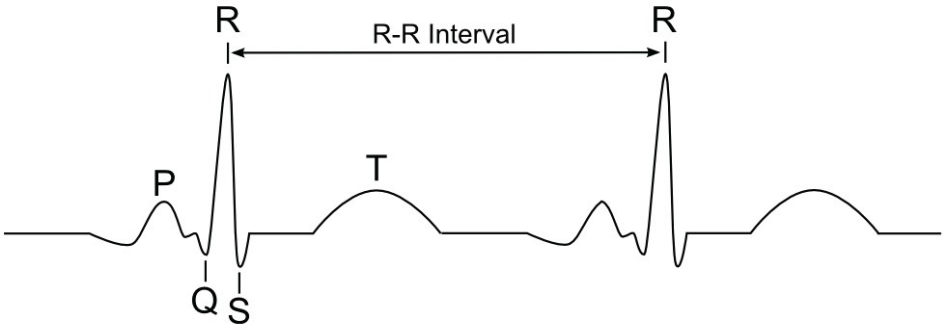
Electrocardiogram Analysis with LabScribe

Introduction

An electrocardiogram is a representation of the electrical activity of the heart over time. The first wave indicates the depolarization of the atria, which appears in the ECG as the P wave. The P wave is followed by the QRS complex, which represents the depolarization of the ventricles. The repolarization of the ventricles appears as the T wave. After a brief fill period, the cycle starts again. The baseline from which the waves deviate is called the isoelectric line. By looking at the timing, and to a lesser extent the amplitude, of these events, various problems with the electrical conduction process can be diagnosed.



Electrocardiogram.

LabScribe offers a number of ways to analyze electrocardiograms. Many elements of the analysis can be done using features in the basic *LabScribe* software. More sophisticated analysis requires a license for the **ECG Advanced Analysis Module**.

This document includes a step by step tutorial for using most of the features of the **ECG Advanced Analysis Module**, as well as other ECG functions in *LabScribe.* It also includes a more detailed **Reference** section that covers the material in the tutorial, and adds additional context and detail. To use the step by step guide, you will need an ECG recording. This can be from any species, but in order to calculate the limb leads and the angle of the electrical axis of the heart, you will need a human ECG of limb Leads I and II. Basic instructions are included for recording a two lead human ECG.

ECG Analysis: Step by Step

Recording a Human ECG

You will need to record an electrocardiogram in order to complete this step by step guide. This ECG can be from any mammalian species, but in order to complete the sections on the calculation of limb leads and the angle of the electrical axis of the heart, it is necessary to record a human ECG of limb Leads I and II.

To record a human ECG to use with this tutorial:

1) Place two disposable ECG electrodes on the underside of the right wrist (one above the other), one on the underside of the left wrist and one on the back of each leg just above each ankle.
2) Using a five-conductor ECG cable, attach wires 1+ to the electrode on the left wrist, 1- and 2- to the right wrist, 2+ to the left ankle, and the ground wire to the right ankle.
3) Plug the cable into the iWorx A/D unit.
4) Choose the ECG Settings file you wish to record with. One possibility is to open the **Six-Lead ECG** settings file in the **Human Heart** category. For the purposes of this Step by Step guide, delete all channels except for Leads I and II from this settings file.
5) While sitting down, relax your muscles and support your hands on a non-metallic surface.
6) Click **Record** and make sure that your electrocardiogram is being recorded on both the **Lead I** and **Lead II** channels. **AutoScale** each channel, and use the **Zoom In** or **Zoom Out** function to display an appropriate time scale.
7) After two minutes, click **Stop**.
8) **Save** the file as “Tutorial ECG”.

