

PHILIPS

Cardiology

DXL ECG Algorithm

The new generation in ECG interpretation

Philips DXL 12/16-Lead ECG Algorithm
Release PH110C



Taking ECG measurements to a new level

The Philips DXL ECG Algorithm uses sophisticated analytical methods for interpreting the resting ECG. While in the past, ECG analysis programs were limited to 12 simultaneous leads, the DXL Algorithm analyzes up to 18 leads of simultaneously acquired ECG waveforms to provide an interpretation of rhythm and morphology for a wide variety of patient populations. The algorithm reflects recommendations, such as the *AHA/ACCF/HRS Recommendations for the Standardization and Interpretation of the Electrocardiogram: Part II¹ (2007)* and the *Fourth Universal Definition of Myocardial Infarction² (2018)*.

Expanded diagnostic capabilities

The DXL Algorithm goes beyond traditional 12-lead interpretation of the resting ECG. It also provides for incremental diagnostic capabilities not associated with analysis programs of the past:

- 18-lead integrated analysis to take advantage of optional right chest and back electrodes to provide extended interpretations for adult chest pain
- Four types of QT interval correction including Bazett, Fridericia and two linear formulas Hodges and Framingham
- Correction of QT interval for wide QRS using the Rautaharju formula
- ST Maps to provide a visual representation of ST deviations in frontal and horizontal planes, responding to the 2009 Recommendations
- Criteria based on clinical research such as "acute global ischemia," "deeply inverted anterior T-waves", and incorporation of updated gender-specific STEMI criteria, as documented in the Fourth Universal Definition of MI
- Critical Values to highlight conditions requiring immediate clinical attention
- Integrated 15-lead pediatric analysis
- Lead Reversal program to identify 19 possible lead reversal and placement errors during ECG acquisition
- Classification of normal and abnormal ST-segment elevation in ST confounders such as left and right bundle branch block and left ventricular hypertrophy
- STEMI-CA (Culprit Artery) criteria to suggest the probable site of the coronary artery occlusion, including proximal left anterior descending coronary artery consistent with the AHA/ACCF/HRS Recommendations

History

In 2002, Philips acquired the former Hewlett-Packard Medical Products Group which pioneered the development of computerized ECG data analysis. Design of specialized algorithms began in the late 1960's and accelerated in the 1970's as Philips enhanced the single lead programs that were the standard at the time. In 1978, Philips introduced its multi-lead, 12-lead analysis program, the first among the major electrocardiography companies.

Philips has been a continuing leader in ECG analysis, with significant innovations and firsts in serial comparison, gender-specific analysis, pediatric analysis, pacemaker detection, sophisticated QT analysis, support of the XML data format, and other areas. In the past, a specialized ECG language – ECG Criteria Language (ECL) – was developed to encourage broader participation and speed development of sophisticated algorithms.

Today, this experience and expertise is reflected in the DXL Algorithm with its industry-leading integration of extended leads and expanded analysis capabilities.



