute. Therefore, the following discussion is presented as guidelines based upon experience and current knowledge, and is likely to

be updated frequently. Given the life-threatening potential of the disease, once the diagnosis of LQTS becomes probable, it is recommended that these infants are referred to a specialist as soon as possible.

- First ECG: QTc above 440 ms, the upper limit of normal.

  Exclude other causes of acquired QT interval prolongation and obtain a detailed family history for the possibility of familial LQTS. Episodes of early sudden death, fainting spells, and seizures-epilepsy should alert to this possibility. The ECG should be repeated after a few days to confirm the abnormal finding. Subsequent management depends on (1) presence or absence of family history suggestive for LQTS, and (2) the degree of QT interval prolongation.

  The presence of complex ventricular arrhythmias would have additional importance. The following stepwise approach involves infants with and without a family history for LQTS (see Figure 4 of the original guideline document). If family history is positive, then--as LQTS is an autosomal dominant disease--the infant has a 50% probability of being affected and complete diagnostic procedures should be performed, as always with LQTS families.

- The second ECG is normal.

  If the first QTc was <470 ms, dismiss the case. If the first QTc was less than or equal to 470 ms, then plan a third ECG after 1-2 months to remain on the safe side.

- The second ECG shows a QTc between 440 and 470 ms.

  In these cases with persistent borderline QT prolongation, electrolytes, including calcium and magnesium, should be checked. Clinical history of autoimmune disease and plasma titres of maternal antibodies (anti Ro/SSA and antiLa) should be performed. T wave morphology may be helpful; for example, the presence of notches on the T wave in the precordial leads further suggests the presence of LQTS. Additionally, mild bradycardia can also be found in LQTS. ECGs should be obtained from the parents and siblings of the neonate.

  In the absence of family history of LQTS, symptoms or arrhythmias, a 24-hour Holter monitoring should be obtained to look for T wave alternans, complex ventricular arrhythmias or marked QTc prolongation, and the ECG should be periodically checked during the first year. No treatment is currently recommended. With a positive family history, the probability of LQTS becomes high. Additional diagnostic procedures (24-hour Holter monitoring, echocardiogram and genetic screening) should be performed and initiation of therapy could be considered.

- The second ECG shows a QTc greater than or equal to 470 and <500 ms.

All diagnostic procedures listed above should be performed and a third ECG should be planned within a month. In case of a positive family history, therapy should be initiated. Even without a family history, therapy should be considered.

Even in infants with a very prolonged QTc in the first month of life, the ECG may normalize. If subsequent ECGs and diagnostic procedures do not confirm the presence of LQTS, it is logical to progressively withdraw therapy and to return to periodic observations.

- <u>The second ECG shows a QTc greater than or equal to 500 ms</u>.

Infants with a QTc $\geq$500 ms are very likely to be affected by LQTS and to become symptomatic. All diagnostic procedures listed above should be performed and these infants should be treated.

Highest risk. The presence of QTc close to 600 ms, or of T wave alternans, or of 2:1 AV block secondary to major QT prolongation, or of hearing loss, identify infants at extremely high risk.

ST segment elevation

- Work-up: Whenever the underlying cause has been identified, it should be treated. If the Brugada syndrome is suspected, careful family history should be collected, 24-hour Holter monitoring obtained, and the patient should be referred to a specialist.

Atrial and ventricular arrhythmias

Atrial/junctional

<u>Premature atrial beats</u>

- A premature atrial beat is a premature P wave. Premature atrial beats usually have a different morphology and mean vector from sinus P waves. In regular sinus rhythm at a normal rate, a P wave that occurs before the next expected P wave is a premature atrial beat. A premature atrial beat may be conducted to the ventricles normally, or with ventricular aberration or not conducted or 'blocked'. Occasionally, blocked premature atrial beats occur in a bigeminal sequence, so-called 'blocked atrial bigeminy'. This rhythm simulates sinus bradycardia; it is important to examine the T waves carefully for blocked P waves (see Figure 5 of the original guideline document). In infants, since the refractory periods of the bundle branches are similar, premature atrial beats may be conducted with either RBBB or left bundle branch aberration. It is relatively common in the same strip to see premature atrial beats conducted normally, aberrantly and blocked.
- It is relatively uncommon for an infant to have both premature atrial beats and premature ventricular beats, although it does occur. Therefore, in an infant with premature P waves and wide QRS complexes on the same strip, a careful search should be made for a premature P wave preceding a wide QRS,

before making the diagnosis of both premature atrial beats and premature ventricular beats on the same strip.