Basic Cardiac Functions: Step by Step

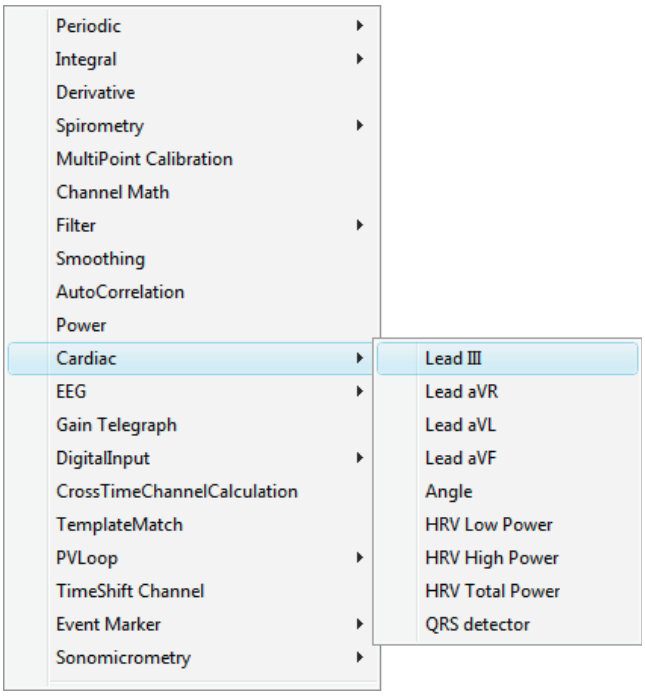
Limb Lead Calculations

On a human ECG, you can calculate Lead III, as well as the augmented limb Leads aVL, aVR, and aVF, from the Lead I and Lead II recordings. If you are analyzing the ECG of another species, you can skip to the **Heart Rate Variability** section below.

Background: *Lead I is a bipolar human limb lead, with the electrodes on the right (-) and left (+) arms. Lead 2 is another limb lead, with the electrodes on the right arm (-) and left foot (+).* ***Lead III*** *is the lead going from the left arm (-) to the left foot (+). There are three unipolar augmented limb leads which go from one of the three electrode locations to an average of the other two.* ***Lead aVR*** *is the augmented lead from the right arm (+) to the left arm and left foot (-),* ***Lead aVL*** *is the augmented lead from the left arm (+) to the combined right arm and left foot (-), and* ***Lead aVF*** *is the augmented lead from the left foot to the combined right and left arms (-).*

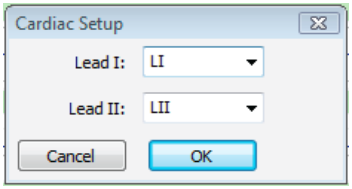
To calculate and display the four remaining limb leads:

1) Click **add function** in the **Lead I Channel Bar**. Scroll down to **Cardiac** in the list of functions and select **Lead III** from the available options.



The Cardiac submenu.

2) In the **Cardiac Setup** dialog, specify the two channels that correspond to Leads I and II. In the example in the figure below, they have been named LI and LII.



Cardiac Setup dialog.

3) Click **OK**, and a computed channel will be added displaying Lead III.
4) Repeat Steps 1-3 for the three augmented leads. You will now see six channels on the screen displaying all six limb leads.
5) Delete the four computed channels before continuing.

Angle of the Electrical Axis of the Heart

If you have recordings from Leads I and II, you can also calculate the **Angle** of the electrical axis of the heart.

Background: *The electrical axis of the heart is the mean direction of the cardiac action potential. The deflection of this axis in relation to the horizontal axis of the heart is the* ***Angle*** *of the electrical axis. The* ***Angle*** *can be calculated from the leads that make up Einthoven's Triangle, the three bipolar limb leads. A normal angle ranges from +90 to -30 degrees. Deviations from this range can indicate a number of morphological and electrical cardiac conditions. Left axis deviation ranges from -30 to -90 degrees. Right axis deviation ranges from +90 to +180 degrees.*

To calculate the electrical **Angle** in *LabScribe*:

1) Choose **Angle** from the list of cardiac functions, and in the dialog that opens specify the two channels that correspond to Leads I and II.
2) Click **OK**, and the beat by beat **Angle** of the electrical axis will be displayed in the computed channel.
3) Delete this channel before continuing.