Analysis Process

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

Acquisition and quality assessment

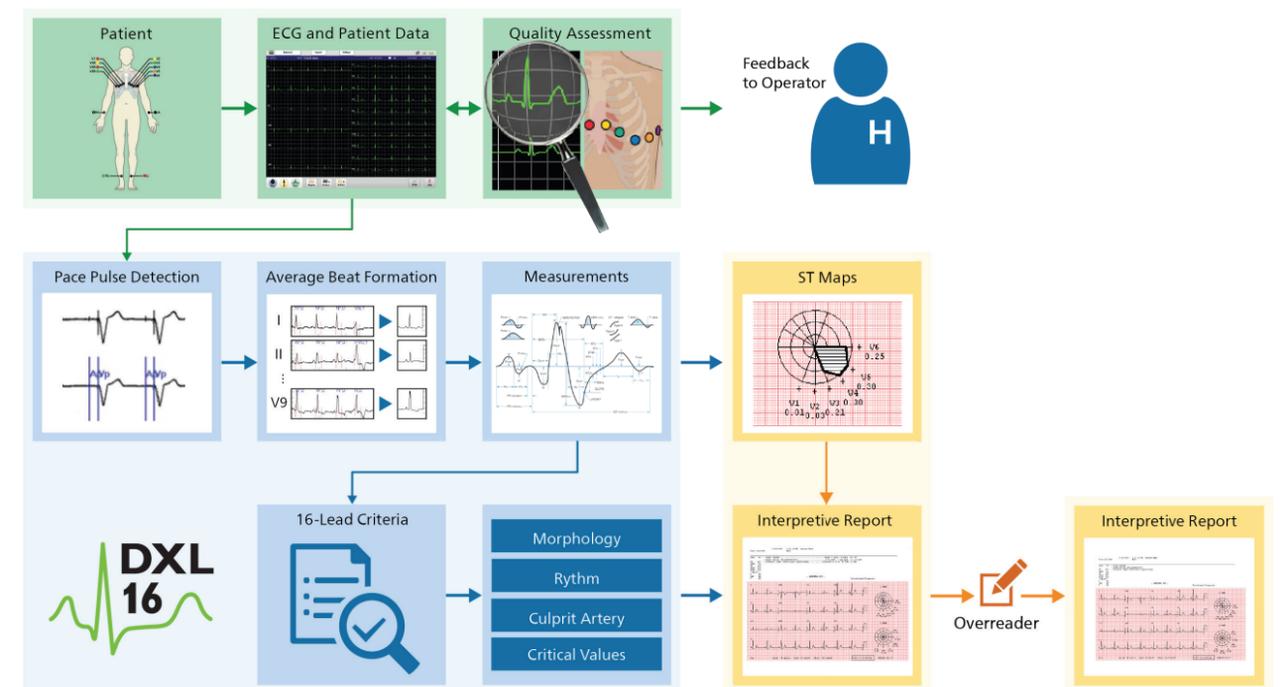
- Continuous signal quality feedback is provided to the user via color-coded waveforms and messages
- 12 to 16 user-selected leads are captured for 10 seconds and digitized at 8 KHz per lead
- Unique Lead Reversal software identifies 19 possible swapped leads for correction
- Waveform recognition and measurement
- Pacemaker pulses are accurately identified
- Each complex in each lead is measured individually. Excessive variation in a lead can be used to determine if that lead is unreliable for global measurements
- Complexes are classified into families based upon rate and morphology parameters. Paced beats are classified independently
- Representative beats are created by averaging aligned beats from the dominant family
- Rhythms with some paced complexes undergo morphologic analysis of the non-paced beats
- Individual lead and global measurements of representative beats are made. Innovative methods are used for difficult measurements, such as onset of P and end of T
- Specialized techniques are employed, such as transverse plane measurements from synthesized vectorcardiograms specifically for pediatric ECGs

Application of criteria

- The criteria can use any combination of lead and global measurements, enhancing the flexibility and power of interpretive capabilities
- Established traditional and modern interpretation criteria, including age- and gender-specific criteria and criteria based upon latest scientific findings and using current nomenclature, are applied
- If additional leads beyond the standard 12 are available, incremental criteria are applied to enhance specificity and sensitivity
- New measurements and criteria are applied for STEMI-CA (to suggest Culprit Artery occlusion sites), ST Maps (to show the spatial orientation of ST deviations), and Critical Values (to highlight ECGs requiring urgent clinical attention)

Waveform Storage

Previous generation technologies down-sampled ECG waveforms for transmission and long-term data storage purposes. The DXL Algorithm uses lossless data compression, ensuring that the original, raw high bandwidth data is available for further review and analysis. This increases the value of collected data for the development of further enhancements and incorporation of new scientific findings. It also supports the needs of pharmaceutical clinical research.



From acquisition to report generation, the Philips DXL 16-Lead Algorithm uses multiple steps to ensure a high quality interpretation.

QT analysis and clinical research

Because 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 “corrections” for heart rate.

