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Physician's Guide to

VERITAS WITH ADULT AND PEDIATRIC RESTING ECG INTERPRETATION

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REFERENCE SUMMARY

VERITAS RESTING ECG INTERPRETATION EVALUATION

PREFACE

This guide describes the criteria that the Mortara Instrument VERITAS™ Adult and Pediatric Resting ECG Interpretation algorithm utilizes to analyze and provide interpretive statements for 12-lead ECGs.

Adult criteria are considered for patient ages 16 years and older. Adult descriptions are detailed in the first sections of this guide. Pediatric criteria are considered for patient ages 15 years and younger. Pediatric descriptions are detailed in the last sections of this guide.

Interpretive statements have two components, the actual interpretive text, and the optional reason statement, which immediately follows in each statement in this Physician's Guide and provides a synopsis of the principle criteria used to reach the specified conclusion. The intention is to provide these reason statements where users find them helpful. They can be omitted on all ECGs via a setup function on the electrocardiograph.

Interpretation of all ECGs proceeds in the sequence of the criteria listing. Ordinarily the last valid statement or conclusion reached within a given section supplants all prior statements.

A condition statement follows each interpretive statement. Conditions and their meanings are listed in order of increasing severity in the table below:

Condition	Meaning
Normal ECG	Normal
Atypical ECG	An unusual pattern has been observed but has no specific significance.
Borderline ECG	Criteria have limited specificity or prognostic significance or where only minimal criteria are met.
Abnormal Rhythm ECG	Abnormal Rhythm
Abnormal ECG	Abnormal
ACUTE MI	Criteria for new or recent myocardial infarction are true or an epicardial injury pattern has been detected
No Further Interpretation Possible	Upon detecting the phenomenon in question, no further useful interpretation of the record is possible.
No Condition Associated	Used with statement prefixes and suffixes.

The statement with the most severe condition provides the conclusion added at the bottom of the interpretative statements when printed. The condition for each statement can be found in the Reference Summary.

Precautions

The VERITAS algorithm generates both a rhythm classification and a contour classification based upon criteria described in this guide. These criteria may sometimes differ from criteria found in ECG textbooks or published literature which are intended to train or educate human ECG readers. Human readers and computer algorithms have different strengths and weaknesses. Human readers are less precise, but better able to evaluate the overall pattern of an ECG as well as including a patient's history and presentation in the evaluation. Computer algorithms are more precise in measuring amplitudes and durations, but less able to evaluate the overall pattern of the ECG and unable to consider a patient's history or presentation. This aspect, coupled with the fact that there are no universally agreed to criteria, means that criteria used for an ECG algorithm will sometimes differ from other published sources.

Statements generated by the VERITAS algorithm should always be reviewed by a physician. The ECG algorithm is not intended to replace a physician review of the ECG. Sensitivity and specificity limitations of ECG algorithms, coupled with their inability to incorporate patient history or presentation, underscore the essential need for physician review of any computer generated interpretation statements.

Not all Mortara products are equipped with the pediatric resting ECG interpretation feature.

Refer to the equipment user manual for proper instructions and precautions pertaining to equipment use.

Definitions

Abbreviations used in this guide and in some "reason" statements:

Abbreviation	Description
STJ	ST segment amplitude at QRS offset
STM	ST segment amplitude at ST segment midpoint
STE	ST segment amplitude at ST segment endpoint
T	Peak of the T wave
SSS	S-wave is present in lead I and lead II and lead III

RHYTHM STATEMENTS

Rhythm Statements and Modifiers

VERITAS rhythm statements describe the predominant rhythm in the 10 seconds of analyzed data. A modifier, listed after the rhythm statements, may also be added to more accurately describe the type of rhythm. The main rhythm statements and their criteria follow.

Rhythm Statements

Sinus Rhythm
Ectopic Atrial Rhythm
Junctional Rhythm
Supraventricular Rhythm

Idioventricular Rhythm

Uncertain Regular Rhythm
Uncertain Irregular Rhythm

Atrial Fibrillation
Atrial Flutter/Tachycardia

Electronic Atrial Pacemaker
Electronic Ventricular Pacemaker

Qualifications of the above rhythm statements based on rate are also generated. For example: “Sinus” may be Sinus Bradycardia, Sinus Rhythm, or Sinus Tachycardia. These rate qualifications are made for Sinus, Ectopic Atrial, Junctional and Supraventricular rhythm statements. Criteria for limits of Bradycardia and Tachycardia based on age are included in the Reference Summary.

Rhythm Statement Criteria

The rationale behind generation of the rhythm statements is described in the following sections. It is important to note that these descriptions are intended to provide a general overview of the VERITAS algorithm logic in a compact reference form. As such, some details and dependencies have been intentionally omitted to improve readability and understanding.

Electronic Atrial or Ventricular Pacemaker

In interpreting resting ECGs where a pacemaker is present, it is important to note that the VERITAS program does not attempt to assess pacemaker performance criteria such as failure to capture or failure to sense. The 10-second ECG is not adequate in duration for an algorithm to make this determination. All pacemaker generated statements are based upon pacing impulses that have been captured and hence resulted in stimulation of atrial or ventricular activity.

There are two independent tests for pacemaker detection: hardware-driven detection (hard pace detection) and software-driven detection (soft pace detection). Hard pace detection is based upon triggering hardware flags and the repeated presence of these flags in a minimum number of beats. These hardware flags are based upon detection of “spikes” in the high resolution front-end data stream (10,000 – 40,000 samples/second depending upon ECG front-end) preceding either atrial activity, ventricular activity, or both. If the hard pace criteria are met, then the appropriate pacemaker statement is set and the subsequent soft pace detection step is skipped.

Soft pace detection utilizes the acquisition data stream (1,000 samples/second) and inspects high frequency, "spike" activity, before atrial and ventricular complexes. This secondary test is used to detect impulses that did not pass the hard pace detection due to low amplitude and/or temporally wide pulses.

The distinction between atrial and ventricular pacing is made on the basis of the latency between the spike and the QRS complex.

The combined results of applying these two tests are presented in the *VERITAS Resting ECG Interpretation Evaluation* section.

If both electronically paced and intrinsic QRS complexes are found, the phrase "-- contour analysis based on intrinsic rhythm" is added to the statement. Most statements based on contour analysis are suppressed for paced complexes, with the exception of the most severe level of ST-elevation statements. Although this can lead to false positive "Acute MI" statements, this was deemed acceptable given the relatively low percentage of artificially paced ECGs in most hospital populations.

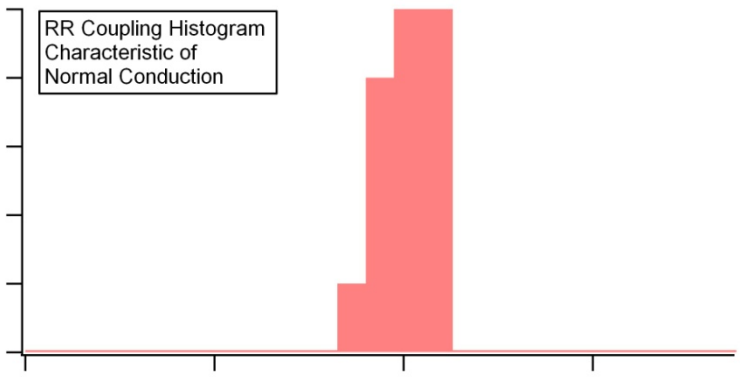
Atrial Flutter/Tachycardia

The Atrial Flutter/Tachycardia statement is generated if flutter waves (P-P) are detected with a rate above 200 and less than 350 beats per minute. Additionally, in the presence of a ventricular rate above 140 beats per minute, a statement of "Possible Atrial Flutter" will be generated.

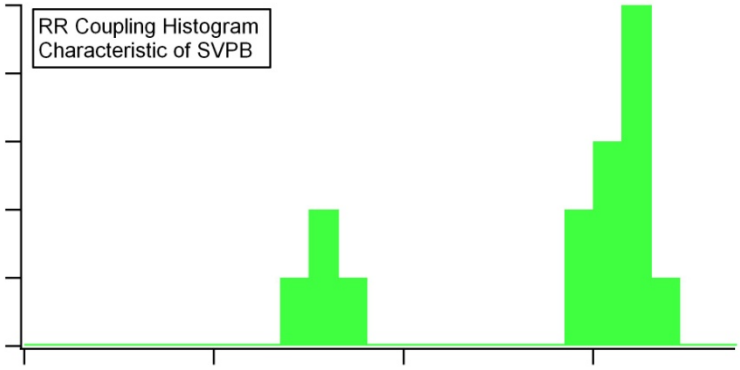
Note that the P-wave axis and PR interval are not defined in the presence of atrial flutter and hence will not be determined by VERITAS.

Atrial Fibrillation

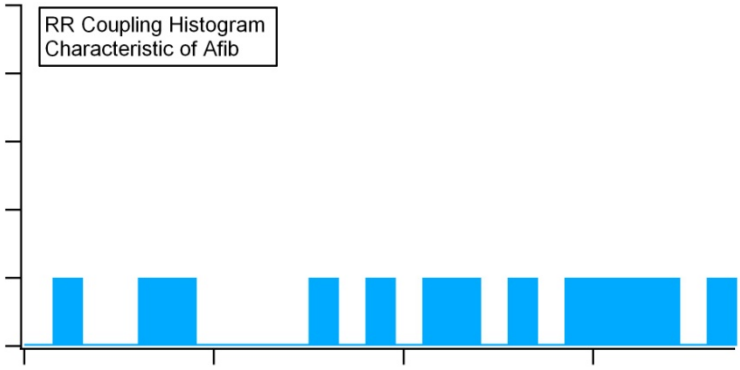
The Atrial Fibrillation statement is triggered based on the presence of low amplitude or undetected P waves in combination with a disorganized rhythm. A disorganized rhythm is characterized by the lack of "clustering" of RR intervals, while highly clustered RR intervals are indicative of an organized rhythm. The clustering criteria are utilized to distinguish premature atrial contractions, from atrial fibrillation as illustrated in the following RR histograms.



Sample RR histogram of normal conduction. Note single cluster of RR intervals characteristic of normal conduction at steady sinus rate.



Sample RR histogram in presence of SVPBs. Note two clusters of RR intervals. The larger cluster would be associated with the normal conduction, the smaller, shorter RR with SVPBs.



Sample RR interval histogram for atrial fibrillation. Note lack of clustering.

Note that the P-wave axis and PR interval are not defined in the presence of atrial fibrillation and hence will not be determined by VERITAS.

Sinus Rhythm

Sinus Rhythm is called in the presence of a normal P-wave axis, between -45 and 120 degrees. For a P-wave axis outside of this range, Ectopic Atrial or Junctional Rhythm is considered.

Junctional Rhythm

The Junctional Rhythm statement is generated in the presence of a superior P-wave axis between -60 and 240 degrees coupled with a short PR interval (less than 140 milliseconds).

Ectopic Atrial

The Ectopic Atrial Rhythm statement is generated in instances when the P-wave axis is outside of the criteria for Sinus Rhythm, but the PR interval is not shortened.

Supraventricular Rhythm

In instances when the QRS is narrow and the rhythm is organized, but no P-wave is detected, a statement of Supraventricular Rhythm is generated. The narrow QRS suggests conduction through the AV node, but the lack of P-wave detection leaves uncertainty as to whether the rhythm is Sinus or Ectopic Atrial in origin.

Note that the P-wave axis and PR interval are not defined when no P-wave is detected by VERITAS. Hence, these values will not be determined.

Idioventricular Rhythm

The Idioventricular Rhythm statement is generated with a slow (less than 45 beats per minute), wide QRS rhythm.

Uncertain Regular/Irregular Rhythm

The Uncertain Regular Rhythm statement is generated when a wide QRS rhythm with no apparent P-wave and regular RR interval is present. The Uncertain Irregular Rhythm statement is generated when a wide QRS rhythm with no apparent P-wave and irregular RR interval is present.

The previous rhythm statements can be qualified with the following modifiers.

Modifiers

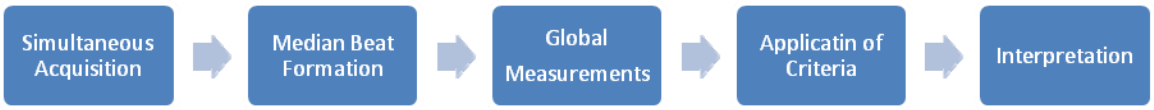
...with (marked) sinus arrhythmia
...with prolonged PR interval
...with short PR interval
...with second degree AV block, Mobitz Type (I, II)
...with high grade AV block
...with (occasional/frequent) ventricular premature complexes
...with (occasional/frequent) ectopic premature complexes
...with (occasional/frequent) atrial premature complexes
...with (occasional/frequent) supraventricular premature complexes
...in a pattern of bigeminy
...with marked rhythm irregularity, possible non-conducted PAC, SA block, AV block, or sinus pause
...possible atrial flutter (regular rate near 150)
...contour analysis based on intrinsic rhythm (pacemaker rhythm alternated with intrinsic rhythm)
...intermittent ventricular preexcitation/WPW

Modifiers Used with Atrial Fibrillation or Flutter

...with (rapid/slow) ventricular response
...with aberrant conduction or ventricular premature complexes

MEDIAN BEAT FORMATION AND MEASUREMENTS

The following summary provides a high-level review of how the Mortara VERITAS algorithm performs automatic ECG measurements. The general flow of how the Mortara algorithm functions is illustrated below.

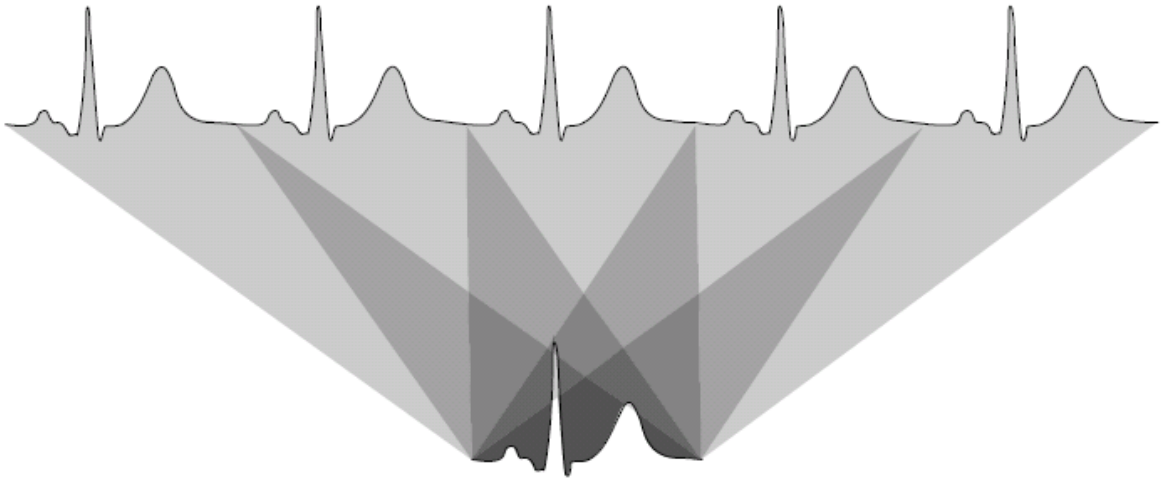


Simultaneous Acquisition

Following 12-lead or 15-lead simultaneous ECG acquisition using front end sampling rates of 10,000 or 40,000 kHz, ECG analysis is performed at 1000 samples/second/channel. Electrocardiographs using a WAM™ or AM12™ acquisition module feature 40,000 kHz sampling, all others feature 10,000 kHz sampling. The high resolution sampling rate is used to detect pacemaker pulses on the surface ECG. All other analysis is performed at the 1000 samples/second data resolution.