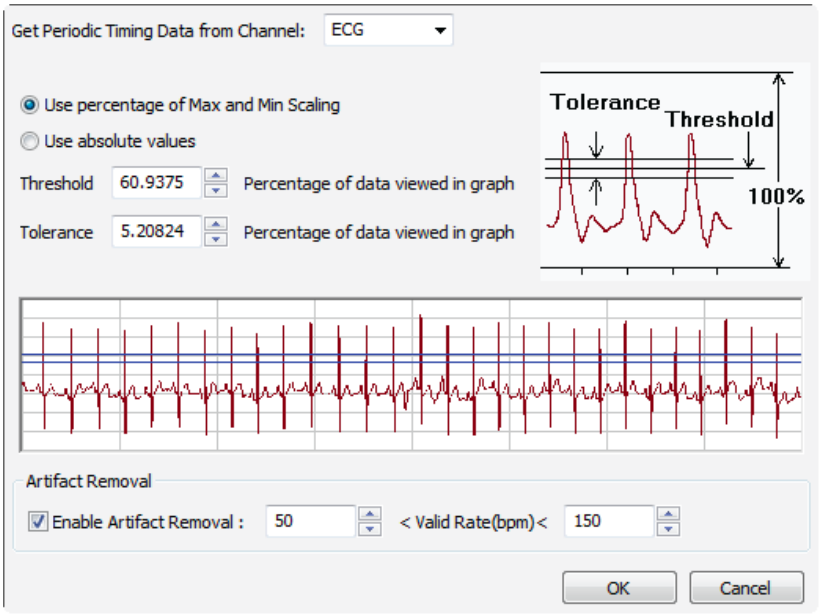
Heart Rate and Heart Rate Variability

Heart rate variability can be calculated using the **Cardiac** functions. Although it is not necessary, it is useful to calculate heart rate before looking at heart rate variability.

Heart Rate

To determine heart rate**:**

1) Click **add function** above a channel with a recorded ECG. From the **Periodic** submenu, choose the **Rate** function, opening the **Periodic** dialog.



Periodic dialog. Threshold is the amplitude value that will trigger detection of a beat. Tolerance determines the permissible range in amplitude for detection of a beat. Both are computed either as a percentage of the total amplitude of the data in the ECG or from absolute amplitude data values.

2) Each of the beats on the ECG needs to be detected. There are two ways of configuring this analysis, each using **Threshold** and **Tolerance** values to detect the beats.
   - To **Use percentage of Max and Min Scaling**, enter the **Threshold** and **Tolerance** values directly into the data boxes, or visually determine the value by positioning the two blue horizontal lines on the sample portion of the ECG recording that appears at the bottom of the dialog so that all R waves pass through both lines. If the **Threshold** and **Tolerance** lines are not immediately obvious, check at the very bottom of the ECG window in the dialog. The horizontal scale of this sample can be changed by changing the time scale of the ECG recording itself.

- To **Use absolute values**, enter the absolute **Threshold** and **Tolerance** amplitudes that should trigger detection of a beat directly into the data boxes. These values can be determined from the original ECG.

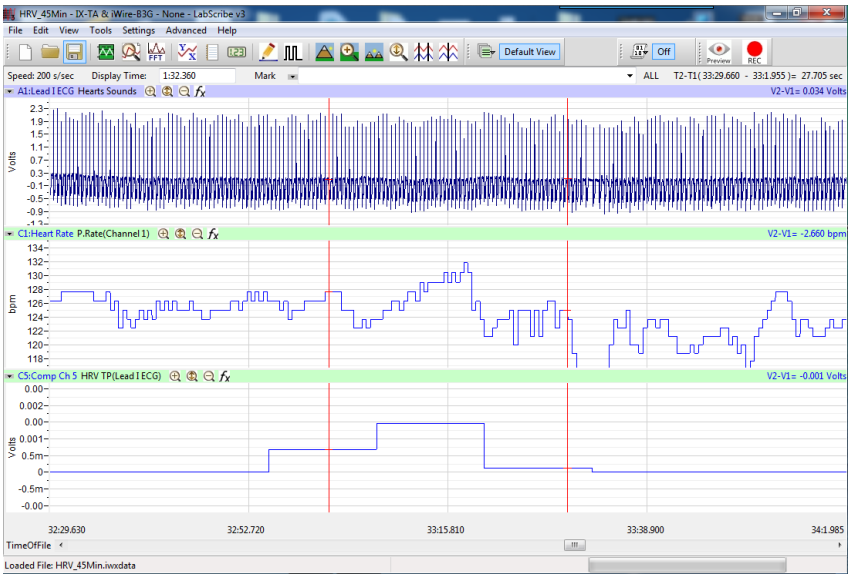
3) In the **Artifact Removal** data boxes, enter the minimum and maximum heart rates that are likely to be encountered in the data. Cycles occurring at a slower or faster rate than these, and therefore most likely representing noise or artifacts, will be eliminated from the analysis.
4) Click **OK**, and a new channel will be added, displaying the beat by beat heart rate.
5) To find the average rate over a selected section of the recording, switch to the **Analysis Window**.
6) In the functions bar above **Channel 1**, click on **add function** and choose the **Mean** function in the **General** submenu.
7) Place the left cursor at the start of the chosen section, and the right cursor at the end. In the **Mean** data box above the **Rate** channel, the average rate over the selection will be displayed.