The DXL Algorithm offers 4 configurable heart rate correction methods for QT interval, Bazett, Fridericia, Hodges and Framingham. The Bazett correction for QT interval is the most widely known, but also is well known for over correcting at higher heart rates. Reports can show two corrected QT values so that the primary QTc value used for calling prolonged QT interval can be something other than Bazett such as Hodges while Bazett corrected QT can still be shown for the broader audience unfamiliar with other QT correction formulas.

Corrected QT can be a problem with a long duration QRS in left or right bundle branch block. The addition to the QT interval due to wide QRS can put the QTc value over the threshold. Rautaharju correction for heart rate and QRS duration alleviates that problem. When the QRS is wide, the DXL Algorithm substitutes the Rautaharju correction so that the QT interval does not appear prolonged just due to the long duration QRS.

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, transmission, 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 monitoring systems and ambulatory monitoring products.

Use of additional right chest and posterior leads

While the limb leads and chest leads comprise the standard 12-lead ECG, it has long been recognized that additional electrodes can provide information that is poorly or not at all seen on the traditional 12-lead ECG.

In addition to the standard limb and chest leads, the DXL Algorithm can incorporate any four of six additional leads from the following:

- right chest leads: V3R, V4R, V5R
- posterior leads: V7, V8, V9

Some users may choose to add just one or two leads to the standard 12, while others may choose to record the maximum of 16 leads to provide the additional waveform information as well to gain the additional sensitivity and specificity that the DXL Algorithm can provide with the additional lead information.

Right heart analysis (V3R, V4R, V5R)

Right ventricular infarcts may accompany inferior myocardial infarction and have strong prognostic implications. The signs are subtle in the right-sided leads and are generally invisible in the standard leads.

The DXL Algorithm is not limited to a single right lead and can take advantage of information that may be present in V3R, V4R, and/or V5R. Additional criteria use this information, plus criteria based upon the traditional 12 leads, to provide improved specificity and sensitivity. For example, consistent with the 2009 Recommendations³, the algorithm supports the recording of both V3R and V4R for patients presenting with evidence of acute inferior wall ischemia or infarction. And the DXL Algorithm provides incremental analysis based upon those additional leads.

Posterior wall analysis (V7, V8, V9)

Posterior myocardial infarction has traditionally been diagnosed from reciprocal changes seen in leads V1 and V2. ST-segment depression may be very subtle in these leads and go unnoticed or misdiagnosed, especially if gender differences are ignored. ST-segment elevation recorded in the posterior leads can aid in the interpretation, especially in the early stages of acute posterior myocardial infarction.

The DXL Algorithm can take advantage of information in one or more of leads V7, V8, and V9 to provide greater specificity and sensitivity in detecting posterior infarcts.

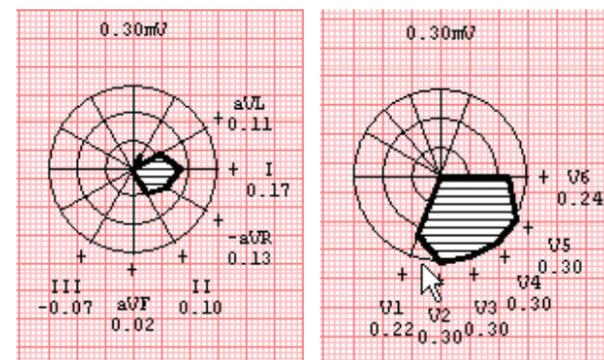
Pediatrics

Many pediatric institutions add three leads to the 12-lead set. The most common sites are V3R, V4R, and V7. The selected incremental leads are integrated into the DXL Algorithm’s pediatric analysis.

ST Maps

The 2009 AHA/ACCF/HRS document recommends the display of the spatial orientation of ST-segment deviations in both frontal and transverse planes. Philips cardiographs can display patented ST Maps in both planes to provide for rapid visual assessment of the degree of ST abnormalities. The maps are plotted in “Cabrera sequence” to reflect the anatomical orientation.

This presentation, previously available only on Philips IntelliVue patient monitors, provides distinct patterns for different anatomic sites of infarcts, global ischemia, pericarditis, and other conditions that are readily seen using such maps.