Median Beat Formation

The Mortara algorithm forms median[i] beats from all 12 leads of the ECG. Median beats are utilized to minimize the impact of noise present in any given single beat. Multiple global measurements can be determined utilizing the median beats including the PR, QRS, and QT duration. Median beat formation involves the identification of a "primary" beat type within a sequence of beats. This categorization identifies beats which are to be included in the median or representative beat formation. Beats which are not considered part of the "primary" class are not included in the formation of the median. In applying these criteria, beats such as occasional premature ventricular complexes are excluded from the median beat formation. Following selection of beats, the beats are aligned and combined to form the median beat. This concept is schematically illustrated in the figure below.



Global Measurements

With the median beats constructed, a series of "global" measurements can be obtained. These measurements are global in the sense that they are not lead specific, but rather span the 12-lead simultaneous data.

In the case of the PR, QRS and QT duration, the VERITAS algorithm determines onsets and offsets by reference to a composite measure of electrical activity reflecting the total activity across all leads. Specific comments for individual measurements follow.

QT

The Mortara algorithm determines QT from the interval between the earliest ventricular depolarization activity and the latest "end-of-T", considering all leads. This determination utilizes median beats, which reduce the effects of noise. A composite measure of electrical activity, reflecting the total activity across all leads, is formed from these median beats. This composite measure is then utilized to infer the moment of earliest ventricular depolarization and the latest "end-of-T". This "global QT" is naturally longer (statistically) than the QT measured in a single lead, due to the impact of isoelectric onsets/offsets in a single lead measurement. Moreover, in the presence of QT interval increases within a single individual's ECG, concomitant axis shifts of the T wave may cause the full extent of the QT increase to be more accurately recorded by the global QT measure.

QRS

The VERITAS algorithm determines QRS duration as the earliest QRS onset (as manifested in any of the 12-lead medians) to the latest QRS offset (considering all 12-lead medians). Comments regarding the "global QT" above similarly apply for the "global QRS".

PR

Using the 12-lead median beats, the Mortara algorithm determines the PR interval using the global onset for the P wave to the global onset of the QRS.

RR

The Mortara algorithm utilizes an average RR interval over 10 second period.

Individual Lead Measurements

Amplitudes and lead specific intervals, unlike global interval duration measurements, are performed on an individual lead basis. These measurements are determined using individual lead median beats and criteria are applied as described in the following sections.

[i] It should be noted that although the term "median" is used, the median beat is not a statistical median in the formal mathematical sense. It is a combination of both averaging and median techniques applied to the ECG signal.

Arm Lead Reversal and Dextrocardia

Criteria

IF	THEN
No Q in lead I and R amplitude < 150uV in lead I **or** Q amplitude > 0 in lead I and P axis > 90 and PR duration ≥ 110 ms and QRS axis > 90	PRINT "Arm leads reversed" **REASON**: *Inverted P & QRS in lead I*
If above criteria are met and R amplitude < 500 µV in lead V6 and Maximum S amplitude > Maximum R amplitude in lead V6 and P amplitude < 20 µV in lead V6 and P' amplitude < -20 µV in lead V6	PRINT "Dextrocardia" **REASON**: *Inverted P & QRS in V6*

Rationale

Simultaneously negative P and QRS contours in lead 'I' are unlikely in a properly recorded ECG. If, in addition, the QRS has a Qr (or rSr') configuration, the most probable explanation is that the arm leads are reversed or dextrocardia is present. If lead V6 has a typical upright configuration, arm lead reversal is more likely: otherwise, dextrocardia is the remaining plausible explanation.

Although the reason statement for both lead reversal and dextrocardia mentions only the inverted P & QRS, the requirement of Qr/rSr' morphology is important to distinguish these cases from pulmonary disease and right ventricular hypertrophy patterns, where rS configurations are the norm. (Further separation from the latter is ensured by the requirement of an inverted P.)

Ventricular Preexcitation

SKIP TEST IF
The test for coupled P wave to QRS is negative
or PR duration > 170 ms
or QRS duration < 100 ms
or Heart rate > 120 BPM
or QRS duration > 200 ms
or PR duration > 100 ms and QRS duration > 160 ms

Criteria

IF	THEN
PR duration < 140 ms and Delta wave is present in 2 leads **or** Delta wave is present in 2 leads and R amplitude > S amplitude in V1 **or** QRS area ratio ≥ 0.6 in 2 leads of I/V5/V6 and R duration > 30 ms in V2 or Delta wave is present in 2 leads and PR duration is < 140 ms and R amplitude ≤ S amplitude in V1	PRINT “Ventricular preexcitation/WPW”

Atrial Enlargement

Criteria

IF	THEN
Heart rate < 120 and P amplitude > 250 µV in any 1 of leads II/III/aVF/V1/V2	PRINT "Possible right atrial enlargement" **REASON**: *0.25 mV P wave*
Heart rate < 120 and P amplitude > 300 µV in any 1 of leads II/III/aVF/V1/V2	PRINT "Right atrial enlargement" **REASON**: *0.3 mV P wave*
P' amplitude < -100 µV in V1 or V2 and negative P wave area ≥ 400 µV/ms in the same lead	PRINT "Possible left atrial enlargement" **REASON**: *-0.1 mV P wave in V1/V2*
P' amplitude < -150 µV in V1 or V2 and negative P wave area ≥ 600 µV/ms in the same lead	PRINT "Left atrial enlargement" **REASON**: *-0.15 mV P wave in V1/V2*

Rationale

The criteria are the customary ones. For those records meeting only minimal criteria, the qualifier "possible" is used to convey this information. Right atrial enlargement is not "read" for rates of 120 or above, because it is unclear whether increased P amplitude at elevated rates should be attributed to enlargement.

Axis Deviation

Criteria

IF	THEN
QRS axis < -20	PRINT "Borderline Left axis deviation" **REASON**: *QRS axis < -20*
QRS axis < -30	PRINT "Marked Left axis deviation" **REASON**: *QRS axis < -30*
QRS axis > 90	PRINT "Borderline Right axis deviation" **REASON**: *QRS axis > 90*
QRS axis > 100	PRINT "Marked Right axis deviation" **REASON:** *QRS axis > 100*
The total net QRS amplitude in leads I, II, and III is < 33% of the total QRS deflection in leads I, II, and III.	PRINT "Indeterminate axis"

Rationale

The criteria are more or less conventional. (Axis deviation statements are omitted when subsequently identified diagnostic categories may be regarded as the probable cause of the axis deviation.)

Whenever the net amplitude is a small fraction of the total QRS deflection in each lead, the measurement of axis is lacking in meaning. The term "indeterminate axis" is used to convey this information.

Low Voltage

SKIP TEST IF
QRS duration ≥ 120 ms

Criteria

IF	THEN
Total QRS deflection < 500 µV in all limb leads	PRINT "Low QRS voltage in extremity leads" **REASON**: *QRS deflection < 0.5 mV in limb leads*
Total QRS deflection < 1000 µV in all V leads	PRINT "Low QRS voltage in precordial leads" **REASON**: *QRS deflection < 1.0 mV in chest leads*
If both of the above are true	PRINT "Low QRS voltage" **REASON**: *QRS deflection < 0.5/1.0 mV in limb/chest leads*

S1-S2-S3 Pattern

Criteria

IF	THEN
S amplitude > 300 µV in I and S amplitude > 400 µV in II and S amplitude > 700 µV in III **or** S amplitude > R amplitude in leads I, II & III and S amplitude > 200 µV in leads I, II & III and the test for R' is negative in any of these leads and age > 15	PRINT "S1-S2-S3 pattern, consistent with pulmonary disease, RVH, or normal variant"

Pulmonary Disease

SKIP TEST IF
QRS duration ≥ 120 ms

Criteria

The test for pulmonary disease is based on counting how many of its typical characteristics are present.

One point is awarded for each of

- Right atrial enlargement
- QRS axis < -30
- QRS axis > 90
- QRS axis is indeterminate
- S1-S2-S3 pattern
- Low voltage in limb leads
- Low voltage in chest leads

Three points are awarded if QRS net amplitude is negative in lead V5 and the R (and R') amplitude in V6 < 500 µV.

IF	THEN
Cumulative points > 3	PRINT “Pattern consistent with pulmonary disease”

Rationale

There is room to doubt whether sufficient ECG criteria exist to diagnose pulmonary disease. However, if at least 4 (from a list of 8 distinct) features common to pulmonary disease are present, then the comment “consistent with” seems prudent.

ADULT CONDUCTION ABNORMALITIES

Right Bundle Conduction

Criteria

IF	THEN
R amplitude > 100 µV in V1 & V2 and R duration > 20 ms in V1 and V2 and no S in V1 or V2 **or** R' amplitude > 100 µV in V1 & V2 and R' duration > 20 ms in V1 & V2 and no S' in V1 or V2	PRINT "Possible right ventricular conduction delay" **REASON**: RSR (QR) in V1/V2
Either of the above is true and QRS duration > 90 ms and QRS duration < 120 ms and S duration ≥ 40 ms in any 2 leads of I/aVL/V4/V5/V6	PRINT "Incomplete right bundle branch block" **REASON**: *90+ ms QRS duration, terminal R in V1/V2, 40+ ms S in I/aVL/V4/V5/V6*
QRS duration ≥ 120 ms **and** S duration ≥ 40 ms in any 2 leads of I/aVL/V4/V5/V6 or R duration > 60 ms and R amplitude > 500 µV in V1 **and** R duration < 100 ms in any 4 leads of I/aVL/V4/V5/V6 and QRS area > 0 in V1 and V1 does not terminate in S or S' **or** QRS duration > 105 ms and S duration ≥ 60 ms in any 3 leads of I/aVL/V4/V5/V6 and R duration > 60 ms in V1 and QRS area > 0 in V1	PRINT "Right bundle branch block" **REASON**: *120+ ms QRS duration, upright V1, 40+ ms S in I/aVL/V4/V5/V6*
The test for right bundle branch block is positive and R amplitude > 1500 µV in V1 and QRS axis > 110	PRINT "Right bundle branch block and possible Right Ventricular Hypertrophy" **REASON**: *RBBB, 1.5 mV R in V1, RAD*

Rationale

Right bundle branch conduction abnormalities exhibit anterior and rightward directed terminal forces. The rightward force should be noticeably prolonged. Thus, in addition to QRS conducting time criteria, tests are included for a widened terminal R wave in V1 and widened terminal S waves in at least two of the lateral leads. Conventional criteria require QRS widths in excess of 0.12 seconds for bundle branch block. However, very wide lateral S waves, a wide R in an upright V1, and QRS duration > 105 ms will also be read as right bundle branch block by most interpreters. This is the basis of the second portion of the complete right bundle branch block test. Specific criteria for right bundle branch block + right ventricular hypertrophy are also included.

Left Bundle Conduction

Criteria

IF	THEN
QRS duration > 105 ms and QRS net amplitude < 0 in V1 & V2 and S duration ≥ 80 ms in V1 & V2 and no Q is present in 2 leads of I/V5/V6 and R duration ≥ 60 ms in 2 leads of I/aVL/V5/V6	PRINT "Moderate intraventricular conduction delay" **REASON**: *105+ ms QRS duration, 80+ ms Q/S in V1/V2, no Q and 60+ ms R in I/aVL/V5/V6* Note: This pattern is sometimes described as "Incomplete left bundle branch block"
QRS axis ≤ -45 and R amplitude > Q amplitude in I & aVL and a Q is present in I and S or S' amplitude > R amplitude in II	PRINT "Left anterior fascicular block" **REASON**: *QRS axis ≤ -45, QR in I, RS in II*
The test for S1-S2-S3 is negative, and the test for Pulmonary Disease is negative and QRS axis ≥ 110 and R amplitude > Q amplitude in III & aVF and a Q is present in III & aVF	PRINT "Left posterior fascicular block" **REASON**: *QRS axis > 109, inferior Q*
QRS net amplitude < 0 in V1 & V2 and S duration ≥ 80 ms in V1 & V2 and Q amplitude < 50 µV in 2 leads of I/V5/V6 and R duration ≥ 60 ms in 2 leads of I/aVL/V5/V6 and QRS area ratio > 0.25 in I or V6 and R duration ≥ 100 ms in 1 lead of I/aVL/V6 **and** QRS duration ≥ 160 ms **or** QRS duration ≥ 140 ms and the average R duration > 85 ms in I/aVL/V6 **or** QRS duration ≥ 120 ms and the average R duration > 85 ms in I/aVL/V6 and QRS area ratio > 0.4 in 2 leads of I/aVL/V6	PRINT "Left bundle branch block" **REASON:** *120+ ms QRS duration, 80+ ms Q/S in V1/V2, 85+ ms R in I/aVL/V6*

Rationale

The meaning of incomplete left bundle branch block beyond describing an ECG pattern is unknown. For this reason the wording of the statement is generic, the criteria are narrowly defined, and whenever a specific label such as left anterior fascicular block is available, the term incomplete left bundle branch block is suppressed.

The test for left bundle branch block introduces a measurement called the "QRS area ratio," which is defined as the ratio of the QRS area (algebraic) to the area of a rectangle defined by QRS onset and offset and the peak positive amplitude. The area ratio is large whenever the QRS is upright and has a wide or notched R wave peak. The thresholds used in the above left bundle branch block tests are empirically determined to correlate with typical left bundle branch block patterns. The area ratio is used in lieu of R duration in order to better discriminate between true left bundle branch block and a monophasic (upright) QRS with nonspecific terminal slurring of the R wave leading to increased QRS duration.

Strict criteria for fascicular blocks are used. This should be noted by readers who use simple axis deviation tests.

Non Specific Conduction Abnormality

Criteria

IF	THEN
The test for Right Bundle Branch Block is negative and The test for Incomplete Right Bundle Branch Block is negative and The test for Left Bundle Branch Block is negative and The test for Incomplete Left Bundle Branch Block is negative and The test for left anterior fascicular block is negative and The test for left posterior fascicular block is negative and The test for RSR Pattern is negative and QRS duration > 110 ms	PRINT “Moderate intraventricular conduction delay” **REASON:** *110+ ms QRS duration*
The test for Right Bundle Branch Block is negative and The test for Left Bundle Branch Block is negative and QRS duration > 130 ms	PRINT “Intraventricular conduction delay” **REASON:** *130+ ms QRS duration*

Rationale

Moderate intraventricular conduction delay is used to connote moderate QRS widening which does not fit any previously defined pattern. Intraventricular conduction delay is used with marked QRS widening. The term “block” is avoided, since the reason for the slow conduction is not clear.

