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Physician's Guide to

VERITAS WITH ADULT AND PEDIATRIC RESTING ECG INTERPRETATION

PRECAUTIONS:

Some Mortara products are not equipped with the pediatric resting ECG interpretation feature.
Refer to user manual for proper instructions and precautions pertaining to equipment use.

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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 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 ECG	Abnormal
Abnormal Rhythm ECG	Abnormal Rhythm
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.

RHYTHM STATEMENTS

Rhythm Statements and Modifiers (UNIPRO)*

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.

Rhythm Statements

Sinus Tachycardia
Sinus Rhythm
Sinus Bradycardia

Atrial Tachycardia (abnormal P axis)
Atrial Rhythm
Atrial Bradycardia

Junctional Tachycardia (superior P axis and Short PR)
Junctional Rhythm
Junctional Bradycardia

Supraventricular Tachycardia (narrow QRS, regular RR, no P)
Supraventricular Rhythm
Supraventricular Bradycardia

Undetermined (regular) rhythm

Atrial fibrillation
Atrial flutter
Electronic ventricular pacemaker

*Electrocardiograph is programmed with the UNIPRO communication protocol.

Modifiers

...with (marked) sinus arrhythmia
...with first degree AV block
...with short PR interval
...with second degree AV block, Mobitz Type (I, II)
...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.

Modifiers Used with Atrial Fibrillation

...with (rapid/slow) ventricular response
...with AV block

Modifiers Used with Atrial Flutter

...with aberrant conduction or ventricular premature complexes
...cannot rule out atrial flutter (Regular rate near 150)
...electronic (atrial/ventricular) pacemaker
...contour analysis based on intrinsic rhythm
...intermittent Wolff-Parkinson-White pattern

Rhythm Statements and Modifiers (UNIPRO32)**

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.

Rhythm Statements

Sinus Tachycardia
Sinus Rhythm
Sinus Bradycardia

Atrial Tachycardia (abnormal P axis)
Atrial Rhythm
Atrial Bradycardia

Junctional Tachycardia (superior P axis and Short PR)
Junctional Rhythm
Junctional Bradycardia

Supraventricular Tachycardia (narrow QRS, regular RR, no P)
Supraventricular Rhythm
Supraventricular Bradycardia

Undetermined (regular) rhythm

Atrial fibrillation
Atrial flutter

Criteria for limits of Tachycardia, Bradycardia as well as PR intervals for age are included in the Pediatric Reference Summary.

Modifiers

...with AV block
...with prolonged PR interval for age
...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.

Modifiers Used with Atrial Fibrillation

...with (rapid/slow) ventricular response
...with AV block

Modifiers Used with Atrial Flutter

...with aberrant conduction or ventricular premature complexes
...cannot rule out atrial flutter
...electronic (atrial/ventricular) pacemaker
...contour analysis based on intrinsic rhythm
...intermittent Wolff-Parkinson-White pattern

**Electrocardiograph is programmed with the UNIPRO32 communication protocol.

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.)

Wolff-Parkinson-White

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	PRINT “Atypical Wolff-Parkinson-White Pattern”
Delta wave is present in 2 leads and R amplitude > S amplitude in V1	PRINT “Type A Wolff-Parkinson-White Pattern”
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 “Type B Wolff-Parkinson-White Pattern”

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 "Moderate Left axis deviation" **REASON**: *QRS axis < -20*
QRS axis < -30	PRINT "Abnormal Left axis deviation" **REASON**: *QRS axis < -30*
QRS axis > 90	PRINT "Moderate Right axis deviation" **REASON**: *QRS axis > 90*
QRS axis > 100	PRINT "Abnormal 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. Borderline cases are characterized by the use of the term "moderate." (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 limb leads" **REASON**: *QRS deflection < 0.5 mV in limb leads*
Total QRS deflection < 1000 µV in all V leads	PRINT "Low QRS voltage in chest 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 “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 "RsR' (QR) in V1/V2 consistent with right ventricular conduction delay"
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 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 plus 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 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 "Incomplete left bundle branch block" **REASON**: *105+ ms QRS duration, 80+ ms Q/S in V1/V2* *no Q and 60+ ms R in I/aVL/V5/V6*
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*
The test for Incomplete Left Bundle Branch Block is positive 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 criteria for this statement 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 "Nonspecific 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 "Nonspecific intraventricular conduction block" **REASON:** *130+ ms QRS duration*

Rationale

Intraventricular conduction delay is used to connote QRS widening which does not fit any previously defined pattern, and is not so great as to be considered block.