- Work-up: In patients with frequent premature atrial beats, a follow-up ECG at 1 month may be performed. Relatively long periods of blocked atrial bigeminy may simulate sinus bradycardia. The distinction is important since blocked atrial bigeminy is most often benign while severe sinus bradycardia may accompany systemic illness.

Supraventricular tachycardia (SVT)

- SVT is a rapid regular tachyarrhythmia, which results from an abnormal mechanism originating proximal to the bifurcation of the bundle of His and does not have the morphology of atrial flutter. This definition of SVT specifically excludes sinus tachycardia (see Table 2 of the original guideline document) and premature wide QRS. The usual infant with SVT has an extremely regular R-R interval after the first 10-20 beats, most often at rates greater than 230 beats . min^{-1} and usually 260-300 per min. In 60% of cases, the P waves are visible, but the P waves almost always have a different morphology from sinus. In over 90% of infants and children with SVT, the QRS complex is narrow and in only 3% is the QRS complex different from the underlying sinus QRS.
- Therefore, the persistent aberration of SVT in infants is exceedingly rare, implying that in the majority of infants with a QRS complex different from sinus, the diagnosis is VT. In very rare cases of SVT in infants, there may be atrial tachycardia with AV block or junctional tachycardia with AV dissociation.
- Work-up: It is important to document SVT with a 12-lead ECG before attempting conversion of the rhythm unless the infant is critically ill. After sinus rhythm is achieved, the WPW pattern should be sought on a 12-lead ECG. Treatment to prevent further episodes of SVT in infancy is generally recommended. An echocardiogram is indicated to determine ventricular function or the presence of congenital heart disease.

Atrial flutter

- Atrial flutter is characterized by a rapid, regular form of atrial depolarization: the 'flutter wave'. The picket fence morphology is similar to adults. However, the flutter wave durations are generally 0·09 to 0·18 s with atrial rates in infants between 300-500 beats . min^{-1}. In general, there is variable AV conduction from 1:1 to 4:1 yielding an irregular ventricular rate.
- The QRS complex is usually the same as in sinus rhythm although there may be occasional aberrancy (see Table 2 of the original guideline document). Due to the occasional association with Wolff-Parkinson-White (WPW), this pattern should be specifically sought.
- Other types of supraventricular arrhythmias such as atrial fibrillation or multifocal tachycardia are extremely rare in the neonate.
- Work-up: Conversion to sinus rhythm should be attempted. An echocardiogram is worthwhile to determine ventricular function and the possible presence of congenital heart disease.

Ventricular arrhythmias

Premature ventricular beats

- A premature ventricular beat is manifest on the surface ECG as a premature abnormal QRS (not similar to the sinus QRS complex) that is not preceded by a premature P wave. It is important to recognize that in infants, the QRS duration may be normal--or slightly prolonged (i.e., less than 0Â·08 s)--but if the complex has a different morphology from the sinus, and is not preceded by a premature P wave, the diagnosis is a premature ventricular beat.
- The relationship between morphology and the site of origin is not exact enough to be able to predict which ventricle is causing the arrhythmia. It is not possible to distinguish premature ventricular beats from premature atrial beats with aberrancy on the basis of QRS morphology.
- Work-up: The QT interval should be measured carefully during periods of sinus rhythm (see section on repolarization abnormalities). In complex ventricular arrhythmias, 24-hour Holter monitoring may be worthwhile. An echocardiogram may be performed to determine ventricular function or structural abnormalities. Occasionally maternal drugs that cause ventricular arrhythmias may be transferred in utero or post-natally in breast milk.