ADULT HYPERTROPHY

Right Ventricular Hypertrophy

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, right bundle branch block or left bundle branch block is positive
or age < 16
or S amplitude < 250 µV in I
or S amplitude > 1000 µV in V1
or QRS axis < 60
or QRS duration > 140 ms and net QRS amplitude < 0 in V1
or Q amplitude > S amplitude and R exists in I

Criteria

The test for right ventricular hypertrophy is based on counting how many of (or in what degree) its common characteristics are present.

One point is awarded for each of:

- R/R′ amplitude > 500 µV in V1
- Net QRS amplitude > 0 in V1
- Net QRS amplitude > 500 µV in V1
- Net QRS amplitude < 0 and S amplitude > 500 µV in V5 or V6
- QRS axis ≥ 90
- QRS axis ≥ 100
- QRS axis ≥ 110
- Possible right atrial enlargement has been called
- S1, S2, S3 is present
- Age>30
- If Indeterminate Axis is true, no points are given for QRS axis

IF	THEN
Cumulative points > 3	PRINT "Possible right ventricular hypertrophy" **REASON:** *Some/all of: prominent R in V1, late transition, RAD, RAE, SSS*
Cumulative points > 5	PRINT "Right ventricular hypertrophy" **REASON:** *Some/all of: prominent R in V1, late transition, RAD, RAE, SSS*
The test for possible right ventricular hypertrophy is positive and STJ > STM > STE **or** one of (STM, STE, and T) < -100 µV in V1, V2, and V3 and QRS duration < 120 ms	PRINT "Right ventricular hypertrophy and ST-T change" **REASON:** *Some/all of: prominent R in V1, late transition, RAD, RAE, SSS, right precordial ST depression*

NOTE: *STJ = ST segment amplitude at QRS offset; STM = ST segment amplitude at ST segment midpoint; STE = ST segment amplitude at ST segment endpoint; T = peak of the T wave.*

Left Ventricular Hypertrophy

Criteria

Tests for left ventricular hypertrophy include various voltage criteria, QRS duration, repolarization abnormalities (strain), and left atrial enlargement (as a correlated factor). To arrive at composite voltage criteria, the common standard criteria are scored by degree of excess over the appropriate threshold. These thresholds depend on the age of the patient, as well as the lead or combination of leads.

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, or left bundle branch block is positive **or** QRS duration > 140 ms and net QRS amplitude < 0 in V1

Thresholds

AGE	S(V1)	R(V5)	R(Max of V5 or V6) + S(V1)
<20	--	--	--
20-29	3.0 mV	3.0 mV	4.5 mV
30-39	2.4 mV	2.6 mV	4.0 mV
40+	2.4 mV	2.6 mV	3.5 mV

A threshold of 1.1 mV for R (aVL) is used independent of age or sex.

Voltage Criteria

IF	THEN SCORE
R/R'(aVL) > 1.1 mV	2 points + 1 point/0.1 mV excess
S/S'(V1) > threshold	2 points + 1 point/0.2 mV excess
R/R'(V5) > threshold	2 points + 1 point/0.2 mV excess
R/R' (V5/V6)+S/S_(V1) > threshold	2 points + 1 point/0.3 mV excess

The measure of QRS conduction time in the context of left ventricular hypertrophy is from QRS onset to the peak negative second derivative after the R peak in V5. Ordinarily, the latter point corresponds to the S nadir:

IF	THEN
Cumulative points > 0	Left ventricular hypertrophy is possible
Cumulative points > 2	Moderate voltage criteria for left ventricular hypertrophy exists
Cumulative points > 4	Voltage criteria for left ventricular hypertrophy are present
Peak 2nd derivative - QRS onset > 68 ms in V5	The conduction time threshold is met
The test for Atrial Fibrillation is negative and (STE < STJ) and (STE < -50 µV) and (R amplitude > 1100 µV) in at least 1 lead of I, aVL, V4, V5 and V6 **or** T amplitude (V1) + T amplitude (V6) > 200 µV	Left ventricular hypertrophy exists with repolarization abnormalities
Cumulative points are > 0 and the conduction time threshold is exceeded **or** the criteria for possible left atrial enlargement are met **or** left ventricular hypertrophy with repolarization abnormalities exists	Non-voltage criteria for left ventricular hypertrophy are present.
Cumulative points are > 0 and voltage criteria exist for left ventricular hypertrophy	PRINT "Minimal voltage criteria for left ventricular hypertrophy, consider normal variant" **REASON:** *Meets criteria in one of: R(aVL), S(V1), R(V5), R(V5/V6)+S(V1)*
Cumulative points are > 2 and voltage criteria exist for left ventricular hypertrophy	PRINT "Moderate voltage criteria for left ventricular hypertrophy, consider normal variant" **REASON:** *Meets criteria in one of: R(aVL), S(V1), R(V5), R(V5/V6)+S(V1)*

Left Ventricular Hypertrophy Criteria (Continued)

IF	THEN
Cumulative points are > 4 and voltage criteria exist for left ventricular hypertrophy	PRINT "Voltage criteria for left ventricular hypertrophy" **REASON:** *Meets criteria in one of: R(aVL), S(V1), R(V5), R(V5/V6)+S(V1)*
Non-voltage criteria are met and the test for repolarization abnormalities is negative	PRINT "Possible left ventricular hypertrophy" **REASON:** *Voltage criteria plus LAE or QRS widening*
Non-voltage criteria are met and repolarization abnormalities exist	PRINT "Left ventricular hypertrophy and ST-T change" **REASON:** *Voltage criteria plus ST/T abnormality*
Cumulative points are > 2 **or** Non-voltage criteria are met	A flag for Left Ventricular Hypertrophy is set which is used in conjunction with other criteria

Rationale

ECG criteria for left ventricular hypertrophy are imperfect. The sensitivities of various favorite voltage criteria are not better than 30-40%. Specificities greater than 90% may initially seem sufficient, but application to a general population would evidently generate more false than true positives. The philosophy in the above criteria has been to combine several voltage criteria in order to increase the net sensitivity. In order to minimize the impact of an unavoidable decrease of specificity, records minimally exceeding only one criterion and exhibit no non-voltage criteria are identified as possible normal variants. In all cases, records meeting only voltage criteria are identified as such.

Non-voltage tests for left ventricular hypertrophy include the presence of left atrial enlargement, QRS widening, and repolarization changes. Whenever any of these are present in combination with at least one voltage criterion, a stronger statement is made. A new measure of QRS widening is used in place of intrinsicoid deflection time and/or the total QRS width. Instead, an attempt is made to measure the duration of leftward forces in lead V5. The motivation is to be more sensitive than intrinsicoid timing, while avoiding spurious increases in total QRS duration.

Repolarization changes, for the purpose of identifying non-voltage left ventricular hypertrophy criteria, include depressed, downsloping ST segments in any of the lateral leads, or a T amplitude in V1 greater than that in V6.

ADULT MYOCARDIAL INFARCT

Myocardial Infarct Discussion

Computer criteria for myocardial infarct depart from standard textbook criteria in greater degree than most electrocardiographers would probably expect. The reason is that conventionally accepted criteria describe stereotypical infarction. When these criteria are applied, they have a high specificity, but a very low sensitivity. For example, a recent review of inferior infarct criteria reported a sensitivity of only 4% using New York Heart Association criteria. In order to achieve more useful results, computer programs must incorporate some of the same unpublished "unconventional" criteria used by experienced ECG interpreters.

Conventional criteria focus on Q wave duration as the primary test for the presence of infarction, and the computer tests that follow naturally retain this focus. The single most important additional criterion, seldom mentioned in reviews in infarction criteria, is a test for repolarization abnormalities characteristic of acute or recent infarction. For example, elevated ST segments and negative T waves are strong indicators of infarction in the presence of otherwise non-diagnostic Q waves. Taking into account these repolarization abnormalities greatly increases both sensitivity and specificity for new or recent infarcts. For old infarcts, the problem is more complex. Gains can be made by considering Q and R wave amplitudes and QRS duration. These factors are quantitatively added by converting to "Q duration equivalents." Thus for every 30 μV of Q amplitude, 1 ms is added to the actual Q duration to obtain an "equivalent" duration. Likewise, for each 120 μV of R amplitude, 1 ms is subtracted, and for every 4 ms of QRS duration beyond 100 ms, 1 ms is added (up to a maximum correction of 5 ms), or subtracted for durations less than 100 ms. This last factor attempts to exploit the frequent increase in QRS duration concomitant with infarction, whether due to left ventricular hypertrophy, peri-infarction block or other types. To further reduce the impact of a wide, but very small Qs, the equivalent duration is reduced by 1 ms for every μV that the Q amplitude is short of 100 μV.

Age and sex affect the a priori probability of infarction. These factors are also incorporated by modifying the equivalent Q duration. For males, 1 ms is subtracted from the equivalent Q duration for every two years under the age of 40, up to a maximum correction of 10 ms. Likewise, for females, 1 ms is subtracted for every two years under 50, again up to a maximum of 10 ms.

It should be noted that the above adjustments to the equivalent Q duration are not very large, and should not be expected to cause unreasonable departures from conventional interpretation. Mostly, they can expect to affect the certainty attached to a given interpretation.

With some exception, infarct diagnostic statements are given qualifiers intended to reflect the certainty of the particular interpretation. These qualifiers are:

- Possible. . . Typical equivalent Q duration 30-34 ms
- Probable. . . Typical equivalent Q duration 35-39 ms
- (Unqualified). . . Typical equivalent Q duration 40+ ms

The presence of repolarization abnormalities characteristic of the infarct can cause the qualifier to be omitted, that is, upgrade to strongest statement.

Anterior Infarct

Define: **Alternate T amplitude =**
1. If the test for T' is negative, T - larger of STE or T end
2. If the test for T'□ is positive, lesser of T & T' - larger of STE or T end

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation or left bundle branch block is positive **or** QRS duration > 140 ms and net QRS amplitude < 0 in V1

Criteria

IF	THEN
STM and STE amplitude > 200 µV in V3 and V4 and Alternate T amplitude ≥ 0 in V3 and V4	Conditions for a new anterior infarct are present
STM and STE amplitude > 50 µV in V3 or V4 and Alternate T amplitude < 0 in V3 or V4	Conditions for a recent anterior infarct are present
Criteria for a new or recent anterior infarct are not met and STM amplitude < 30 µV in V3 and V4 and Alternate T amplitude ≥ 0 in V3 and V4	Conditions for an old anterior infarct are present
Criteria for a new, recent or old anterior infarct are not met	The age description is “of indeterminate age”
Equivalent Q duration ≥ 30 ms in V2 or V4	Test 1 for anterior infarct is positive
Equivalent Q duration ≥ 30 ms in V3 or V5	Test 2 for anterior infarct is positive
Equivalent Q duration ≥ 30 ms in V3 and Test 1 for anterior infarct is positive **or** Equivalent Q duration ≥ 30 ms in V4 and Test 2 for anterior infarct is positive **or** R amplitude < 200 µV in V4	PRINT “Possible anterior infarct” **REASON**: *30 ms Q wave in V3/V4 or R < 0.2 mV in V4*
Equivalent Q duration ≥ 35 ms in V3 and Test 1 for anterior infarct is positive and the left ventricular hypertrophy flag is not set **or** Equivalent Q duration ≥ 35 ms in V4 and TEST 2 for anterior infarct is positive	PRINT “Probable anterior infarct” **REASON**: *35 ms Q wave in V3/V4*

Anterior Infarct Criteria (Continued)

IF	THEN
Equivalent Q duration ≥ 40 ms in V3 and Test 1 for anterior infarct is positive and the left ventricular hypertrophy flag is not set and the test for low voltage in the chest leads is negative and the test for non-specific intraventricular conduction block is negative **or** Equivalent Q duration ≥ 40 ms in V4 and Test 2 for anterior infarct is positive **or** If the test for "Possible anterior infarct" is positive and either recent or new criteria have been met	PRINT “Anterior infarct” **REASON:** *40+ ms Q wave and/or ST/T is abnormality in V3/V4*

IF	THEN APPEND
Anterior infarct is new	Possibly acute
Anterior infarct is recent	Probably recent
The age of the anterior infarct is undetermined	Of indeterminate age
Anterior infarct is old	Probably old

Septal Infarct

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation or left bundle branch block is positive **or** the test for anterior infarct is positive and Q amplitude > 0 in V1 **or** QRS duration > 140 ms and net QRS amplitude < 0 in V1

Criteria

IF	THEN
STM and STE amplitude > 200 µV in V2 and alternate T amplitude ≥ 0 in V2	"New" septal infarct is present
STM and STE amplitude > 50 µV in V2 and alternate T amplitude < 0 in V2	"Recent" septal infarct is present
Septal infarct is not new or recent and STM amplitude < 50 µV in V2 and alternate T amplitude ≥ 0 in V2	Septal infarct is "old"
The criteria for a septal infarct have been met and it is neither new, recent, or old	Qualifier "Of indeterminate age" will be used
Equivalent Q duration ≥ 30 ms in V2 **or** the test for Right Bundle Branch Block is positive and Equivalent Q duration > 20 ms in V2	PRINT "Possible septal infarct" **REASON:** *30 ms Q wave in V1/V2*
Equivalent Q duration ≥ 35 ms in V2 and left ventricular hypertrophy flag is not set	PRINT "Probable septal infarct" **REASON:** *35 ms Q wave in V1/V2*
Equivalent Q duration ≥ 40 ms in V2 and the left ventricular hypertrophy flag is not set	PRINT "Septal infarct" **REASON:** *40+ ms Q wave in V1/V2*

IF	THEN APPEND
Septal infarct is new	Possibly acute
Septal infarct is new	Probably recent
The age of the septal infarct is undetermined	Of indeterminate age
Septal infarct is old	Probably old

Anteroseptal Infarct

SKIP TEST IF
Positive criteria for a Lateral Infarct exists

Criteria

IF	THEN
Both an anterior infarct and a septal infarct cannot be ruled out	PRINT "Possible anteroseptal infarct" **REASON:** *30 ms Q wave in V1-V4*
Anteroseptal infarct cannot be ruled out and if the test for anterior infarct or septal infarct is positive	PRINT "Probable anteroseptal infarct" **REASON:** *35 ms Q wave in V1-V4*
Anteroseptal infarct cannot be ruled out and either an unqualified anterior or septal infarct exists	PRINT "Anteroseptal infarct" **REASON:** *40+ ms Q wave in V1-V4*
A recent septal infarct or anterior infarct has been called	"Probably recent" will be appended to the anteroseptal infarct call
Anterior infarct is not recent and either a new septal infarct or anterior infarct exists	"Possibly acute" is appended to the anteroseptal infarct call
Anterior infarct is not new and the tests for septal infarct age undetermined and/or anterior infarct age undetermined are positive	"Of indeterminate age" is appended to the anteroseptal infarct call
The tests for both septal infarct old and anterior infarct old are positive	"Probably old" is appended to the anteroseptal infarct call

Lateral Infarct

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker or ventricular preexcitation is positive