ADULT HYPERTROPHY

Right Ventricular Hypertrophy

SKIP TEST IF
The test for Right Bundle Branch Block is positive
or the test for 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 with repolarization abnormality" **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 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, may be 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, may be 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 with repolarization abnormality" **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:

- Cannot rule out. . . Typical equivalent Q duration 30-34 ms
- Possible. . . 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 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 “age undetermined”
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 “Cannot rule out 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 “Possible 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 "Cannot rule out 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 new	Probably recent
The age of the anterior infarct is undetermined	Age undetermined
Anterior infarct is old	Probably old

Septal Infarct

SKIP TEST IF
The test for 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 "Age undetermined" 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 "Cannot rule out 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 "Possible 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	Age undetermined
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 “Cannot rule out 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 “Possible 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	“Age undetermined” 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

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 “age undetermined:” will be used
Equivalent Q duration ≥ 30 ms in 2 leads of I/V5/V6 and a lateral infarct cannot be ruled out	PRINT “Cannot rule out 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 a lateral infarct “cannot be ruled out”	PRINT “Possible 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** lateral infarct “cannot be ruled out” 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*

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

Anterolateral Infarct

Criteria

IF	THEN
Both an anterior infarct and a lateral infarct "cannot be ruled out"	PRINT "Cannot rule out anterolateral infarct" **REASON:** *30 ms Q wave in I/aVL/V3-V6*
The tests for anterior infarct or lateral infarct are positive	PRINT "Possible 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 "Age undetermined" is appended to the record
Both the lateral infarct and anterior infarct are qualified as "old"	Anterolateral infarct call will be qualified as "probably old"

Inferior Infarct

Criteria

IF	THEN
STM and STE amplitude > 100 µV in II and aVF and Alternate T amplitude ≥ 0 in II & aVF	"New" inferior infarct is present
STM and STE amplitude > 50 µV in II or aVF and Alternate T amplitude < 0 in II or aVF	"Recent" inferior infarct is present
Inferior infarct is not new or recent and STM amplitude < 30 µV in II and aVF and Alternate T amplitude ≥ 0 in II and aVF	Inferior infarct is "old"
inferior infarct is not new, recent, or old	Qualifier "age undetermined" 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 "Cannot rule out 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 "Possible 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*
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 "age undetermined"
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 right bundle branch block, left bundle branch block, intraventricular conduction block, myocardial infarct 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 > 450 ms
Either myocardial infarct, right bundle branch block, left bundle branch block, intraventricular conduction block is present and the left ventricular hypertrophy flag is not set

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 epicardial 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 myocardial infarct, right bundle branch block, left bundle branch block, intraventricular conduction block, 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” **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” **REASON:** *Marked ST elevation w/o normally inflected T wave*

Anterior and Septal Epicardial Injury

SKIP TEST IF
The test for pericarditis, left bundle branch block, right bundle branch block, intraventricular conduction block is positive

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

Criteria

IF	THEN
6 times STJ amplitude > QRS deflection in V1 & V2 **or** STJ amplitude > ST LIMIT/2 and T is not upward inflected in V1 and V2 and Alternate T amplitude ≥ in V1 and V2 and the test for septal infarct is negative and the left ventricular hypertrophy flag is not set	PRINT “Possible septal epicardial injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in V1/V2*
4 times STJ amplitude > QRS deflection in V1 & V2 **or** STJ amplitude > ST LIMIT and T is not upward inflected in V1 and V2 and Alternate T amplitude ≥ 0 in V1 and V2 and test for septal infarct is negative and the left ventricular hypertrophy flag is not set	PRINT “Septal epicardial injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in V1/V2*

Anterior and Septal Epicardial Injury Criteria (Continued)

IF	THEN
6 times STJ amplitude > QRS deflection in 2 leads of V2-V5 **or** STJ amplitude > ST LIMIT/2 and T is not upward inflected in 2 leads of V2-V5 and Alternate T amplitude ≥ 0 in V2-V5 and the test for anterior infarct is negative and the left ventricular hypertrophy flag is not set	PRINT "Possible anterior epicardial injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V2-V5*
4 times STJ amplitude > QRS deflection in 2 leads of V2-V5 **or** STJ amplitude > ST LIMIT and T is not upward inflected in 2 leads of V2-V5 and alternate T amplitude ≥ 0 in V2-V5 and the test for anterior infarct is negative and the left ventricular hypertrophy flag is not set	PRINT "Anterior epicardial 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 "Possible anteroseptal epicardial 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 "Anteroseptal epicardial injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V1-V4*