Ventricular tachycardia (VT)

- Ventricular tachycardia (VT) is a series of three or more repetitive complexes that originate from the ventricles. The complexes are therefore different from the patient's normal QRS; usually, the QRS duration is prolonged for the age of the patient (0Â·09 s or more in infants). It is therefore usually a 'wide QRS' tachycardia. However, infants may have a QRS duration in VT less than 0Â·09 s but clearly different from the sinus complex (see Table 2 of the original guideline document).
- The specific morphology of the QRS is generally not helpful to distinguish VT from supraventricular tachycardia with aberration. However, SVT in infants with a different QRS beyond the first 10-20 beats is rare, therefore, in this situation, a diagnosis of VT should be strongly considered. In infants, the rate of VT may be from 200-500 beats . min-1.
- There may be a slight variation in the R-R interval over several beats. There may be sinus P waves continuing unrelated to VT (AV dissociation), retrograde P waves or no visible P waves. There may also be fusion and capture beats. The diagnosis of VT should be strongly considered if the patient has premature ventricular beats during times of sinus rhythm with a similar morphology to the tachyarrhythmia.
- Work-up: An underlying cardiac or central nervous system abnormality may be found in infants with VT. The QT interval should be carefully measured (see section on repolarization abnormalities), 24-hour Holter monitoring and echocardiogram should be obtained. Treatment is generally indicated.

Accelerated ventricular rhythm

- Accelerated ventricular rhythm is also known as 'slow VT'--generally the rate is <200 beats . min^{-1}. It occurs at approximately the same rate as the infant´s sinus rate, and the rhythms tend to alternate.
- Work-up: While these infants most often have a normal heart, a work-up similar to ventricular tachycardia (VT) is indicated.

CLINICAL ALGORITHM(S)

An algorithm on QT prolongation management is provided.

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

The type of supporting evidence is not specifically stated for each recommendation.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

In general, early identification of life-threatening arrhythmogenic disorders, which often manifest in infancy, childhood or even later, may allow initiation of effective preventive therapy.

POTENTIAL HARMS

Not stated

QUALIFYING STATEMENTS

QUALIFYING STATEMENTS

This guideline document is not intended to be all-inclusive or to substitute for textbooks on paediatric and neonatal electrocardiogram (ECG).

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

IMPLEMENTATION TOOLS

Clinical Algorithm
Personal Digital Assistant (PDA) Downloads
Pocket Guide/Reference Cards

For information about availability, see the "Availability of Companion Documents" and "Patient Resources" fields below.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Living with Illness
Staying Healthy

IOM DOMAIN

Effectiveness

Bulgarian Society of Cardiology - Medical Specialty Society
Czech Society of Cardiology - Medical Specialty Society
Estonian Cardiac Society - Medical Specialty Society
Finnish Cardiac Society - Medical Specialty Society
French Society of Cardiology - Medical Specialty Society
Hellenic Cardiological Society - Medical Specialty Society
Irish Cardiac Society - Medical Specialty Society
Italian Federation of Cardiology - Medical Specialty Society
Latvian Society of Cardiology - Medical Specialty Society
Lebanese Society of Cardiology - Medical Specialty Society
Lithuanian Society of Cardiology - Medical Specialty Society
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San Marino Society of Cardiology - Medical Specialty Society
Slovenian Society of Cardiology - Medical Specialty Society
Spanish Society of Cardiology - Medical Specialty Society
Swiss Society of Cardiology - Medical Specialty Society
Ukrainian Society of Cardiology - Medical Specialty Society

GUIDELINE STATUS

This is the current release of the guideline.

GUIDELINE AVAILABILITY

Electronic copies: Available from the European Society of Cardiology (ESC) Web site.

Print copies: Available from Elsevier Science Ltd. European Heart Journal, ESC Guidelines - Reprints, 32 Jamestown Road, London, NW1 7BY, United Kingdom. Tel: +44.207.424.4422; Fax: +44 207 424 4433; Web site: www.eurheartj.org.

AVAILABILITY OF COMPANION DOCUMENTS

The following is available:

- Recommendations for Task Force creation and report production. Sophia Antipolis (France): European Society of Cardiology, 2002. Electronic copies: Available in Portable Document Format (PDF) from the European Society of Cardiology (ESC) Web site.
- Interpretation of the neonatal electrocardiogram. Pocket guidelines. Order form available in Portable Document Format (PDF) from the ESC Web site. Also available for PDA download from the ESC Web site.

PATIENT RESOURCES

None available

NGC STATUS

This NGC summary was completed by ECRI on April 16, 2003.

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