Criteria

IF	THEN
STM AND STE AMP > 200 µV in V5 & V6 and STM and STE amplitude > 100 µV in I & aVL and Alternate T amplitude ≥ 0 in I, aVL, V5 & V6	New lateral infarct is present
STM and STE amplitude > 50 µV in I, aVL, V5 or V6 and Alternate T amplitude < 0 in I, aVL, V5 or V6	Recent lateral infarct is called
The criteria for new or recent lateral infarct are not met and STM < 30 µV in I, aVL, V5 and V6 and alternate T amplitude > 0 in I, aVL, V5 or V6	Old lateral infarct is present
The tests for new, recent or old lateral infarct are negative	Qualifier “of indeterminate age:” will be used
Equivalent Q duration ≥ 30 ms in 2 leads of I/V5/V6 and test for Right Bundle Branch Block is positive **or** Equivalent Q duration ≥ 30 ms and Q amplitude ≥ 300 µV in 2 leads of I/V5/V6	PRINT “Possible lateral infarct” **REASON**: *30 ms Q wave in I/aVL/V5/V6*
Equivalent Q duration ≥ 35 ms in 1 lead of I/V5/V6 and the test for “possible lateral infarct“ is positive	PRINT “Probable Lateral infarct” **REASON**: *35 ms Q wave in I/V5/V6*
Equivalent Q duration ≥ 40 ms in 1 lead of I/V5/V6 and the test for lateral infarct is positive **or** the test for “possible lateral infarct“ is positive and the tests for a new or recent lateral infarct are positive	PRINT “Lateral infarct” **REASON**: *40+ ms Q wave and/or ST/T abnormality in I/aVL/V5/V6*

Lateral Infarct Criteria (Continued)

IF	THEN APPEND
Lateral infarct is new	Possibly acute
Lateral infarct is recent	Probably recent
The age of the lateral infarct is undetermined	Of indeterminate age
Lateral infarct is old	Probably old

Anterolateral Infarct

Criteria

IF	THEN
Both an anterior infarct and a lateral infarct "cannot be ruled out"	PRINT "Possible anterolateral infarct" **REASON:** *30 ms Q wave in I/aVL/V3-V6*
The tests for anterior infarct or lateral infarct are positive	PRINT "Probable anterolateral infarct" **REASON:** *35 ms Q wave in I/aVL/V3-V6*
The tests for an unqualified anterior infarct or lateral infarct are positive	PRINT "Anterolateral infarct" **REASON:** *40+ ms Q wave in I/aVL/V3-V6*
The test for either a recent lateral infarct or anterior infarct is positive	"Probably recent" is appended to the anterolateral infarct statement
The infarct is not a recent anterolateral infarct and the test for a new lateral infarct or anterior infarct is positive	"New" anterolateral infarct is present "Probably acute" is appended to the statement
The infarct is not a new anterolateral infarct and the tests for "age undetermined" lateral infarct and/or an "age undetermined" anterior infarct are positive	"Age undetermined" anterolateral infarct is present "of indeterminate age" is appended to the statement
Both the lateral infarct and anterior infarct are qualified as "old"	Anterolateral infarct call will be qualified as "probably old"

Inferior Infarct

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation or left bundle branch block is positive

Criteria

IF	THEN
STM and STE amplitude > 100 µV in 2 leads of II/III/aVF **or** STM and STE amplitude > 75 µV in 2 leads of II/III/aVF and STM amplitude < -50 µV in 2 leads of V1/V2/V3 and QRS duration < 120 ms **and** Alternate T amplitude ≥ 0 in 2 leads of II/III/aVF	"New" inferior infarct is present
STM and STE amplitude > 50 µV in 2 leads of II/III/aVF and Alternate T amplitude < 0 in 2 leads of II/III/aVF	"Recent" inferior infarct is present
Inferior infarct is not new or recent and STM amplitude < 30 µV in 2 leads of II/III/aVF and Alternate T amplitude ≥ 0 in 2 leads of II/III/aVF	Inferior infarct is "old"
inferior infarct is not new, recent, or old	Qualifier "of indeterminate age" will be used
Equivalent Q duration ≥ 30 ms in II or aVF Q amplitude in lead I < Q amplitude in lead II **or** Q amplitude in lead I < Q amplitude in aVF	PRINT "Possible inferior infarct" **REASON:** *30 ms Q wave in II/aVF*
Equivalent Q duration ≥ 35 ms in II or aVF and an inferior infarct cannot be ruled out	PRINT "Probable inferior infarct" **REASON:** *35 ms Q wave in II/aVF*
Inferior infarct cannot be ruled out and Equivalent Q duration ≥ 40 ms in II or aVF **or** The test for a new or recent Inferior infarct is positive	PRINT "Inferior infarct" **REASON:** *40+ ms Q wave and/or ST/T abnormality in II/aVF*

Inferior Infarct Criteria (Continued)

IF	THEN
QA > S amplitude in 1 lead of II & aVF	Suppress Abnormal left Axis Deviation
Inferior infarct is “new”	Append “possibly acute”
Inferior infarct is “recent”	Append “probably recent”
Age of the inferior infarct is undetermined	Append “of indeterminate age”
Inferior infarct is “old”	Append “probably old”

Inferior Infarct with Posterior Extension

SKIP TEST IF
The test for an inferior infarct is negative
The test for Right Bundle Branch Block is positive
A Q-wave is present in V1 or V2

Criteria

IF	THEN
R duration ≥ 40 ms in V1 & V2 **or** R duration ≥ 35 ms and QRS net amplitude > 0 in V1 or V2 **or** R duration ≥ 30 ms and QRS net amplitude > 0 in V1 and V2	Append “with posterior extension” “prominent R Wave in V1/V2” to the inferior infarct statement

Infarct Suppressions

Criteria

IF	THEN
The test for inferior infarct, lateral infarct, anteroseptal infarct or septal infarct is positive	Suppress left axis deviation, incomplete left bundle branch block, intraventricular conduction delay
The test for anteroseptal infarct or a lateral infarct is positive	Suppress pulmonary disease

ADULT ST ELEVATION

ST Segment Elevation

SKIP TEST IF
The test for either arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, right bundle branch block, left bundle branch block, marked intraventricular conduction delay, myocardial infarction or left ventricular hypertrophy with repolarization is positive

Criteria

IF	THEN
STJ/STM/STE all ≥ 50 µV and T is not upward inflected in 2 leads of I, II, III, aVF, V3-V6	PRINT "Nonspecific ST elevation" **REASON:** *0.05+ mV ST elevation*

Early Repolarization

SKIP TEST IF
Corrected QT interval > 460 ms in males or > 470 ms in females
The test for arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, myocardial infarction, right bundle branch block, left bundle branch block, marked intraventricular conduction delay or left ventricular hypertrophy is positive

Criteria

IF	THEN
Count of leads V1-V6 for which STJ and STM amplitude > 75 µV plus count of leads I, II, III, aVL, aVF for which STJ & STM > 50 µV exceeds 2 and sum of STJ amplitudes > 450 µV for leads passing above test	PRINT "ST elevation, consistent with injury, pericarditis, or early repolarization" **REASON:** *ST elevation w/o normally leads inflected T wave*
ST elevation is present, per the above conditions and more than 1/2 of the leads passing ST elevation test above also have well-inflected T waves	PRINT "ST elevation, probably early repolarization" **REASON:** *ST elevation with normally inflected T wave*
Above count > 5 and sum > 450 µV	PRINT "Early repolarization" **REASON:** *ST elevation with normally inflected T wave*

Pericarditis

SKIP TEST IF
The test for arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, myocardial infarction, right bundle branch block, left bundle branch block, marked intraventricular conduction delay or left ventricular hypertrophy is positive

Criteria

IF	THEN
4 times STJ & T amplitude & T amplitude > 0 in at least 4 leads of I, II, V4-V6 and STJ and STM amplitude > -100 µV in all leads except aVR and count of leads I, II, aVF with STJ and STM amplitude > 75 µV plus count of leads V2-V6 with STJ and STM amplitude > 90 µV is ≥ to 5	PRINT "Possible acute pericarditis – exclude acute MI" **REASON:** *Marked ST elevation w/o normally inflected T wave*
Possible acute pericarditis is present and count of leads I, II, aVF with STJ and STM amplitude > 90 µV plus count of leads V2-V6 with STJ and STM amplitude > 110 µV is ≥ to 5	PRINT "Acute pericarditis – exclude acute MI" **REASON:** *Marked ST elevation w/o normally inflected T wave*

Anterior and Septal Epicardial Injury

SKIP TEST IF
The test for pericarditis is positive

DEFINE
ST LIMIT = 300 µV (add 100 µV for any precordial lead with net QRS amplitude < 0)

Criteria

IF	THEN
STJ amplitude > ST LIMIT/2 in V1 and V2 and T is not upward inflected V1 or V2 or 6 times STJ amplitude > QRS deflection in V1 and V2 or the test for septal infarct is negative **and** the tests for left ventricular hypertrophy, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, right bundle branch block and intraventricular conduction block are negative or R amplitude > 1.5 times S amplitude in V1 and V2	PRINT “ST elevation, consider septal injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in V1/V2*
The test for “ST elevation, consider septal injury” is positive and 4 times STJ amplitude > QRS deflection in V1 and V2 **or** STJ amplitude > STE amplitude in V1 and V2 and STE amplitude > 200 µV in V1 and V2	PRINT “Marked ST elevation, consider septal injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in V1/V2*

Anterior and Septal Epicardial Injury Criteria (Continued)

IF	THEN
STJ amplitude > ST LIMIT/2 and T is not upward inflected in 2 leads of V2-V5 **or** STJ amplitude > ST LIMIT/2 2 leads of V2-V5 and STM amplitude < -50 µV in 2 leads of V5, V6, II, AVF, III **or** 6 times STJ amplitude > QRS deflection in 2 leads of V2-V5 **and** the test for anterior infarct is negative **and** the tests for left ventricular hypertrophy, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, right bundle branch block and intraventricular conduction block are negative or R amplitude > 1.5 times S amplitude in 3 leads of V2-V5	PRINT "ST elevation, consider anterior injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V2-V5*
The test for "ST elevation, consider anterior injury" is positive and 4 times STJ amplitude > QRS deflection in 2 leads of V2-V5 **or** STJ amplitude > STE amplitude or T amplitude < 0 and STM amplitude > 200 µV in 2 leads of V2, V3, V4 and the test for anterior infarct is negative	PRINT "Marked ST elevation, consider anterior injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V2-V5*
The test for a possible anterolateral epicardial injury is positive and the test for possible anterior and possible septal epicardial injury is positive	PRINT "ST elevation, consider anteroseptal injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V1-V4*
The test for a possible anteroseptal epicardial injury is positive and additional criteria substantiates an anterior injury or septal injury	PRINT "Marked ST elevation, consider anteroseptal injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V1-V4*

Lateral Epicardial Injury

SKIP TEST IF
The test for pericarditis is positive

Criteria

IF	THEN
STJ amplitude > ST LIMIT/2 and T is not upward inflected in 2 leads of I, aVL, V5, V6 **or** STJ amplitude > ST LIMIT/2 in 2 leads of I, aVL, V5, V6 and STM amplitude < -50 µV in 2 leads of V1, V2, V3, III, aVR **or** 6 times STJ amplitude > QRS deflection in 4 leads of I, aVL, V5, V6 **and** the test for a lateral infarct is negative and the tests for left ventricular hypertrophy, arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, right bundle branch block and intraventricular conduction block are negative or R amplitude > 1.5 times S amplitude in 3 leads of I, aVL, V5 or V6	PRINT “ST elevation, consider lateral injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in I/aVL/V5/V6*
The test for “ST elevation, consider lateral injury” is positive and 4 times STJ amplitude > QRS deflection in 2 leads of I, aVL, V5, V6 **or** STJ amplitude > STE amplitude and STE amplitude > 200 µV in 2 leads of I, aVL, V5, V6 and the test for lateral infarct is negative	PRINT “Marked ST elevation, consider lateral injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in I/aVL/V5/V6*

Lateral Epicardial Injury Criteria (Continued)

IF	THEN
The test for both possible anterior and lateral injury is positive	PRINT “ST elevation, consider anterolateral injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in V3-V6*
The test for possible anterolateral epicardial injury is positive and the test for anterior and/or lateral injury is positive	PRINT “Marked ST elevation, consider anterolateral injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in V3-V6*

Inferior Epicardial Injury

SKIP TEST IF
The test for pericarditis is positive

Criteria

IF	THEN
STJ amplitude > ST LIMIT/2 in 2 leads of II, III, aVF while T is not upward inflected in II, III or aVF or while STM amplitude < -50 µV in 2 leads of V1-V3 **or** 6 times STJ amplitude > QRS deflection in 2 leads of II, III, aVF **and** STJ amplitude > 50 µV in 2 leads of II, III, aVF **and** STM amplitude > 50 µV in 2 leads of II, III, aVF **and** the test for inferior infarct is negative **and** and the tests for left ventricular hypertrophy, arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, right bundle branch block and intraventricular conduction block are negative or R amplitude > 1.5 times S amplitude in 2 leads of II, III, aVF	PRINT “ST elevation, consider inferior injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in II/aVF*

Inferior Epicardial Injury Criteria (Continued)

IF	THEN
The test for "ST elevation, consider inferior injury" is positive and 4 times STJ amplitude > deflection in 2 leads of II, III, aVF **or** STJ amplitude > STE amplitude in 2 leads of II, III, aVF and STE amplitude > 100 µV in 2 leads of II, III, aVF and the tests for left ventricular hypertrophy, arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, right bundle branch block and intraventricular conduction block are negative and the test for inferior infarct is negative	PRINT "Marked ST elevation, consider inferior injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in II/aVF*

ADULT ST DEPRESSION

Minimal and Moderate ST Depression

SKIP TEST IF
Any test for arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, right bundle branch block, left bundle branch block, marked intraventricular conduction delay, left or right ventricular hypertrophy with repolarization, or pericarditis is positive Any test for epicardial injury is positive Any test myocardial infarction is positive

Criteria

IF	THEN
STJ amplitude < -100 µV and STE amplitude ≥ 0 in 2 Leads (except aVR and III)	PRINT "Junctional ST depression, consider normal variant" **REASON:** *0.1+ mV junctional ST depression*
STJ amplitude < -100 µV and STE amplitude < 0 and STE amplitude ≥ STJ amplitude / 2 in 2 leads (except aVR and III)	PRINT "Marked junctional ST depression" **REASON:** *Junctional depression with weak upslope*
STJ/STM/STE amplitude all < -25 µV in 2 leads (except aVR and III)	PRINT "Minimal ST depression" **REASON:** *0.025+ mV ST depression*
STM amplitude < -50 µV and STE amplitude < 0 or STJ/STM/STE amplitude all < -50 µV in 2 leads (except aVR and III)	PRINT "Moderate ST depression" **REASON:** *0.05+ mV ST depression*

Minimal ST depression and moderate junctional depression with upward sloping ST segment cause a borderline classification; the more pronounced levels give an abnormal statement. No suggestion is provided for the possible cause of the ST depression, e.g. digitalis effect.