STEMI detection

ST-segment elevations in ECG tracings provide highly effective risk stratification in early 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 “door-to-balloon” and “discovery-to-treatment” times.

The DXL Algorithm provides advanced capabilities for fast, accurate detection of STEMI based on the newest recommendations. Unique to Philips, the DXL Algorithm can provide information in 16 ECG leads selected at the time of acquisition, allowing right heart (V3R, V4R, and/or V5R) and posterior (V7, V8, and/or V9) information to be included in the data presentation and subsequent analysis.

Classical STEMI applies only to ST elevation in a group of leads. With obstructions in the left main coronary artery or multiple obstructions in several coronary arteries, an ECG pattern of widespread ST depression is seen along with ST elevation seen in aVR and/or VI. This pattern, recognized by the DXL Algorithm, is called global ischemia and has prognostic significance. Another pattern associated with acute proximal LAD occlusion detected by the PH110C version of the DXL Algorithm is deeply inverted T-waves in leads V2 – V4 with concomitant QT interval prolongation.

Gender-specific ECG interpretation

As cardiac medicine continues to advance, there has been continued learning regarding the physiological differences between men and women. Gender-specific criteria are not new to Philips. They have been incorporated into the multi-lead algorithms since 1987 and have been enhanced continually based upon the latest research and guidelines.

For example, the DXL Algorithm applies gender, lead and age limits for improved detection of acute MI. Based upon the 2009 recommendations, STEMI criteria are subject to reduced ST thresholds in women. The algorithm also uses gender-specific axis deviation and MI 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 an ECG interpretation that helps clinicians more accurately assess the cardiac state of patients of either sex.

Critical Values are highly visible independent statements on the ECG report that highlight conditions requiring immediate clinical attention. Specific statements are made for:

- acute MI
- global ischemia
- complete heart block
- extreme tachycardia

Use of the Critical Values feature is configurable and can be used to support 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 and quality initiatives.

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. With the DXL Algorithm, the interpretation now can use the availability of additional leads – typically 15 in the pediatric application.

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, 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 transverse measurements from a derived vectorcardiogram with more traditional measurements from the standard 12 leads and the extra pediatric leads.

Left ventricular hypertrophy criteria

The widely accepted Cornell criteria for left ventricular hypertrophy are included with the traditional criteria. This increases the sensitivity and specificity of detection.

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 pace with these pacemaker developments, the DXL Algorithm is designed to handle a variety of atrial, ventricular, and A-V sequential pacing modes. A sophisticated patented noise-adaptive pulse detector is run on all acquired leads with confirmation from multiple leads differentiating true pulses from noise.

If the pacemaker is known to be present at the time of acquisition, the algorithm pulse detector sensitivity can be increased to improve detection of extremely small pulses. In addition, 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 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, a problem that has plagued previous generation algorithms.