Lateral Epicardial Injury

SKIP TEST IF
The test for pericarditis, left bundle branch block, right bundle branch block, intraventricular conduction block is positive

Criteria

IF	THEN
6 times STJ amplitude > QRS deflection in 4 leads of I/aVL/V5/V6 **or** STJ amplitude > ST LIMIT/2 and T is not upward inflected in 2 leads of I, aVL, V5, and V6 and Alternate T amplitude ≥ 0 in I, aVL, V5 and V6 and the test for a lateral infarct is negative	PRINT "Possible lateral epicardial injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in I/aVL/V5/V6*
4 times STJ amplitude > QRS deflection in 2 leads of I/aVL/V5/V6 **or** STJ amplitude > ST LIMIT and T is not upward inflected in 2 leads of I, aVL, V5 and V6 and Alternate T amplitude ≥ 0 in I, aVL, V5 and V6 and the test for a lateral infarct is negative	PRINT "Lateral epicardial injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in I/aVL/V5/V6*
The test for both possible anterior and lateral injury is positive	PRINT "Possible anterolateral epicardial 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 "Anterolateral epicardial injury" **REASON:** *Marked ST elevation w/o normally inflected T wave in V3-V6*

Inferior Epicardial Injury

SKIP TEST IF
The test for pericarditis, left bundle branch block, right bundle branch block, intraventricular conduction block is positive

Criteria

IF	THEN
6 times STJ amplitude > QRS deflection in II and aVF **or** STJ amplitude > ST LIMIT/2 and T is not upward inflected in II and aVF and Alternate T amplitude ≥ 0 in II and aVF and the test for inferior infarct is negative	PRINT “Possible inferior epicardial injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in II/aVF*
4 times STJ amplitude > deflection in II & aVF **or** STJ amplitude > ST LIMIT and T is not upward inflected in II and aVF and Alternate T amplitude ≥ 0 in II and aVF and the test for inferior infarct is negative	PRINT “Inferior epicardial injury” **REASON:** *Marked ST elevation w/o normally inflected T wave in II/aVF*

ADULT ST DEPRESSION

ST Depression

SKIP TEST IF
The test for left bundle branch block, intraventricular conduction block, left ventricular hypertrophy with repolarization, or pericarditis is positive

Criteria

IF	THEN
The tests for right ventricular hypertrophy with repolarization, ST elevation and right bundle branch block are negative and STJ amplitude < -100 μV and STE amplitude ≥ 0 in 2 Leads (except aVR and III)	PRINT "Junctional depression, probably normal" **REASON:** *0.1+ mV junctional ST depression*
The tests for right ventricular hypertrophy with repolarization, ST elevation, and right bundle branch block are negative and STJ < -100 μV and STE < 0 and STE ≥ STJ/2 in 2 leads (except aVR and III)	PRINT "Abnormal Junctional depression" **REASON:** *Junctional depression with weak upslope*
The tests for right ventricular hypertrophy with repolarization, ST elevation, and right bundle branch block are negative and STM or STE < both STJ and -50 μV in 2 leads (except aVR and III)	PRINT "ST depression, possible digitalis effect" **REASON:** *Downsloping or coved ST depression*
The tests for right ventricular hypertrophy with repolarization, ST elevation, and right bundle branch block are negative and STJ/STM/STE all < -25 μV in 2 leads (except aVR and III)	PRINT "Minimal ST depression" **REASON:** *0.025+ mV ST depression*

ST Depression Criteria (Continued)

IF	THEN
The tests for right ventricular hypertrophy with repolarization, ST elevation and right bundle branch block are negative and STM < -50 µV and STE < 0 or STE < all of STJ/STM -50 µV in 2 leads (except aVR and III)	PRINT "Moderate ST depression" **REASON:** *0.05+ mV ST depression*
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 "Marked ST depression, possible 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, consistent with subendocardial injury" **REASON:** *0.2+ mV ST depression*
The test for atrial fibrillation is positive and either minimal or moderate ST depression is present or "marked" ST depression w/o .1 + mV ST depression	Append "probably digitalis effect"
The test for atrial fibrillation is positive and there is "marked" ST depression w/o .2 + mV ST depression	Append "or digitalis effect"