Subendocardial Injury

SKIP TEST IF
Any test for epicardial injury is positive
Any test acute or recent myocardial infarction is positive

Criteria if a test for arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, marked intraventricular conduction delay, left ventricular hypertrophy with repolarization, or pericarditis is positive

IF	THEN
STM < -100 µV and R amplitude > 1.5 times S amplitude in 3 leads (except aVR and III)	PRINT "ST depression, consider subendocardial injury" **REASON:** *0.1+ mV ST depression*
STM < -200 µV and R amplitude > 1.5 times S amplitude in 3 leads (except aVR and III)	PRINT "Marked ST depression, consider subendocardial injury" **REASON:** *0.2+ mV ST depression*

Criteria in other cases

IF	THEN
STJ/STM/STE all < -100 µV in 2 leads (except aVR and III and except V1/V2 if right bundle branch block is present or right ventricular hypertrophy with repolarization is present)	PRINT "ST depression, consider subendocardial injury" **REASON:** *0.1+ mV ST depression*
STJ/STM/STE all < -200 µV in 2 leads (except aVR and III and except V1/V2 if right bundle branch block is present or right ventricular hypertrophy with repolarization is present)	PRINT "Marked ST depression, consider subendocardial injury" **REASON:** *0.2+ mV ST depression*

ADULT T WAVE ABNORMALITIES

T Wave Abnormality, Ischemia

SKIP TEST IF
Arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, left bundle branch block, intraventricular conduction block, left ventricular hypertrophy with repolarization, right ventricular hypertrophy with repolarization, subendocardial injury, ST elevation or pericarditis is (are) true Any test for acute or recent myocardial infarction is positive

Criteria

IF	THEN
The test for anteroseptal infarct is negative and the test for right ventricular hypertrophy with repolarization is negative and Alternate T amplitude ≤ -100 µV in 2 leads of V2/V3/V4 if RBBB is not present or ≤ -300 µV in V3 and V4 if RBBB is present	PRINT "Moderate T wave abnormality, consider anterior ischemia" **REASON:** *-0.1+ mV T wave in V3/V4*
The test for anterior ischemia is positive and Alternate T amplitude < -500 µV in 1 lead of V2/V3/V4 (excluding V2 if right bundle branch block is present)	PRINT "Marked T wave abnormality, consider anterior ischemia" **REASON:** *-0.5+ mV T wave in V3/V4*
The test for lateral infarct is negative and Alternate T amplitude < -100 µV in 2 leads of I/aVL/V4/V5/V6 (excluding aVL if R(aVL) ≤ 500 µV)	PRINT "Moderate T wave abnormality, consider lateral ischemia" **REASON:** *-0.1+ mV T wave in I/aVL/V5/V6*
The test for lateral ischemia is positive and Alternate T amplitude ≤ -500 µV in 1 lead of I/aVL/V5/V6 (excluding aVL if R(aVL) ≤ 500 µV)	PRINT "Marked T wave abnormality, consider lateral ischemia" **REASON:** *-0.5+ mV T wave in I/aVL/V5/V6*
The tests for both possible anterior and lateral ischemia are positive	PRINT "Moderate T wave abnormality, consider anterolateral ischemia" **REASON:** *-0.1+ mV T wave in V3-V6*
The test for possible anterolateral ischemia is positive and lateral and/or anterior ischemia is marked	PRINT "Marked T wave abnormality, consider anterolateral ischemia" **REASON:** *-0.5+ mV T wave in I/aVL/V3-V6*

T Wave Abnormality Ischemia Criteria (Continued)

IF	THEN
The test for nonspecific ST abnormalities is positive and the test for possible anterior ischemia and/or possible lateral ischemia is positive	Prefix "ST deviation and" to the T wave abnormality statement
The test for inferior infarct is negative and alternate T amplitude < -100 µV in II or aVF (excluding aVF if net QRS amplitude < 0) and alternate T amplitude < 0 in II and aVF	PRINT "Moderate T wave abnormality, consider inferior ischemia" **REASON:** *-0.1+ mV T wave in II/aVF*
The test for inferior ischemia is positive and non-specific ST abnormalities are present	Prefix "ST &" T wave abnormality, possible inferior ischemia
The test for possible inferior ischemia is positive and Alternate T amplitude < -500 uV in II or aVF (excluding aVF if net QRS amplitude < 0)	PRINT "Marked T wave abnormality, consider inferior ischemia" **REASON:** *-0.5+ mV T wave in II/aVF*

T Wave Abnormality, Nonspecific

SKIP TEST IF
Arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, right bundle branch block, left bundle branch block, intraventricular conduction block, left ventricular hypertrophy with repolarization, right ventricular hypertrophy with repolarization, subendocardial injury, ST elevation, pericarditis, myocardial infarct, possible anterior ischemia, possible lateral ischemia or possible inferior ischemia exist

DEFINE
TMIN= 1. 25 µV + net QRS amplitude/20 if net amplitude ≥ 0 2. 25 µV if net QRS amplitude < 0

Criteria

IF	THEN
QRS axis - T axis > 60 and T axis < 0 **or** QRS - T axis < -60 and T axis > 90	PRINT “Abnormal QRS-T angle” **REASON:** *QRS-T axis difference > 60*
Count of I/II/aVL/aVF/V3-V6 with alternate T amplitude < TMIN and R amplitude > 500 µV is ≥ 2	PRINT “Nonspecific T wave abnormality”
Nonspecific ST abnormalities and nonspecific T-wave abnormalities exist and the test for tall T waves is negative	PRINT “Nonspecific ST & T wave abnormality”
T amplitude > 1000 µV and T amplitude > 1/2 R amplitude in 3 leads of I/II/V1-V6 or T amplitude > 1200 µV and T amplitude > 1/2 R amplitude in 2 leads of I/II/V1-V6	PRINT “Tall T waves, possible hyperkalemia”

“Non-specific T wave abnormality” causes a borderline classification; no attempt is made to identify a possible reason for T wave changes, e.g. digitalis effect.

QT-Interval

Interpretative criteria are based on the QT-interval corrected for the heart rate, or, more precisely, corrected for the average RR-interval (QTc) in the 10 s recording. The Mortara QT correction utilizes a linear formula consistent with the general form determined in the Framingham heart study. In addition, QTc values calculated with other published correction formulas can be displayed by Mortara electrocardiographs. Calculations are executed according to the following formulas (units in seconds):

Linear correction: $QTc = QT + 0.14*(1-RR)$
Bazett correction: $QTcB = QT / \sqrt{RR}$
Fridericia correction: $QTcF = QT / RR^{⅓}$

SKIP TEST IF
Arm lead reversal, ventricular rhythm, electronic ventricular pacemaker, ventricular preexcitation, right bundle branch block, left bundle branch block, intraventricular conduction block, left ventricular hypertrophy with repolarization, right ventricular hypertrophy with repolarization, subendocardial injury, ST elevation, pericarditis, myocardial infarct, possible anterior ischemia, possible lateral ischemia or possible inferior ischemia exist Ventricular rate > 100 bpm

Criteria

IF	THEN
QTc > 470 ms **or** QTc > 460 ms and sex is male	PRINT “Prolonged QT interval”

ADULT BRUGADA

Brugada

SKIP TEST IF
T amplitude < -1mV in any of V4, V5, and V6
Atrial flutter is present
LBBB is present
QRS duration > 160ms
Rate > 120 BPM
More than 1 of V1-V3 has no R wave and an upsloping ST segment
More than 1 of V1-V3 has an R amplitude > 2.5 times the S amplitude

Criteria

IF	THEN
STJ ≥ 50 µV and ST segment is downsloping and STJ ≥ 200 µV in at least 1 of V1-V3	PRINT "Type 3 Brugada pattern (non-diagnostic)" **REASON:** *Coved/saddleback ST elevation > 0.1mV in 2 of V1-3*
STJ ≥ 150 µV and STE ≥ 100 µV and T amplitude > STM and STE in 2 of V1-V3 and STJ ≥ 200 µV in at least one of V1-V3	PRINT "Type 2 Brugada pattern (non-diagnostic)" **REASON:** *Saddleback ST elevation > 0.2mV with positive/biphasic T wave in 2 of V1-3*
STJ ≥ 150 µV and STM < STJ and STE < STM and T amplitude < 0 in 2 of V1-V3 and STJ ≥ 200 µV in at least one of V1-V3	PRINT "Type 1 Brugada pattern, exclude recent infarction, CABG, myocarditis, or drug effect" **REASON:** *Coved-type ST elevation > 0.2mV with negative T wave in 2 of V1-3*

PEDIATRIC CRITERIA

Arm Lead Reversal and Dextrocardia

Criteria

IF	THEN
No Q in lead I and R amplitude < 150 µV in lead I **or** Q amplitude > R amplitude in lead I and Maximum S amplitude > 150 µV in lead I and P amplitude in lead III > P amplitude lead II and P axis > 90 and QRS axis > 90	PRINT "Arm leads reversed" **REASON**: *rS or Qr in I, P(III) > P(II), QRS axis > 90*

IF	THEN
If P axis ≥ 90 and P axis ≤ 180 and Maximum R amplitude < 500 µV in V6 and Maximum S amplitude > R amplitude in V6 and P amplitude < 20 µV in lead V6 and P' amplitude < -20 µV in lead V6	PRINT "Dextrocardia"

Wolff-Parkinson-White

Criteria

IF	THEN
If Delta wave is present in some of V1/V2/V3/V4/V5/V6 and PR duration ≤ 119 ms and QRS duration ≥ 97 ms and Ventricular rate < 150 bpm	PRINT "Ventricular preexcitation/WPW" **REASON**: *Delta Waves*

Atrial Enlargement

Criteria

IF	THEN
Age ≥ 10 years and P amplitude > 200 µV in any 1 lead of I/II/III/aVF/V1/V2 and P amplitude > 150 µV in any 2 leads of I/II/III/aVF/V1/V2	PRINT "Possible right atrial enlargement" **REASON**: *0.2 mV P wave, Age ≥ 10 yr*
P amplitude > 250 µV in any 1 lead of I/II/III/aVF/V1/V2 and P amplitude > 200 µV in any 2 leads of I/II/III/aVF/V1/V2	PRINT "Right atrial enlargement" **REASON**: *0.25 mV P wave*
P' amplitude < -70 µV and negative P wave area ≥ 400 µV ms in V1	PRINT "Possible left atrial enlargement"
P' amplitude < -100 µV and negative P wave area ≥ 400 µV/ms in V1	PRINT "Left atrial enlargement"

Axis Deviation

Criteria

IF	THEN
QRS axis < Minimum QRS axis for age	PRINT "Left axis deviation" **REASON**: *QRS axis < [Minimum QRS axis for age]*
QRS axis > Maximum QRS axis for age	PRINT "Right axis deviation" **REASON**: *QRS axis > [Maximum QRS axis for age]*

Please see pediatric criteria table for **QRS Axis for Age** in Reference Summary. Axis deviation statements are omitted when subsequently identified diagnostic categories may be regarded as the probable cause of the axis deviation, e.g. right or left bundle branch conduction blocks.

PEDIATRIC CONDUCTION ABNORMALITIES

Right Bundle Conduction

Criteria

IF	THEN
QRS duration ≥ Maximum QRS duration for age and R' amplitude ≥ 150 µV in V1 and R' duration ≥ 20 ms in V1 and R' amplitude > 4 x S' amplitude in V1	PRINT "Right bundle branch block" **REASON**: *QRS ≥ [Maximum QRS duration for age], RSR' in V1*
QRS duration ≥ Maximum QRS duration for age and R amplitude ≥ 550 µV and no S wave is present in V1	PRINT "Right bundle branch block" **REASON**: *QRS ≥ [Maximum QRS duration for age], no S in V1*

Please see pediatric criteria table for **QRS Duration for Age** in Reference Summary.

Left Bundle Conduction

Criteria

IF	THEN
QRS axis ≤ -60	PRINT "Left anterior fascicular block" **REASON**: *QRS axis -60 to -90*
S duration ≤ 20 ms in 3 of I/aVL/V5/V6 and Terminal QRS axis ≤ 90 and QRS duration ≥ Maximum QRS duration for age and R wave amplitude ≤ 450 µV and R wave duration ≤ 39 ms in some of V1/V2/V3 **or** R wave amplitude ≥ 450 µV and R wave duration ≤ 39 ms in some of V1/V2/V3 and QRS duration > 135 ms	PRINT "Left bundle branch block" **REASON**: *QRS ≥ [Maximum QRS duration for age], terminal QRS leftward*

Please see pediatric criteria table for **QRS Duration for Age** in Reference Summary.

Ventricular Conduction Delay

Criteria

IF	THEN
The test for Right Bundle Branch Block is negative and The test for Left Bundle Branch Block is negative and The test for Left Anterior Fascicular Block is negative and QRS duration ≥ Maximum QRS Duration for age	PRINT "Ventricular Conduction Delay" **REASON:** *QRS duration ≥ [Maximum QRS Duration for age]*

Please see pediatric criteria table for **QRS Duration for Age** in Reference Summary.

PEDIATRIC HYPERTROPHY

Right Ventricular Hypertrophy

SKIP TEST IF
Test for Right Bundle Branch Block is positive, or Test for Left Bundle Branch Block is positive, or Test for Ventricular Conduction Delay is positive

Criteria

Criteria statements for Right Ventricular Hypertrophy are printed only if the "Print reason" option on the electrocardiograph is turned on; otherwise, only the summary statements are printed.