STEMI-CA for identification of culprit artery

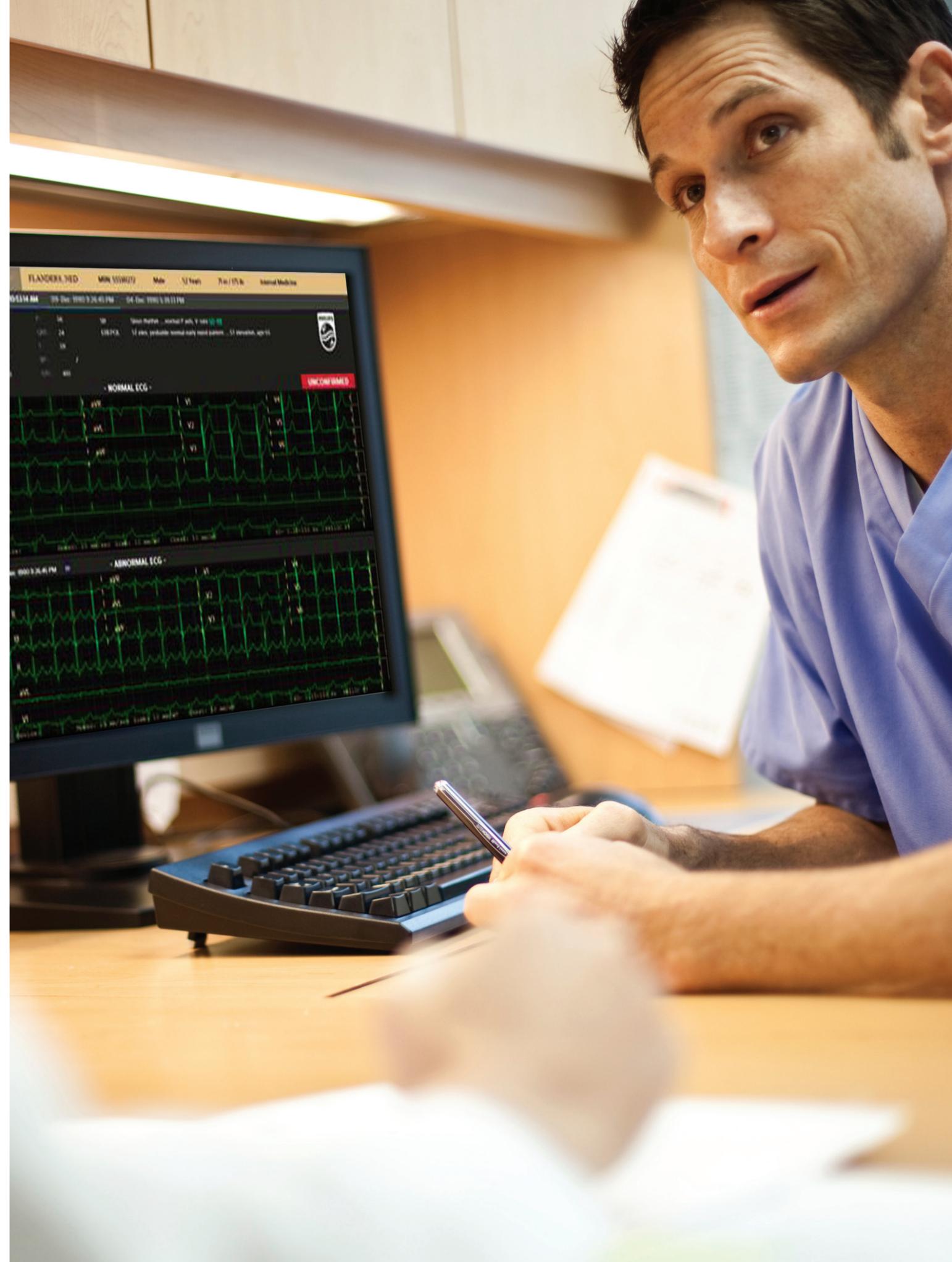
If STEMI criteria are met, the DXL Algorithm's STEMI-CA criteria can identify the likely culprit artery or probable anatomical site causing the functional ischemia. This may have prognostic significance as well as help to pinpoint the offending lesion when multiple obstructions are present and can thus be used to optimize the treatment approach in the cath lab.

Specific anatomic sites can include the following coronary arteries:

- proximal left anterior descending artery (proxLAD)
- left anterior descending artery (LAD)
- right coronary artery (RCA)
- left circumflex artery (LCx)
- left main or multi-vessel disease (LM/MVD)Critical Values

Nomenclature

The DXL Algorithm conforms to the latest AHA/ACCF/HRS statement recommendations for the standardization and interpretation of the ECG.



1. AHA/ACCF/HRS Recommendations for the Standardization and Interpretation of the Electrocardiogram, Part II: Electrocardiography Diagnostic Statement List. J Am Coll Cardiol, 2007; 49:1128-135.
2. Fourth Universal Definition of Myocardial Infarction. Circulation (2018); 138 (2): pg e618 -e651
3. AHA/ACCF/HRS Recommendations for the Standardization and Interpretation of the Electrocardiogram, Part VI: Acute Ischemia/Infarction. Circulation, 2009; 119:e262-e270.

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

This brochure 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.

