

Philips DXL ECG Algorithm for the HeartStart MRx

Application Note



Introduction

Back in the late 1970-s Philips pioneered the development of computerized ECG data analysis, introducing its first 12-lead algorithm to cardiac care clinicians. As a result of three decades of ongoing research, development, and enhancement, Philips introduced the DXL ECG Algorithm.

The Philips DXL ECG algorithm, developed by Philips' Advanced Algorithm Research Center (AARC), uses sophisticated analytical methods for interpreting cardiac

data. In HeartStart MRx, the DXL algorithm analyzes 12 leads of simultaneously acquired ECG waveforms to provide an interpretation of rhythm and morphology across a wide variety of patient populations.

The DXL Algorithm conforms to the 2007 AHA/ACC/HRS statement recommendations for the standardization and interpretation of the ECG¹ and guidelines for ST segment Elevation Myocardial Infarction (STEMI) management.

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Diagnostic Capabilities Summary

The Philips DXL ECG Algorithm goes beyond traditional 12-lead interpretation. It offers incremental diagnostic capabilities not associated with other ECG analysis programs:

- ▶ ST segment Elevation Myocardial Infarction—Culprit coronary Artery (STEMI-CA) criteria to suggest the probable site of the occlusion.
- ▶ Updated diagnostic criteria based upon the latest clinical research. One example is the addition of “global ischemia” due to left main or multivessel occlusion.
- ▶ Enhanced Critical Value statements to highlight conditions requiring immediate clinical attention.
- ▶ Updated interpretive statements to reflect the 2007 AHA/ACC/HRS recommendations¹.

NOTE: This Application Note describes features of the Philips DXL ECG algorithm that may not be available on all Philips products incorporating ECG analysis. Please refer to the documentation supplied with your Philips product for specific versions and available features.

For example, this Application Note focuses on the HeartStart MRx product versions F.00 and above that utilize the 12-lead functionality of the Philips DXL ECG Algorithm.

Analysis Process

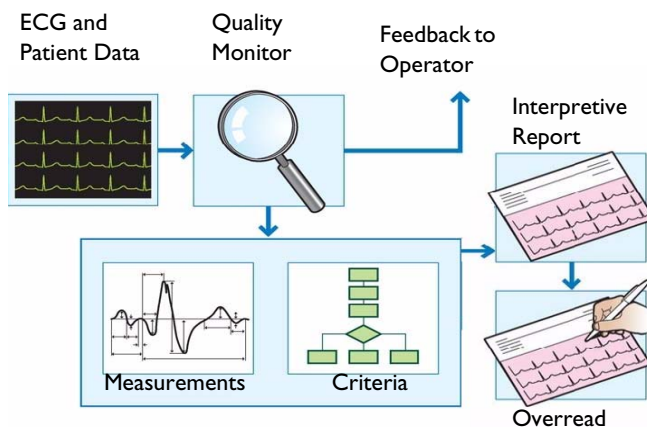
The DXL algorithm performs multiple steps to produce precise and consistent ECG measurements that are used to generate interpretive statements.

NOTE: A computer-interpreted ECG report is not intended to be a substitute for interpretation by a qualified physician. An overread and confirmation of computer-based ECGs by a physician is required.

Acquisition and Quality Assessment

- ▶ 12 leads are captured for 10 seconds and digitized at a sampling rate of 8 KHz.
- ▶ Signal quality is evaluated. If the signal quality is poor, then a display message notifies the user.
- ▶ If the signal quality is adequate, then it is downsampled and presented to the DXL algorithm at a rate of 1 KHz.