IF	THEN
Age ≥ 1 month and S amplitude ≥ 1000 µV in V6	PRINT REASON "RVH voltage criteria: *S(V6) > 1mV, 1mo-15yr"* ***NOTE**: Final comment is "Borderline ECG"*
Age ≥ 1 month and R amplitude ≥ 2500 µV in V2 and QRS deflection positive in V3R or V1	PRINT REASON "RVH voltage criteria: *R(V2) > 2.5mV, 1mo-15yr"*
Age ≥ 1 month and maximum R amplitude/S amplitude < 1.2 in V6 and QRS deflection positive in V3R or V1	PRINT REASON "RVH voltage criteria: *R/S(V6) < 1.2, 1mo-15yr"* ***NOTE**: Final comment is "Borderline ECG"*
Maximum R amplitude/S amplitude < minimum V6 R/S amplitude ratio for Age *NOTE: for age ≥ 3yr: and QRS deflection positive in V3R or V1*	PRINT REASON "RVH voltage criteria: *R/S(V6) < [Minimum V6 R/S amplitude ratio for age]"*
Age < 5 days and maximum R amplitude > 2200 µV in V3R or V1	PRINT REASON "RVH voltage criteria: *R(V3R/V1) < 2.2mV, < 5day"* ***NOTE**: Final comment is "Borderline ECG"*
Age ≥ 5 days and age < 30 days and maximum R amplitude > 2200 µV in V3R or V1	PRINT REASON "RVH voltage criteria: *R(V3R/V1) < 2.2mV, 5-30day"*
Age ≥ 30 days and age < 16 years and maximum R amplitude > 1700 µV in V3R or V1	PRINT REASON "RVH voltage criteria: *R(V3R/V1) < 1.7mV, 1mo-15yr"*
Maximum R amplitude/maximum S amplitude > maximum V3R/V1 R/S amplitude ratio for Age and R-amplitude in V3R/V1 ≥ 300 µV	PRINT REASON "RVH voltage criteria: *R/S(V3R/V1) > [*Maximum V3R/V1 R/S amplitude ratio for Age*]"*
Age < 3 months and R' amplitude ≥ 2000 µV and R' duration ≥ 20 ms and no S' in V3R or V1	PRINT REASON "RVH voltage criteria: *R'(V3R/V1) > 2 mV, <3mo"*

Right Ventricular Hypertrophy Criteria (Continued)

IF	THEN
Age ≥ 2 months and Age < 1 year and R' amplitude ≥ 1600 µV and R' duration ≥ 12 ms and no S' in V3R or V1	PRINT REASON "RVH voltage criteria: *R'(V3R/V1) > 1.6 mV, 2-11mo"*
Age ≥ 1 year and R' amplitude > 1000 µV and R' duration ≥ 12 ms and R' amplitude > R amplitude and R' amplitude > R amplitude and no S' in V3R or V1	PRINT REASON "RVH voltage criteria: *R'(V3R/V1) > 1 mV, 1-15yr"*
Age < 5 days and QRS with only R-wave and R amplitude ≥ 1000 µV in V3R or V1	PRINT REASON "RVH voltage criteria: *Pure R(V3R/V1) > 1 mV, <5day"* ***NOTE**: Final comment is "Borderline ECG"*
Age ≥ 5 days and age < 30 days and QRS with only R-wave and R amplitude ≥ 1000 µV in V3R or V1	PRINT REASON "RVH voltage criteria: *Pure R (V3R/V1) > 1 mV, 5-30day"*
Age ≥ 30 days and QRS with only R-wave and R amplitude ≥ 500 µV in V3R or V1	PRINT REASON "RVH voltage criteria: *Pure R (V3R/V1) > 0.5 mV, 1mo-15yr"*
Age < 30 days and Q amplitude ≥ 70 µV and Q duration ≥ 20 ms and R amplitude ≥ 500 and R amplitude > S amplitude in V3R or V1	PRINT REASON "RVH voltage criteria: *QR in V3R/V1, < 1mo"*
Age ≥ 30 days Q amplitude ≥ 70 µV and Q duration ≥ 20 ms and R amplitude ≥ 500 and R amplitude > S amplitude in V3R or V1	PRINT REASON "RVH voltage criteria: *QR in V3R/V1, 1mo-15yr"*

Right Ventricular Hypertrophy Criteria (Continued)

IF	THEN
Age > 5 days and age < 5 years and T amplitude ≥ 100 µV and T amplitude > 2 x STM amplitude in V3R or V1	PRINT REASON "RVH T wave criteria: *T upright in V3R/V1, 5day-4yr"*
Age ≥ 5 years and age < 9 years and T amplitude ≥ 150 µV and T amplitude > 2 x STM amplitude in V3R or V1	PRINT REASON "RVH T wave criteria: *T upright in V3R/V1, 5-8yr"* ***NOTE**: Final comment is "Borderline ECG"*

Please see pediatric criteria table for **V6 R/S Amplitude Ration for Age** in Reference Summary. Additionally, the following definitions are utilized: **STJ** = ST segment amplitude at QRS offset; **STM** = ST segment amplitude at ST segment midpoint; **STE** = ST segment amplitude at ST segment endpoint.

Summary Statement

Depending upon which RVH criteria are satisfied, a summary statement reflecting the different criteria and their degree will be generated. Summary statements for RVH include the following:

Possible Right Ventricular Hypertrophy [Voltage Criteria Only]
Possible Right Ventricular Hypertrophy [T wave Changes]
Possible Right Ventricular Hypertrophy [Axis Criteria Only]

> ***NOTE**: Final comment is "Borderline ECG"*

Probable Right Ventricular Hypertrophy [Voltage Criteria Only]
Probable Right Ventricular Hypertrophy [T wave Changes]

Right Ventricular Hypertrophy [Severe Voltage Criteria]

> ***NOTE**: R/S(V3R/V1) > [Maximum V3R/V1 R/S amplitude ratio for Age], 1-11 mo; Pure R (V3R/V1) > 0.5 mV, 1mo-15yr; QR in V3R/V1, 1mo-15yr*

Right Ventricular Hypertrophy [T wave Changes & RAD for Age]
Right Ventricular Hypertrophy [Voltage & T wave Changes]
Right Ventricular Hypertrophy [Voltage & RAD for Age]
Right Ventricular Hypertrophy [Voltage & RAE]
Right Ventricular Hypertrophy [Voltage, RAD for Age & T wave Changes]

Consider Associated Right Ventricular Hypertrophy [R(V1) > 1.5 mV & LVH]
Consider Biventricular Hypertrophy [R+S > 6mV in 2 of V2-V4]

> ***NOTE**: Final comment is "Borderline ECG*

Left Ventricular Hypertrophy

SKIP TEST IF
Test for Left Bundle Branch Block is positive, or Test for Right Bundle Branch Block is positive, or Test for Ventricular Conduction Delay is positive

Criteria

Criteria statements for Left Ventricular Hypertrophy are printed only if the "Print reason" option on the electrocardiograph is turned on; otherwise, only the summary statements are printed.

IF	THEN
Q amplitude ≥ 600 µV and R amplitude ≥ 1000 µV in V5 or V6	PRINT REASON "LVH voltage criteria: *Q > 0.6mV & R > 1 mV in V5/V6"* ***NOTE**: Final comment is "Borderline ECG"*
R amplitude ≥ 3000 µV in I, II, aVL, or aVF	PRINT REASON "LVH voltage criteria: *R > 3 mV in 1 of I/II/aVL/aVF"* ***NOTE**: Final comment is "Borderline ECG"*
S amplitude ≥ 3500 µV in V2	PRINT REASON "LVH voltage criteria: *S (V2) > 3.5 mV"* ***NOTE**: Final comment is "Borderline ECG"*
R amplitude ≥ 2300 µV in V6 and T amplitude ≤ 1/10 of R amplitude in V6	PRINT REASON "LVH voltage criteria: *R(V6) > 2.3 mV & small T"* ***NOTE**: Summary statement is "Borderline ECG"*
R amplitude ≥ 3000 µV in V6	PRINT REASON "LVH voltage criteria: *R(V6) ≥ 3.0 mV"*
R amplitude ≥ 2300 µV and Q amplitude ≥ 600 µV in V6	PRINT REASON "LVH voltage criteria: *R(V6) > 2.3 mV & Q(V6) > 0.6mV"*
R amplitude of V5 + S amplitude of V1 ≥ 3500 µV and T amplitude ≤ 1/10 of R amplitude in V6	PRINT REASON "LVH voltage criteria: S(V1) + *R(V5) ≥ 3.5 mV & small T"* ***NOTE**: Final comment is "Borderline ECG"*
R amplitude of V5 + S amplitude of V1 ≥ 4500 µV	PRINT REASON "LVH voltage criteria: S(V1) + *R(V5) ≥ 4.5 mV"*
STM ≤ -10 µV and down sloping ST-segment and T amplitude ≤ -50 µV in 2 of I/aVL/V4/V5/V6	PRINT REASON "LVH ST-T criteria: *ST < -0.01 mV & T < -0.05 mV in 2 of I/aVL/V4-6"*

Summary Statement

Depending upon which LVH criteria are satisfied, a summary statement reflecting the different criteria and their degree will be generated. Summary statements for LVH include the following:

Possible Left Ventricular Hypertrophy [Voltage Criteria Only]
Possible Left Ventricular Hypertrophy [T wave Changes]

***NOTE**: Final comment is "Borderline ECG*

Probable Left Ventricular Hypertrophy [Severe Voltage Criteria]
Probable Left Ventricular Hypertrophy [LAD for Age & ST-T Changes]
Probable Left Ventricular Hypertrophy, mild, or diastolic overload [moderate voltage criteria and ST-elevation]

Left Ventricular Hypertrophy [Voltage Criteria & LAD for Age]
Left Ventricular Hypertrophy, probably mild, or diastolic overload [moderate voltage criteria and ST-elevation]
Left Ventricular Hypertrophy, Probably Severe, or Systolic Overload [Voltage Criteria & ST-T Rightward]

Consider Associated Left Ventricular Hypertrophy [Q > 0.1mV & R > 1mV in V6 & R+S > 3.5 mV in V4 with RVH]
Consider Biventricular Hypertrophy [R+S > 6mV in 2 of V2-V4]

***NOTE**: Final comment is "Borderline ECG*

PEDIATRIC ST SEGMENT ABNORMALITIES

ST Segment Elevation

SKIP TEST IF
The test for either right bundle branch block, left bundle branch block, is positive

Criteria

IF	THEN
Lesser of STJ or STM ≥ 150 µV in 2 leads of V2,V3,V4,V5,V6	PRINT "Anterior ST elevation, consider normal variant" **REASON:** *ST > 0.15 mV in 2 of V2-V5*
STJ/STM/STE all ≥ 150 µV in 1 of II/III/aVF and STJ/STM/STE all ≥ 100 µV in 2 of II/III/aVF	PRINT "Inferior ST elevation, consider normal variant" **REASON:** *ST > 0.15 mV in 1 of II/III/aVF*
Lesser of STJ or STM ≥ 150 µV in 2 leads of I/aVL/V6	PRINT "Anterolateral ST elevation, consider normal variant" **REASON:** *ST > 0.15 mV in 2 of I/aVL/V6*
Lesser of STJ or STM ≥ 150 µV in 2 leads of I/aVL/V6 and Test is positive for any LVH criteria	PRINT "Anterolateral ST elevation, probably secondary to LVH" **REASON:** *ST > 0.15 mV in 2 of I/aVL/V6 & LVH*

ST Segment Depression

SKIP TEST IF
The test for either right bundle branch block, left bundle branch block, is positive

Criteria

IF	THEN
STJ/STM < -200 µV in 1 of V2/V3/V4/V5	PRINT "Anterior ST depression, consider subendocardial injury" **REASON:** *ST < -0.2mV in 1 of V2-V5*
STJ/STM < -200 µV in 1 of II/III/aVF	PRINT "Inferior ST depression, consider subendocardial injury" **REASON:** *ST < -0.2mV in 1 of II/III/aVF*
STJ/STM < -200 µV in 1 of I/aVL/V6 and STJ/STM < -200 µV in 1 of V2/V3/V4/V5	PRINT "Anterolateral ST depression, consider subendocardial injury" **REASON:** *ST < -0.2mV in 1 of I/aVL/V2-6*
STJ/STM < -200 µV in 1 of I/aVL/V6 and STJ/STM < -200 µV in 1 of V2/V3/V4/V5 a test for LVH is positive	PRINT "Anterolateral ST depression, probably secondary to LVH" **REASON:** *ST < -0.2mV in 1 of I/aVL/V2-V6 and LVH*

PEDIATRIC T WAVE ABNORMALITIES

T Wave Abnormality, Ischemia

SKIP TEST IF
Age < 12 Any test for right bundle branch block, left bundle branch block or intraventricular conduction delay is positive

Criteria

IF	THEN
T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 2 of V1/V2/V3	PRINT "Minimal anterior T wave changes" **REASON:** *T < -0.01 mV in 2 of V1-V3*
T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 2 of V1/V2/V3 and T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 1 of V4/V5	PRINT "Minimal anterior T wave changes" **REASON:** *T < -0.01 mV in V1-V5*
T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 2 of V1/V2/V3	PRINT "Moderate anterior T wave changes" **REASON:** *T < -0.1 mV in 2 of V1-V3*
T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 2 of V1/V2/V3 and T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 1 of V4/V5	PRINT "Moderate anterior T wave changes" **REASON:** *T < -0.1 mV in V1-V5*
T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 2 of V1/V2/V3	PRINT "Anterior T wave changes" **REASON:** *T < -0.5 mV in 2 of V1-V3*
T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 2 of V1/V2/V3 and T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 1 of V4/V5	PRINT "Anterior T wave changes" **REASON:** *T < -0.5 mV in V1-V5*

T Wave Abnormality Ischemia Criteria (Continued)

IF	THEN
T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3	PRINT "Marked anterior T wave changes, consider ischemia" **REASON:** *T < -1 mV in 2 of V1-V3*
T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3 and T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 1 of V4/V5	PRINT "Marked anterior T wave changes, consider ischemia" **REASON:** *T < -1 mV in V1-V5*
T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3 and test is positive for any RVH criteria	PRINT "Consider anterior ischemia, probably secondary to RVH" **REASON:** *T < -1 mV in V1-V3 & RVH*
T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 2 of II/III/aVF	PRINT "Moderate inferior T wave changes" **REASON:** *T < -0.1 mV in 2 of II/III/aVF*
T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 1 of II/III/aVF	PRINT "Inferior T wave changes" **REASON:** *T < -0.5 mV in 1 of II/III/aVF*
T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 1 of II/III/aVF or T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 2 of II/III/aVF	PRINT "Marked inferior T wave changes, consider ischemia" **REASON:** *T < -1 mV in 1 of II/III/aVF or T < -0.5 mV in 2 of II/III/aVF*
T amplitude ≥ 1000 µV or T' amplitude ≥ 1000 µV in 2 of I/aVL/V2/V3/V4/V5/V6 and test for LVH is negative	PRINT "Tall T-waves, consider normal variant" **REASON:** *T > 1mV in 2 of* I/aVL/V2-V6

T Wave Abnormality Ischemia Criteria (Continued)

IF	THEN
T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 1 of I/aVL/V6 and T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 2 of V1/V2/V3 and T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 1 of V4/V5 and not T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3	PRINT "Moderate anterolateral T wave changes" **REASON:** *T < -0.01 mV in I/aVL/V2-V6*
T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 1 of I/aVL/V6 and T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 2 of V1/V2/V3 and T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 1 of V4/V5 and not T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3	PRINT "Moderate anterolateral T wave changes" **REASON:** *T < -0.1 mV in I/aVL/V2-V6*

T Wave Abnormality Ischemia Criteria (Continued)

IF	THEN
T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 1 of I/aVL/V6 and T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 2 of V1/V2/V3 and T amplitude ≤ -100 µV or T' amplitude ≤ -100 µV in 1 of V4/V5 and not T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3 and a test is positive for any LVH criteria	PRINT "Consider anterolateral ischemia, probably secondary to LVH" **REASON:** *T < -0.1 mV in I/aVL/V2-V6 & LVH*
T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 1 of I/aVL/V6 and T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 2 of V1/V2/V3	PRINT "Anterolateral T wave changes, consider ischemia" **REASON:** *T < -0.5 mV in 1 of I/aVL/V2-V6*
T amplitude ≤ -500 µV or T' amplitude ≤ -500 µV in 1 of I/aVL/V6 and T amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3	PRINT "Marked anterolateral T wave changes, consider ischemia" **REASON:** *T < -1 mV in 1 of I/aVL/V2-V6*

QT Prolongation

Interpretative criteria are based on the QT-interval corrected for the heart rate, or, more precisely, corrected for the average RR-interval (QTc) in the 10 s recording. The Mortara QT correction utilizes a linear formula consistent with the general form determined in the Framingham heart study. In addition, QTc values calculated with other published correction formulas can be displayed by Mortara electrocardiographs. Calculations are executed according to the following formulas (units in seconds):

Linear correction: $QTc = QT + 0.14*(1-RR)$
Bazett correction: $QTcB = QT / \sqrt{RR}$
Fridericia correction: $QTcF = QT / RR^{⅓}$

SKIP TEST IF
Ventricular rate is above the Tachycardia limit

Criteria

IF	THEN
QTc > 460 ms	PRINT “Prolonged QT Interval”

Please see pediatric criteria table for **Tachycardia** in the Reference Summary.