ADULT T WAVE ABNORMALITIES

T Wave Abnormality, Ischemia

SKIP TEST IF
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

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 (excluding V2 if right bundle branch block is present)	PRINT "T wave abnormality, possible 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 "T wave abnormality, consistent with 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 "T wave abnormality, possible 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 "T wave abnormality, consistent with 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 "T wave abnormality, possible 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 "T wave abnormality, consistent with 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 &" to the T wave abnormality statement
The test for atrial fibrillation is positive and the tests for possible anterior ischemia and/or possible lateral ischemia are positive	Append "or digitalis effect"
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 "T wave abnormality, possible 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
T wave abnormality is present and the test for possible inferior ischemia is positive and the test for possible atrial fibrillation is positive	Append "or digitalis effect" to the T wave abnormality statement
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 "T wave abnormality, consistent with inferior ischemia" **REASON:** *-0.5+ mV T wave in II/aVF*

T Wave Abnormality, Nonspecific

SKIP TEST (except test Short QT) **IF**
left bundle branch block, intraventricular conduction block, left ventricular hypertrophy with repolarization, right ventricular hypertrophy with repolarization, subendocardial injury, ST elevation, pericarditis, myocardial infarct, right bundle branch block, 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 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”
The test for atrial fibrillation is positive and the test for either nonspecific T wave or ST abnormalities is positive	Append “probably digitalis effect”
T amplitude > 1000 µV and T amplitude > 1/2 R amplitude in 3 leads of I/II/V1-V6	PRINT “Tall T waves, possible hyperkalemia”
QTc < 360 ms and heart rate < 140	PRINT “Short QT interval”
QTc > 450 ms	PRINT “Long QT interval”

ADULT BRUGADA

Brugada

SKIP TEST IF
QRS duration ≥ 110 ms

Criteria

IF	THEN
STJ ≥ 100 µV and the lesser of STM or STE < STJ and T amplitude > the lesser of STM or STE in some of V1/V2/V3 and T amplitude < 0 in some of V1/V2/V3	PRINT “Type 3 Brugada pattern (non-diagnostic)”
STJ ≥ 200 µV and the lesser of STM or STE < STJ and the lesser of STM or STE > 100 µV and T amplitude > the lesser of STM or STE in some of V1/V2/V3	PRINT “Type 2 Brugada pattern (non-diagnostic)”
STJ ≥ 200 µV and the lesser of STM or STE < STJ and T amplitude < 0 in some of V1/V2/V3	PRINT “Type 1 Brugada pattern (non-diagnostic)”

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 "Wolff-Parkinson-White Syndrome" **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 "Consider 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 "Consider 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 for age" **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 Pediatric 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 Pediatric Reference Summary.

Left Bundle Conduction

Criteria

IF	THEN
QRS axis ≤ -60	PRINT "Left anterior superior 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 Pediatric 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 Pediatric 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 Pediatric 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:

Consider Right Ventricular Hypertrophy [Voltage Criteria Only]
Consider Right Ventricular Hypertrophy [T wave Changes]
Consider 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:

Consider Left Ventricular Hypertrophy [Voltage Criteria Only]
Consider 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]

Left Ventricular Hypertrophy [Voltage Criteria & LAD for Age]
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 "Probable normal anterior ST variation" **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 "Non-specific inferior ST segment changes, probably normal variation" **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 "Probable normal anterolateral ST variation" **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 segment changes, 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 "Non-specific anterior ST segment changes, consider subendocardial injury" **REASON:** *ST < -0.2mV in 1 of V2-V5*
STJ/STM < -200 µV in 1 of II/III/aVF	PRINT "Non-specific inferior ST segment changes, 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 "Non-specific anterolateral ST segment changes, 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 segment changes, 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

Criteria

IF	THEN
T amplitude ≤ -10 µV or T' amplitude ≤ -10 µV in 2 of V1/V2/V3	PRINT "Anterior, non-specific 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 "Anterior, non-specific 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 "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 "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 amplitude ≤ -1000 µV or T' amplitude ≤ -1000 µV in 2 of V1/V2/V3	PRINT "Anterior T wave changes" **REASON:** *T < -1 mV in 2 of V1-V3*

T Wave Abnormality Ischemia Criteria (Continued)

IF	THEN
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 "Anterior T wave changes" **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 "Non-specific 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 "Non-specific 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 "Consider inferior 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 "Non-specific anterolateral T wave changes, probably 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 "Non-specific 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 "Non-specific 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 "Non-specific anterolateral T wave changes, probable 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 "Consider anterolateral ischemia" **REASON:** *T < -1 mV in 1 of I/aVL/V2-V6*