Figure 1 Philips 12-lead DXL ECG Algorithm



Waveform Recognition and Measurement

The DXL algorithm:

- ▶ Accurately identifies pacemaker pulses.
- ▶ Measures each P-Q-R-S-T complex in each of the leads individually. Can suppress a lead based on global measurements if it shows excessive variation.
- ▶ Classifies complexes into families based on rate and morphology parameters. Classifies paced beats independently.
- ▶ Creates average representative beats for the dominant beat family.
- ▶ Performs morphologic analysis of the non-paced beats even in paced rhythms.
- ▶ Measures individual lead and global parameters of representative beats. Uses innovative methods for difficult measurements, such as onset of P and end of T. Uses specialized techniques, such as synthesized vectorcardiograms, for transverse plane measurements (specifically for pediatric ECGs).
- ▶ Analyzes atrial arrhythmia, searching for different rhythms, such as Complete Heart Block, Second Degree Block, Atrial Fibrillation/Flutter, etc.

Application of ECG Criteria

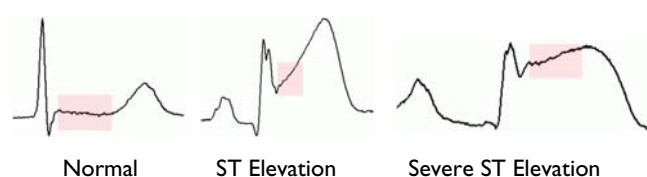
- ▶ The ECG criteria can use any combination of lead and global measurements, enhancing the flexibility and power of interpretive capabilities
- ▶ The DXL algorithm applies established traditional and modern interpretation criteria, including age- and gender-specific criteria and criteria based upon the latest scientific findings.
- ▶ The DXL algorithm applies new measurements and criteria for:
 - *STEMI-CA* — to suggest Culprit Artery occlusion sites, and
 - *Critical Values* — to highlight ECGs requiring urgent clinical attention.

The DXL algorithm uses lossless data compression, ensuring that the original, raw signals are available for further review and analysis, and the complete data are saved on the device. This approach increases the value of collected data, helps to develop further algorithm improvements, and enables new clinical research.

STEMI Detection

ST segment elevations in ECG tracings provide highly effective risk stratification in acute coronary syndromes. For patients with ST segment Elevation acute Myocardial Infarction (STEMI), the most critical factor in improving survival rates is the earliest possible administration of reperfusion therapy and reduction of “discovery-to-treatment” times.

Figure 2 **STEMI**



The DXL algorithm provides advanced capabilities for fast, accurate detection of STEMI based on the current guidelines.

Difficulties in STEMI Diagnosis

The following factors complicate reliable diagnosis of STEMI:

Intermittence

The fact that STEMI may come and go during the early phases of a heart attack makes its speedy accurate recognition especially important. The patient may experience coronary spasm and relief, where ST becomes elevated and then goes back to normal.

Different Non-MI ST Elevation Causes

Conditions other than acute infarct can also cause changes in the ST segment level and shape:

- ▶ Pericarditis (inflammation of the sac surrounding the heart);
- ▶ Some medications (e.g. digitalis);
- ▶ ST elevation may persist after an infarct becomes chronic;
- ▶ etc.

STEMI Criteria

To overcome the difficulties in STEMI diagnosis, the DXL Algorithm:

- ▶ Requires at least two adjacent leads with sufficient ST elevation to meet the 2005 ACC/AHA guidelines;
- ▶ Uses the greatest ST elevation in most leads to form a more definite interpretation;
- ▶ Looks at the distribution of ST elevation among the various leads to determine what the culprit artery might be, based upon defined criteria;
- ▶ Suggests a culprit artery only when the STEMI findings are strong to avoid false positives.

STEMI-CA for Identification of Culprit Artery

If STEMI criteria are met, the DXL algorithm's STEMI-CA criteria identify the culprit artery or probable anatomical site causing the functional ischemia. This may have prognostic significance and help to pinpoint the "culprit" lesion when multiple obstructions are present and thus optimize the treatment approach in the catheterization laboratory.

Specific anatomic sites can include the following coronary arteries (see Figure 3):

- ▶ left anterior descending (LAD),
- ▶ right coronary artery (RCA),
- ▶ left circumflex (LCx),
- ▶ left main or equivalent multi-vessel disease (LM/MVD).