Brugada Pattern

The Brugada pattern seldom expresses at a young age, unless pharmacologically provoked. It would be unnecessary alarming to provide for a statement for Brugada pattern at an age below 16 years.

PEDIATRIC TRICUSPID ATRESIA

Tricuspid Atresia

Criteria

IF	THEN
Left axis deviation and Left ventricular hypertrophy and Right atrial enlargement	PRINT “Consider tricuspid atresia” **REASON:** *RAE + LAD + LVH*

PEDIATRIC ENDOCARDIAL CUSHION DEFECT

Endocardial Cushion Defect

Criteria

IF	THEN
QRS Axis > -170 or QRS Axis < -30 and Q amplitude ≥ 80 µV and R amplitude ≥ 100 µV in aVL and Test for RVH or RBBB is true	PRINT “Consider endocardial cushion defect” **REASON:** *QRS -30 to -170, RVH or RSR’ in V1*

PEDIATRIC ATRIAL SEPTAL DEFECT

Atrial Septal Defect

Criteria

IF	THEN
QRS Axis > 0 and QRS Axis ≤ 180 and RSR' pattern in V1	PRINT "Consider atrial septal defect" **REASON:** *QRS 1-180, RSR' in V1*

REFERENCE SUMMARY

Age Tables

The following tables should be used in reference to parameters that are stated as minimum or maximum "for age". In the following, **d** indicates days, **mo** indicates months, and **yr** indicates years. On the bottom line, where relevant, are the adult references.

QRS Axis for Age

Age	QRS Axis Minimum (Left Axis Deviation Criteria)	QRS Axis Maximum (Right Axis Deviation Criteria)
< 6d	60	180
6 – 30d	60	160
1 – 2mo	40	135
3 – 5mo	20	135
6mo – 15yr	0	135
>= 16yr	-20	90

QRS Duration for Age

Age	QRS Duration
< 1yr	99ms
1 – 15yr	109ms
>= 16yr	119ms

Prolonged PR Duration, Bradycardia, and Tachycardia for Age

Age	PR Duration (ms)	Bradycardia (bpm)	Tachycardia (bpm)
< 1d	129	94	145
< 8d	129	100	175
< 1mo	129	115	190
< 3mo	139	124	190
< 1yr	139	110	178
< 3yr	159	98	163
< 5yr	159	65	132
< 8yr	169	65	115
< 12yr	179	60	107
< 16yr	179	60	102
>= 16yr	209	55	99

V6 R/S Amplitude Ratio for Age

Age	V6 R/S Amplitude Ratio
1 – 3mo	0.5
4 – 11mo	0.7
1 – 2yr	0.8
3 – 15yr	0.9

V1/V3R R/S Amplitude Ratio for Age

Age	V1/V3R R/S Amplitude Ratio
1 – 3mo	7
4 – 11mo	4.5
1 – 2yr	3
3 – 7yr	2.3
8 – 15yr	2

Conditions – Rhythm Statements

Statement	Condition
Sinus rhythm	Normal ECG
Sinus tachycardia	Abnormal Rhythm ECG
Sinus bradycardia	Borderline ECG
Ectopic atrial rhythm	Abnormal Rhythm ECG
Ectopic atrial tachycardia	Abnormal Rhythm ECG
Ectopic atrial bradycardia	Abnormal Rhythm ECG
Junctional rhythm	Abnormal Rhythm ECG
Junctional tachycardia	Abnormal Rhythm ECG
Junctional bradycardia	Abnormal Rhythm ECG
Idioventricular rhythm	Abnormal ECG
Ventricular tachycardia	Abnormal ECG
Supraventricular rhythm	Atypical ECG
Supraventricular tachycardia	Abnormal Rhythm ECG
Supraventricular bradycardia	Abnormal Rhythm ECG
Uncertain irregular rhythm	Atypical ECG
Uncertain regular rhythm	Atypical ECG
With marked sinus arrhythmia	Borderline ECG
With prolonged PR interval (adult)	Abnormal ECG
With prolonged PR interval (pediatric)	Borderline ECG
With short pr interval	Borderline ECG
With 2nd degree AV block, Mobitz type I (Wenckebach)	Abnormal ECG
With 2nd degree AV block, Mobitz type II	Abnormal ECG
With occasional ventricular premature complexes	Borderline ECG
With frequent ventricular premature complexes	Abnormal Rhythm ECG
With occasional ectopic premature complexes	Borderline ECG
With frequent ectopic premature complexes	Abnormal Rhythm ECG

Conditions – Rhythm Statements (Continued)

Statement	Condition
With occasional atrial premature complexes	Borderline ECG
With frequent atrial premature complexes	Abnormal Rhythm ECG
With occasional supraventricular premature complexes	Borderline ECG
With frequent supraventricular premature complexes	Abnormal Rhythm ECG
In a bigeminal pattern	Abnormal Rhythm ECG
With marked rhythm irregularity, possible non-conducted PAC, SA block, AV block, or sinus pause	Abnormal Rhythm ECG
Atrial fibrillation	Abnormal Rhythm ECG
Atrial flutter/tachycardia	Abnormal Rhythm ECG
With high grade AV block	Abnormal ECG
Electronic atrial pacemaker	Abnormal Rhythm ECG
Electronic ventricular pacemaker	Abnormal Rhythm ECG
Intermittent ventricular preexcitation/WPW	Abnormal ECG

Conditions – Contour Statements, Adult

Statement	Condition
Arm leads reversed	Atypical ECG
Dextrocardia	Abnormal ECG
Possible right atrial enlargement	Borderline ECG
Right atrial enlargement	Abnormal ECG
Possible left atrial enlargement	Borderline ECG
Left atrial enlargement	Abnormal ECG
Ventricular preexcitation/WPW	Abnormal ECG
Borderline left axis deviation	Borderline ECG
Marked left axis deviation	Abnormal ECG
Borderline right axis deviation	Borderline ECG
Marked right axis deviation	Abnormal ECG
Indeterminate axis	Atypical ECG
Low QRS voltage in extremity leads	Borderline ECG
Low QRS voltage in precordial leads	Borderline ECG
Low QRS voltage	Abnormal ECG
S1-S2-S3 pattern, consistent with pulmonary disease, RVH, or normal variant	Borderline ECG
Pattern consistent with pulmonary disease	Abnormal ECG
Possible right ventricular conduction delay	Borderline ECG
Incomplete right bundle branch block	Borderline ECG
Right bundle branch block	Abnormal ECG
Right bundle branch block and possible right ventricular hypertrophy	Abnormal ECG
Moderate intraventricular conduction delay	Abnormal ECG

Conditions – Contour Statements, Adult (Continued)

Statement	Condition
Left anterior fascicular block	Abnormal ECG
Left posterior fascicular block	Abnormal ECG
Left bundle branch block	Abnormal ECG
Moderate intraventricular conduction delay	Borderline ECG
Intraventricular conduction delay	Abnormal ECG
Possible right ventricular hypertrophy	Abnormal ECG
Right ventricular hypertrophy	Abnormal ECG
Right ventricular hypertrophy and ST-T change	Abnormal ECG
Minimal voltage criteria for LVH, consider normal variant	Borderline ECG
Moderate voltage criteria for LVH, consider normal variant	Borderline ECG
Voltage criteria for LVH	Abnormal ECG
Possible left ventricular hypertrophy	Abnormal ECG
Left ventricular hypertrophy and ST-T change	Abnormal ECG
Any infarction, possibly acute	***ACUTE MI***
Any infarction , probably recent	***ACUTE MI***
Any infarction, of indeterminate age	Abnormal ECG
Possible infarction, probably old	Borderline ECG
Probable infarction, probably old	Abnormal ECG
Infarction, probably old	Abnormal ECG
Nonspecific ST elevation	Borderline ECG
ST elevation consistent with injury, pericarditis, or early repolarization	Abnormal ECG
ST elevation, probably early repolarization	Borderline ECG
Early repolarization	Normal ECG
Possible acute pericarditis - exclude acute mi	***ACUTE MI***
Acute pericarditis - exclude acute mi	***ACUTE MI***
ST elevation, consider septal injury	***ACUTE MI***
Marked ST elevation, consider septal injury	***ACUTE MI***
ST elevation, consider anterior injury	***ACUTE MI***
Marked ST elevation, consider anterior injury	***ACUTE MI***
ST elevation, consider lateral injury	***ACUTE MI***
Marked ST elevation, consider lateral injury	***ACUTE MI***
ST elevation, consider inferior injury	***ACUTE MI***
Marked ST elevation, consider inferior injury	***ACUTE MI***
ST elevation, consider anterolateral injury	***ACUTE MI***
Marked ST elevation, consider anterolateral injury	***ACUTE MI***
ST elevation, consider anteroseptal injury	***ACUTE MI***
Marked ST elevation, consider anteroseptal injury	***ACUTE MI***
Junctional ST depression, consider normal variant	Borderline ECG
Marked junctional ST depression	Abnormal ECG
Minimal ST depression	Borderline ECG

Conditions – Contour Statements, Adult (Continued)

Statement	Condition
Moderate ST depression	Abnormal ECG
ST depression, consider subendocardial injury	Abnormal ECG
Marked ST depression, consider subendocardial injury	Abnormal ECG
Moderate T-wave abnormality, consider anterior ischemia	Abnormal ECG
Marked T-wave abnormality, consider anterior ischemia	Abnormal ECG
Moderate T-wave abnormality, consider lateral ischemia	Abnormal ECG
Marked T-wave abnormality, consider lateral ischemia	Abnormal ECG
Moderate T-wave abnormality, consider anterolateral ischemia	Abnormal ECG
Marked T-wave abnormality, consider anterolateral ischemia	Abnormal ECG
Moderate T-wave abnormality, consider inferior ischemia	Abnormal ECG
Marked T-wave abnormality, consider inferior ischemia	Abnormal ECG
Abnormal QRS-T angle	Abnormal ECG
Nonspecific T-wave abnormality	Borderline ECG
Nonspecific ST& T-wave abnormality	Borderline ECG
Tall T-waves, suggests hyperkalemia	Abnormal ECG
Prolonged QT interval	Abnormal ECG
Type 3 Brugada pattern (non-diagnostic)	Borderline ecg
Type 2 Brugada pattern (non-diagnostic)	Borderline ecg
Type 1 Brugada pattern, exclude recent infarction, CABG, myocarditis or drug effect	Abnormal ecg

Conditions – Contour Statements, Pediatric

Statement	Condition
Arm leads reversed	Atypical ECG
Dextrocardia	Abnormal ECG
Possible right atrial enlargement	Borderline ECG
Right atrial enlargement	Abnormal ECG
Possible left atrial enlargement	Borderline ECG
Possible left atrial enlargement	Borderline ECG
Left atrial enlargement	Abnormal ECG
Ventricular preexcitation/wpw	Abnormal ECG
Right axis deviation	Borderline ECG
Left axis deviation	Borderline ECG
Intraventricular conduction delay	Abnormal ECG
Right bundle branch block	Abnormal ECG
Left anterior fascicular block	Abnormal ECG
Left bundle branch block	Abnormal ECG
Possible right ventricular hypertrophy	Borderline ECG
Probable right ventricular hypertrophy	Borderline ECG

Conditions – Contour Statements, Pediatric (Continued)

Statement	Condition
Right ventricular hypertrophy	Abnormal ECG
Possible left ventricular hypertrophy	Borderline ECG
Probable left ventricular hypertrophy	Abnormal ECG
Probable left ventricular hypertrophy, mild, or diastolic overload	Abnormal ECG
Left ventricular hypertrophy	Abnormal ECG
Left ventricular hypertrophy, probably mild, or diastolic overload	Abnormal ECG
Left ventricular hypertrophy, probably severe, or systolic overload	Abnormal ECG
Anterior ST elevation, consider normal variant	Normal ECG
Inferior ST elevation, consider normal variant	Borderline ECG
Anterolateral ST elevation, consider normal variant	Normal ECG
Anterolateral ST elevation, probably secondary to lvh	Borderline ECG
Anterior ST depression, consider subendocardial injury	Borderline ECG
Inferior ST depression, consider subendocardial injury	Borderline ECG
Anterolateral ST depression, consider subendocardial injury	Borderline ECG
Anterolateral ST depression, probably secondary to lvh	Borderline ECG
Minimal anterior T-wave changes	Normal ECG
Moderate anterior T-wave changes	Normal ECG
Anterior T-wave changes	Normal ECG
Marked anterior T-wave changes, consider ischemia	Borderline ECG
Marked anterior T-wave changes, consider ischemia	Borderline ECG
Consider anterior ischemia, probably secondary to rvh	Borderline ECG
Moderate inferior T-wave changes	Borderline ECG
Inferior T-wave changes	Borderline ECG
Marked inferior T-wave changes, consider ischemia	Abnormal ECG
Tall T-waves, consider normal variant	Borderline ECG
Moderate anterolateral T-wave changes	Borderline ECG
Consider anterolateral ischemia, probably secondary to lvh	Borderline ECG
Anterolateral T-wave changes, consider ischemia	Abnormal ECG
Marked anterolateral T-wave changes, consider ischemia	Abnormal ECG
Prolonged QT interval	Abnormal ECG
Consider tricuspid atresia	Abnormal ECG
Consider endocardial cushion defect	Abnormal ECG
Consider atrial septal defect, septum secundum	Abnormal ECG
Probable anterolateral infarct, consider anomalous origin of the coronary artery	Abnormal ECG
Consider Ebstein anomaly	Abnormal ECG

VERITAS RESTING ECG INTERPRETATION EVALUATION

METHOD

Introduction and General Methodology

To test the analysis program, five hundred and fifty-eight (558) 12-lead ECGs were randomly collected from adult patients in a clinical and hospital setting over a two (2) month period. These ECGs were collected and then stored in digital form. Separately, five hundred and fifty-three (553) pediatric 15-lead ECGs (standard 12 leads plus V3R, V4R and V7) were collected from various pediatric hospital settings.

To test the criteria, ECGs from the data bases were submitted to a doctor to interpret as one would when reading a standard ECG available in a typical heart station. In addition, the same ECGs were interpreted by the Mortara Instrument VERITAS Analysis program running on a personal computer.

No reinterpretation was allowed by the doctor or the electrocardiograph.

Some categories of statements have been tested separately with different databases and methodologies, specifically pediatric ventricular hypertrophy statements and electronic pacemaker statements. The reasons and methods are explained below.

Pediatric Ventricular Hypertrophy

Left and Right Ventricular Hypertrophy (LVH and RVH) are the most common ECG interpretations in a typical pediatric cardiology population. Criteria for hypertrophy are complex, sometimes controversial, and highly age dependent. This is why the performance of the program for Left and Right Hypertrophy has been tested differently and more extensively. Approximately one thousand three hundred (1,300) 15-lead ECGs (standard 12 leads plus V3R, V4R and V7) were randomly collected in various pediatric cardiology centers.