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*

PEDIATRIC QT INTERVAL ABNORMALITIES

QT Prolongation

Criteria

IF	THEN
QTc > 450	PRINT “Long QT Interval” **REASON:** *QTc > 450*

QT Shortening

Criteria

IF	THEN
QTc < 340 and Ventricular rate < 140	PRINT “Short QT Interval” **REASON:** *QTc < 340*

PEDIATRIC BRUGADA

Brugada

SKIP TEST IF
QRS duration ≥ 110 ms

Criteria

IF	THEN
STJ ≥ 100 µV and the lesser of STM or STE < STJ and T amplitude > the lesser of STM or STE in some of V1/V2/V3 and T amplitude < 0 in some of V1/V2/V3	PRINT “Type 3 Brugada pattern (non-diagnostic)”
STJ ≥ 200 µV and the lesser of STM or STE < STJ and the lesser of STM or STE > 100 µV and T amplitude > the lesser of STM or STE in some of V1/V2/V3	PRINT “Type 2 Brugada pattern (non-diagnostic)”
STJ ≥ 200 µV and the lesser of STM or STE < STJ and T amplitude < 0 in some of V1/V2/V3	PRINT “Type 1 Brugada pattern (non-diagnostic)”

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.

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

QRS Duration for Age

Age	QRS Duration
< 1yr	99ms
1 – 15yr	109ms

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	NEED	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

VERITAS RESTING ECG INTERPRETATION EVALUATION

METHOD

Introduction and General Methodology

To test the analysis program 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, 553 pediatric 15 lead ECG's (standard 12 leads plus V3R, V4R and V7) were collected from various pediatric hospital settings.

In addition, consecutive 568 ECG's were added, half from a hospital digital ECG archive, half from an ambulance service, in order to increase the statistical reliability for the major rhythm categories sinus rhythm, atrial fibrillation and atrial flutter.

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 Veritias 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 1300 15-lead ECG's (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 ECG's 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 ECG's 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 Pre-Excitation) 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 intra-ventricular conduction are poorly defined.

ECGs with a erroneous order of the V-leads (for instance V7 at the place of V3R) were also excluded, leading to 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, 69 ECG's from patients with various types of pacemaker stimulation (6 atrial only, 48 ventricular, 15 atrial and ventricular; about 25% also showed intrinsic rhythm) were collected from a pacemaker evaluation center. These ECG's were used to establish the sensitivity of the VERITAS program (more precisely, the percentage of undetected pacemaker rhythms).

A large database with circa 7000 ECG's from various institutions,was used to measure the number of false positive pacemaker detections: all ECG's with an "Artificial Pacemaker" statement from the VERITAS program were reviewed by an expert. In this way it was possible to establish the percentage of false positives. The statistical measurements (see below) were subsequently calculated on the basis of a population with 1% pacemaker ECG's.

Comparison by Categories

For purposes of determining specificity, sensitivity, 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 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 been tested only in those. Some statements have very different meaning or prevalence in pediatric or adult population, and have been tested separately.

Below is the 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 delays and fascicular blocks 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). Below, summary statistical measurements like sensitivity and specificity are given (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

	+	-
+	1461	53
-	15	150

Atrial Fibrillation

	+	-
+	99	10
-	16	1554

Atrial Flutter

	+	-
+	5	5
-	2	1660

Miscellaneous Rhythms

	+	-
+	28	0
-	26	1057

High Degree AV-Block

	+	-
+	2	5
-	0	1104

Ventricular Preexcitation

	+	-
+	7	8
-	0	1096

Table 1, Rhythm Criteria Truth Matrices (Continued)

Premature Ventricular Complexes

	+	-
+	58	3
-	14	1036

Supraventricular Premature Complexes

	+	-
+	25	3
-	14	1075

Atrial Electronic Pacemaker

	+	-
+	0.38 %	0.38 %
-	0.04 %	98.96 %

Ventricular Electronic Pacemaker

	+	-
+	0.81 %	0.19 %
-	0.04 %	98.96 %

Table 2, Contour Criteria Truth Matrices

Prolonged PR-Interval

	+	-
+	61	11
-	6	1033

Short PR-Interval (Adult Only)