Figure 3 **Coronary Arteries**

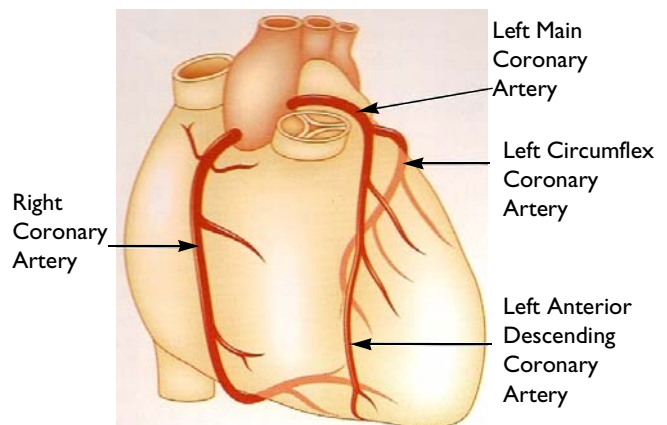


Figure 4 shows some clinical examples of the way that STEMI-CA statements appear in a 12-lead report from the DXL algorithm:

Figure 4 **Clinical Examples of STEMI-CA (for three different ECGs)**

Inferoposterior infarct, acute (LCx)
Lateral leads are also involved...

Anterolateral infarct, acute (LAD)

Repol abnrm, severe global ischemia (LM/MVD)

Additional STEMI-CA Benefits

In addition to identifying the Culprit Artery, STEMI-CA has the following advantages in comparison with other diagnostic methods:^{2,3}

- ▶ Angiography findings alone may be difficult to interpret because they may show chronic lesions in several arteries.
- ▶ Angiography may show obstructions that are not necessarily causing problems.
- ▶ STEMI-CA can assist in directing treatment in the catheterization laboratory to the likely lesion location.
- ▶ STEMI-CA can identify “severe global ischemia”—a condition when either left main coronary artery or multiple vessels are obstructed.

Critical Values

The Joint Commission on the Accreditation of Healthcare Organizations sets the following goal: “[The institution should] take action to improve the timeliness of reporting, and the timeliness of receipt by the responsible licensed caregiver, of critical test results and values.”⁴

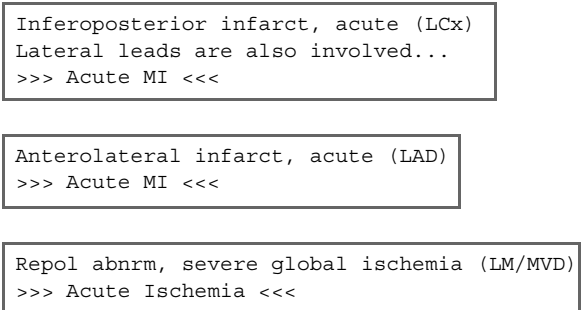
Critical Values are highly visible (highlighted in red on the HeartStart MRx display) independent statements on the ECG report that highlight conditions requiring immediate clinical attention. Specific statements are:

- ▶ >>> Acute MI <<<
- ▶ >>> Acute Ischemia <<<
- ▶ >>> Complete Heart Block <<<
- ▶ >>> Extreme Tachycardia <<<

These statements are designed to be used by emergency medical personnel in the field as a trigger for their STEMI protocol that would likely include alerting the hospital ahead of the patient arrival and transport directly to a cardiac specialty hospital.

Critical Values can go hand-in-hand with the STEMI-CA statements:

Figure 5 Critical Values and STEMI-CA



Use of Critical Values is configurable and supports quality initiatives in multiple areas of the medical enterprise. For example, in the emergency department, Critical Values can support a hospital’s focus on door-to-balloon initiatives.