To test the criteria, ECGs from this database were submitted to a cardiologist without automatic interpretation (blind reading) and in a standard 3x5 format at 10 mm/mV and 25 mm/s. The cardiologist was asked to divide the ECGs in 3 groups: “No RVH”, “Possible RVH” and “RVH”. Subsequently, the same cardiologist was represented with the ECGs but now had to divide the ECGs in “No LVH”, “Possible LVH” and “LVH”. In addition, the same ECGs were interpreted by the VERITAS Pediatric ECG Interpretation algorithm.

ECGs with a wide QRS (Right Bundle Branch Block, Left Bundle Branch Block, Ventricular Conduction Delay and Ventricular Preexcitation) were excluded from the analysis. The VERITAS algorithm omits the RVH and LVH calls in these cases because criteria for hypertrophy in the presence of abnormal intraventricular conduction are poorly defined.

ECGs with an erroneous order of the V-leads (for instance V7 in the V3R position) were also excluded, leading to one thousand one hundred seventy-four (1,174) included ECGs in total. Subsequently, the VERITAS algorithm was run again using only the standard 12 leads.

The tables below indicate the performance of the VERITAS program, using as “truth” both the possible and definite hypertrophy groups from the cardiologist, in confrontation with any hypertrophy call of the program. Note that the “truth” was always defined on the full 15-lead ECG.

Pacemaker Detection

The acquisition method of the aforementioned databases did not allow for adequate testing of the detection of artificial pacemaker rhythms because of the low prevalence of some pacemaker types and because of insufficient quality of the pacemaker pulse registration in the older data. Instead, sixty-nine (69) ECGs from patients with various types of pacemaker stimulation [six (6) atrial only, forty-eight (48) ventricular, fifteen (15) atrial and ventricular; about 25% also showed intrinsic rhythm] were collected from a pacemaker evaluation center. These sixty-nine (69) ECGs were used to establish the sensitivity of the VERITAS program (more precisely, the percentage of undetected pacemaker rhythms). A large database with circa seven thousand (7,000) ECGs from various institutions was used to measure the number of false positive pacemaker detections: all ECGs with an "Artificial Pacemaker" statement from the VERITAS program were reviewed by an expert. This allowed the possibility to establish the percentage of false positives. The statistical measurements (see below) were subsequently calculated on the basis of a population with 1% pacemaker ECGs.

Comparison by Categories

For purposes of determining specificity, sensitivity, and positive and negative predictive accuracy, statements have been grouped into categories. This has been done for various reasons: A higher number per category increases statistical significance; severity and probability statements (minimal, marked, possible, probable) are not well defined and highly subjective; some electrocardiographic regions (septal, anteroseptal, anterior, anterolateral and lateral) overlap and are not well defined; tachycardia, bradycardia and "normal" rate differ only in heart rate, while the algorithm that establish the statements is the same; the VERITAS algorithm sometimes issues a generic statement (e.g. supraventricular, uncertain) when an abnormality is detected, while the cardiologist will usually attempt to be more specific.

Some statements exist only for adult or pediatric populations and have only been tested in those populations. Some statements have very different meaning or prevalence in a pediatric or adult population and have been tested separately.

Following is a list of categories that have been used for statistical analysis, and the VERITAS statements that are grouped into them:

- Sinus Rhythm
  - Normal Sinus Rhythm
  - Sinus Bradycardia
  - Sinus Tachycardia
- Atrial Fibrillation
- Atrial Flutter

- Miscellaneous Rhythms
  - Ectopic Atrial Rhythm
  - Ectopic Atrial Tachycardia
  - Ectopic Atrial Bradycardia
  - Junctional Rhythm
  - Junctional Tachycardia
  - Junctional Bradycardia
  - Idioventricular Rhythm
  - Ventricular Tachycardia
  - Supraventricular Rhythm
  - Supraventricular Tachycardia
  - Supraventricular Bradycardia
  - Uncertain Irregular Rhythm
  - Uncertain Regular Rhythm

- Supraventricular Premature Complexes
  - With Occasional Atrial Premature Complexes
  - With Frequent Atrial Premature Complexes
  - With Occasional Supraventricular Premature Complexes
  - With Frequent Supraventricular Premature Complexes

- Ventricular Premature Complexes
  - With Occasional Ventricular Premature Complexes
  - With Frequent Ventricular Premature Complexes
  - With Occasional Ectopic Premature Complexes
  - With Frequent Ectopic Premature Complexes

- Atrial Electronic Pacemaker

- Ventricular Electronic Pacemaker

- High degree AV-block
  - With second degree AV-block type Mobitz 1 (Wenckebach)
  - With second degree AV-block type Mobitz 2
  - With high degree AV-block

- Prolonged PR-Interval (First Degree AV-block)

- Short PR-interval (adult only)

- Right Atrial Enlargement
  - Possible Right Atrial Enlargement
  - Right Atrial Enlargement

- Left Atrial Enlargement
  - Possible Left Atrial Enlargement
  - Left Atrial Enlargement

• Right Axis Deviation
  Borderline Right Axis Deviation
  Marked Right Axis Deviation

• Left Axis Deviation
  Borderline Left Axis Deviation
  Marked Left Axis Deviation

• Low QRS Voltage (adult only)
  Low QRS Voltage In Extremity Leads
  Low QRS Voltage In Precordial Leads
  Low QRS Voltage
  S1-S2-S3 Pattern, Consistent With Pulmonary Disease, RVH, Or Normal Variant
  Pattern Consistent With Pulmonary Disease

• Right Bundle Conduction
  Right Bundle Branch Block
  Right Bundle Branch Block, plus possible right ventricular hypertrophy
  Note: moderate right conduction delays have not been considered

Nonspecific intraventricular conduction block
  Note: moderate conduction delays have not been considered

• Left bundle branch block
  Note: moderate left conduction delay and fascicular block have not been considered

• Right Ventricular Hypertrophy
  Possible Right Ventricular Hypertrophy
  Probable Right Ventricular Hypertrophy
  Right Ventricular Hypertrophy
  Right Ventricular Hypertrophy and ST-T Change

• Left Ventricular Hypertrophy
  Minimal Voltage Criteria For LVH, Consider Normal Variant
  Moderate Voltage Criteria For LVH, Consider Normal Variant
  Voltage Criteria For LVH
  Possible Left Ventricular Hypertrophy
  Probable Left Ventricular Hypertrophy
  Left Ventricular Hypertrophy And S-T Change

Note: separate tables are compiled for Ventricular Hypertrophy for Adults, Pediatric 12-lead ECG's and Pediatric 15-lead ECG's

• Inferior Infarction (adult only)
  All inferior infarction statements

• Anterior Infarction (adult only)
  All septal, anterior, lateral, anteroseptal and anterolateral infarction statements

• ST-T changes - adult
  All adult ST-depression and T-wave abnormality statements

• ST-T changes - pediatric
All pediatric ST-depression and T-wave abnormality statements

• Prolonged QT

• Consider Endocardial Cushion Effect (pediatric only)

RESULTS

Results are presented in two different forms. In order to more clearly view the positive and negative calls by the physician and the Mortara Instrument VERITAS Analysis Program, the following tables present data in a 2 x 2 truth matrix format (Table 1 and 2). Summary statistical measurements such as sensitivity and specificity are given below (Table 3 and 4). For this presentation, the categories have been divided in two groups: rhythm statements and statements based on waveform morphology.

Definitions

In the matrix format shown, the Physician Statement is used as the gold standard against which the Mortara Instrument VERITAS ECG Analysis Program is compared.

Physician Statement	Mortara Instrument VERITAS Analysis Program: +	Mortara Instrument VERITAS Analysis Program: -
+	True Positive	False Negative
-	False Positive	True Negative

Specific definitions for each of the terms used above are as follows:

True Positive: (TP)
A true positive is called when the analysis program agrees with the positive diagnostic statement made by the physician, i.e., true positive call by the analysis program.

True Negative: (TN)
A true negative is called when the analysis program agrees with the negative diagnostic statement made by the physician, i.e., the condition under question is not called by either the analysis program or the physician.

False Positive: (FP)
A false positive occurs when the analysis program appends the diagnostic statement to the ECG in question whereas the physician indicates that the condition did not exist, i.e., a false positive call by the analysis program.

False Negative: (FN)
A false negative occurs when the physician appends the diagnostic statement to the ECG in question whereas the analysis program indicates that the condition did not exist, i.e., a false negative call by the analysis program.

In summary, True Positive and True Negatives are correct diagnostic statements made by the analysis program since they truly reflect the positive and negative calls made by the physician. False Positives and False Negatives occur when the analysis program calls do not agree with the physician statement. A False Positive, in effect, overcalls a particular diagnostic statement whereas a False Negative undercalls. The prevalence of the condition in the databases used can be determined by summing the True Positive and False Negative numbers.

In addition, the values for sensitivity, specificity and predictive accuracy are presented in table form following the analysis matrices. True Positives, True Negatives, False Positives and False Negatives have been used to calculate the Sensitivity, Specificity and the Predictive Accuracy.

Formulas used for calculating the above values are:

$$\text{Sensitivity} = \frac{TP}{TP + FN} \qquad \text{Specificity} = \frac{TN}{TN + FP}$$

$$\text{Positive Predictive Accuracy} = \frac{TP}{TP + FP}$$

$$\text{Negative Predictive Accuracy} = \frac{TN}{TN + FN}$$

Table 1, Rhythm Criteria Truth Matrices

Sinus Rhythm

	+	-
+	1011	27
-	3	70

Atrial Fibrillation

	+	-
+	35	2
-	6	1068

Atrial Flutter

	+	-
+	7	1
-	5	1098

Miscellaneous Rhythms

	+	-
+	26	2
-	19	1064

High Degree AV-Block

	+	-
+	5	2
-	0	1104

Ventricular Preexcitation

	+	-
+	6	9
-	0	1096

Table 1, Rhythm Criteria Truth Matrices (Continued)

Premature Ventricular Complexes

	+	-
+	59	2
-	13	1037

Supraventricular Premature Complexes

	+	-
+	24	10
-	4	1073

Atrial Electronic Pacemaker

	+	-
+	0.81 %	0.19 %
-	0.11 %	98.89 %

Ventricular Electronic Pacemaker

	+	-
+	0.98 %	0.02 %
-	0.04 %	98.96 %

Table 2, Contour Criteria Truth Matrices

Prolonged PR-Interval

	+	-
+	61	11
-	9	1030

Short PR-Interval (adult only)

	+	-
+	16	2
-	6	534

Right Atrial Enlargement

	+	-
+	18	13
-	0	1080

Left Atrial Enlargement

	+	-
+	55	13
-	9	1034

Right Axis

	+	-
+	31	3
-	5	1072

Left Axis

	+	-
+	86	9
-	6	1010

Low QRS Voltage (adult only)

	+	-
+	8	6
-	3	541

Right Bundle Conduction

	+	-
+	53	5
-	6	1047

Nonspecific Conduction Abnormality

	+	-
+	11	2
-	12	1086

Table 2, Contour Criteria Truth Matrices (Continued)

Left Bundle Conduction

	+	-
+	13	1
-	3	1094

Right Ventricular Hypertrophy (adult only)

	+	-
+	4	6
-	1	547

Left Ventricular Hypertrophy (adult only)

	+	-
+	123	4
-	10	421

Right Ventricular Hypertrophy (pediatric 12 lead)

	+	-
+	113	59
-	52	950

Left Ventricular Hypertrophy (pediatric 12 lead)

	+	-
+	126	29
-	51	968

Right Ventricular Hypertrophy (pediatric 15 lead)

	+	-
+	137	35
-	74	928

Left Ventricular Hypertrophy (pediatric 15 lead)

	+	-
+	127	28
-	51	968

Table 2, Contour Criteria Truth Matrices (Continued)

Anterior Infarction (adult only)

	+	-
+	52	20
-	1	485

Inferior infarction (adult only)

	+	-
+	68	13
-	3	474

ST-T Changes Adult

	+	-
+	132	22
-	38	366

ST-T Changes Pediatric

	+	-
+	18	3
-	4	528

Prolonged QT

	+	-
+	18	2
-	2	1089

Endocardial Cushion Effect (pediatric)

	+	-
+	6	1
-	6	540

Table 3, Sensitivity, Specificity and Predictive Accuracies, Rhythm Criteria

RHYTHM CRITERIA				
DIAGNOSTIC STATEMENT	SENSITIVITY	SPECIFICITY	POS PREDICTIVE ACCURACY	NEG PREDICTIVE ACCURACY
Sinus Rhythm	97.4	95.9	99.7	72.2
Atrial Fibrillation	94.6	99.4	85.3	99.8
Atrial Flutter	87.5	99.5	58.3	99.9
Miscellaneous Rhythms	92.9	98.2	57.8	99.8
High degree AV-block	71.4	100	100	99.8
Ventricular preexcitation	42.9	100	100	99.2
Ventricular Premature Complexes	96.7	98.8	81.9	99.8
Supraventricular Premature Complexes	70.6	99.6	85.7	99.1
Atrial Electronic Pacemaker	81.0	99.9	88.0	99.8
Ventricular Electronic Pacemaker	98.0	100	96.1	100

Table 4, Sensitivity, Specificity and Predictive Accuracies, Contour Criteria

CONTOUR CRITERIA				
DIAGNOSTIC STATEMENT	SENSITIVITY	SPECIFICITY	POS PREDICTIVE ACCURACY	NEG PREDICTIVE ACCURACY
Prolonged PR-Interval	84.7	99.1	87.1	98.9
Short PR-interval (adult)	88.9	98.9	72.7	99.6
Right Atrial Enlargement	58.1	100	100	98.8
Left Atrial Enlargement	80.9	99.1	85.9	98.8
Right Axis	91.1	99.5	86.1	99.7
Left Axis	90.5	99.4	93.5	99.1
Low QRS Voltage (adult)	57.1	99.4	72.7	98.9
Right Bundle Conduction	91.4	99.4	89.8	99.5
Nonspecific Conduction Abnormality	84.6	98.9	47.8	99.8
Left Bundle Conduction	92.9	99.7	81.3	99.9
Right Ventricular Hypertrophy, adult	40.0	99.8	80.0	98.9
Left Ventricular Hypertrophy, adult	96.9	97.7	92.5	99.1
Right Ventricular Hypertrophy, pediatric 12-lead	65.7	94.8	68.5	94.2
Left Ventricular Hypertrophy, pediatric 12-lead	81.3	95.0	71.2	97.1
Right Ventricular Hypertrophy, pediatric 15-lead	79.7	92.6	64.9	96.4
Left Ventricular Hypertrophy, pediatric 15-lead	81.9	95.0	71.3	97.2
Inferior Infarction	84.0	99.4	95.8	97.3
Anterior Infarction	72.2	99.8	98.1	96.0
ST-T Changes, adult	85.7	90.6	77.6	94.3
ST-T Changes, pediatric	85.7	99.2	81.8	99.4
Prolonged QT	90.0	99.8	90.0	99.8
Endocardial Cushion Effect (pediatric)	85.7	98.9	50.0	99.8