	+	-
+	12	6
-	4	536

Right Atrial Enlargement

	+	-
+	25	6
-	13	1067

Left Atrial Enlargement

	+	-
+	55	13
-	21	1022

Right Axis

	+	-
+	30	4
-	6	1071

Left Axis

	+	-
+	83	12
-	5	1011

Low QRS Voltage (Adult Only)

	+	-
+	8	6
-	3	541

Right Bundle Conduction

	+	-
+	52	6
-	6	1047

Nonspecific Conduction Abnormality

	+	-
+	11	2
-	15	1083

Table 2, Contour Criteria Truth Matrices (Continued)

Left Bundle Conduction

	+	-
+	12	2
-	2	1095

Right Ventricular Hypertrophy (Adult Only)

	+	-
+	5	5
-	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
-	4	482

Inferior Infarction (Adult Only)

	+	-
+	70	11
-	14	463

ST-T Changes Adult

	+	-
+	133	22
-	60	896

ST-T Changes Pediatric

	+	-
+	18	3
-	3	528

Prolonged QT

	+	-
+	20	0
-	14	1077

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	96.5	90.9	99.0	73.9
Atrial Fibrillation	90.8	99.0	86.1	99.4
Atrial Flutter	29.4	99.9	71.4	99.3
Miscellaneous Rhythms	100	97.6	51.9	100
High Degree AV-Block	28.6	100	100	99.5
Ventricular Preexcitation	46.7	100	100	99.3
Ventricular Premature Complexes	95.1	98.7	80.6	99.7
Supraventricular Premature Complexes	73.5	99.8	92.6	99.2
Atrial Electronic Pacemaker	38.0	100	90.5	99.4
Ventricular Electronic Pacemaker	81.0	100	95.3	99.8

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	99.4	91.0	98.9
Short PR-interval (Adult)	66.7	99.3	75.0	98.9
Right Atrial Enlargement	80.6	98.8	100	99.3
Left Atrial Enlargement	80.9	98.0	72.4	98.7
Right Axis	88.2	99.4	83.3	99.6
Left Axis	87.4	99.5	94.3	98.8
Low QRS Voltage (Adult)	57.1	99.7	72.7	99.5
Right Bundle Conduction	89.7	99.4	89.7	99.4
Nonspecific Conduction Abnormality	84.6	98.6	42.3	99.8
Left Bundle Conduction	85.7	99.8	85.7	99.8
Right Ventricular Hypertrophy, Adult	50.0	99.8	83.3	99.1
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	86.4	98.6	83.3	98.9
Anterior Infarction	72.2	99.8	92.9	98.1
ST-T Changes, Adult	85.8	93.7	68.9	97.6
ST-T Changes, Pediatric	85.7	99.7	85.7	99.7
Prolonged QT	100	98.7	58.8	100
Endocardial Cushion Effect (Pediatric)	85.7	99.5	50.0	99.9

Interval Measurements

The global PR-interval, QRS-duration and QT-interval are measured using the "median beat", using all available leads. The first and last wave of the QRS for individual leads start and end with the global onset and offset of the QRS, therefore iso-electric segments before the Q-wave and after the S-wave may be included in the Q or S duration measurements of the program.

The interval measurements have been tested according to IEC 60601-2-51 (2003) on 100 ECG's with established "truth" A positive difference means that the Veritas measurement is bigger than the truth.

Table 5, Accuracy of Interval Measurements

Dimensions in ms

Global measurement	Acceptable mean difference	Measured mean difference	Acceptable standard deviation	Measured standard deviation
PQ.interval	± 10	2.1	10	7.2
QRS-duration	± 10	-0.4	10	5.9
QT-interval	± 25	-7.8	30	10.6

The stability of the measurements in conditions of noise has been measured according to IEC 60601-2-51 (2003), by adding high frequency, line frequency and base-line artifact and comparing the results with the measurements on the same ECG's without noise. Results were as follows:

Table 6, Stability of Interval Measurements Against Noise

Global measurement	Type of added noise	Disclosed differences	
		Mean ms	Standard deviation ms
P-duration	High frequency	1.50	3.21
P-duration	Line frequency	0.63	2.00
P-duration	Base-line	0.13	1.46
QRS-duration	High frequency	-0.38	1.51
QRS-duration	Line frequency	0.13	0.99
QRS-duration	Base-line	-0.25	1.28
QT-interval	High frequency	0.25	1.58
QT-interval	Line frequency	0.13	1.55
QT-interval	Base-line	-0.13	0.99