Gender-, Age-, and Lead-Specific ECG Interpretation

Studies show that the threshold values for ECG interpretation are gender, age, and lead-dependent characteristics. For example, in healthy individuals, the amplitude of the ST junction is greater in men than in women.¹

When the resting ECG reveals ST segment depression greater than 0.1 mV in eight or more body surface leads coupled with ST segment elevation in aVR and is otherwise unremarkable, the automated interpretation should suggest ischemia due to multi-vessel or left main coronary artery obstruction.

In the DXL algorithm, a new Critical Value has been added to reflect “Acute Ischemia” and STEMI-CA provides for left main or multi-vessel disease (LM/MVD).

Gender-Specific Criteria

Gender-specific criteria are not new to Philips. They have been incorporated into our multi-lead algorithms since 1978 and have been enhanced continually based on the latest research and guidelines. The DXL algorithm applies gender, age, and lead limits for improved detection of acute MI. For example, STEMI criteria are subject to reduced ST limits for women. The algorithm also uses gender-specific axis deviation criteria, Cornell gender-specific criteria for detection of left ventricular hypertrophies, and Rochester and Rautaharju criteria for the detection of prolonged QT.

Application of these gender-specific criteria results in ECG interpretations that help clinicians more accurately assess the cardiac state of patients of either sex.

Integrated Pediatric Analysis

Philips introduced the industry’s first pediatric ECG analysis capabilities in 1982 and has built upon that experience to maintain an advanced, fully integrated pediatric interpretation.

The pediatric criteria use 12 distinct age groups—grouped progressively from hours through days, weeks, months, and years—to ensure that the most age-relevant

interpretation criteria are applied for analyzing the available waveform. The age is used throughout the criteria to define normal limits in heart rate, axis deviation, time intervals, and voltage values for interpretation accuracy in tachycardia, bradycardia, prolongation or shortening of PR and QT intervals, hypertrophy, early repolarization, myocardial ischemia and infarct, and other cardiac conditions.

Mild right ventricular hypertrophy and incomplete right bundle branch block differentiation is improved with a unique combination of a derived vectorcardiogram for transverse plane measurements with traditional measurements from the standard 12 leads.

Modern Left Ventricular Hypertrophy Criteria

The DXL algorithm employs the gender-specific Cornell voltage criteria⁵ for left ventricular hypertrophy along with other traditional LVH criteria. This increases the sensitivity and specificity of LVH detection.

QT Analysis

Because of the relatively recent appreciation of the connection between many medications and the development of Torsade de Pointes, there has been renewed interest in the accurate measurement of the QT interval and the various QT interval “corrections.”

The DXL algorithm uses an innovative measurement technique to ensure an accurate and reproducible end of T measurement, even in the presence of large U waves and biphasic or notched T waves. Because high resolution ECG signals are maintained through analysis and storage, the integrity of the end of T remains available for analysis and subsequent high resolution review typical in clinical research.

The same QT algorithm has been further applied for use within Philips IntelliVue real-time monitoring systems and ambulatory monitoring Holter products.

Advanced Pacemaker Detection

Between 2% and 5% of routine diagnostic ECGs are acquired from patients with implanted cardiac pacemakers, devices which have become increasingly capable, efficient, and complex. To keep up with these pacemaker developments, the DXL algorithm handles a variety of atrial, ventricular, and A-V sequential pacing modes. A sophisticated noise-adaptive pulse detector runs on all acquired leads with confirmation from multiple leads differentiating true pulses from noise.

Analysis of pacemaker pulse locations with respect to P-waves and QRS complexes permits classification of a variety of pacemaker rhythms and identification of non-paced QRS complexes for further morphologic analysis in ECGs with both paced and non-paced beats.

Although the detector is quite sensitive, even to low amplitude pacer spikes typical of modern pacemakers, it can still differentiate these spikes from the very narrow and sharp QRS complexes typical of neonatal ECGs.

Reference

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- 5 Casale P.N., et al., Improved sex-specific criteria of left ventricular hypertrophy for clinical and computer interpretation of electrocardiograms: validation with autopsy findings, *Circulation*, 1987; 75 (3): 565-72.



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