Heart Rate Variability

Heart rate variability is a measure of the amount of cyclic fluctuation there is from the average beat length (RR). These fluctuations often occur over time in a regular pattern. It's possible to use **Power** functions to determine how much of the variability is due to fast cycling (**HRV High Power**) and how much is due to slower cycling (**HRV Low Power**). **HRV Total Power** is a measure of the overall variance.

To determine **HRV Total Power:**

1) Click on **add function** above the ECG data channel.
2) Select **HRV Total Power** from the **Cardiac** functions. This will once again open the **Periodic** dialog, already seen when you were determining the heart rate.
3) Configure the **Periodic** dialog as instructed in the **Rate** section above. Click **OK**.
4) The **HRV Total Power** function, computed over time, will be displayed in the added function channel. Notice the HRV increases in areas where the rate undergoes more change, and decreases in areas where the rate remains constant.



Human ECG recording with computed channels showing Rate and HRV Total Power functions.

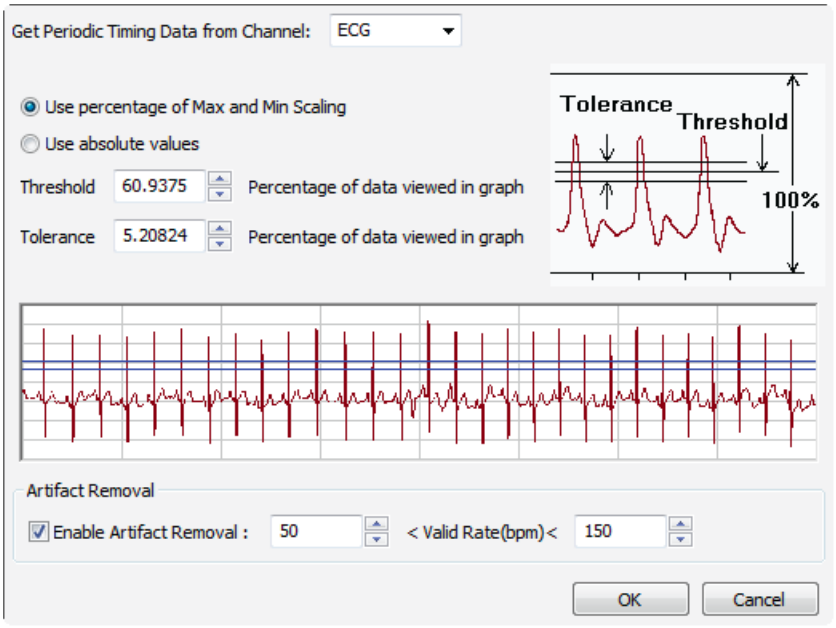
5) To compute and display **HRV Low Power** or **HRV High Power**, follow Steps 1-5 for the desired function.
6) Delete the **HRV** and **Rate** channels before continuing.

QRS Detection

The **QRS Detector** can be used to mark R waves on a computed channel by placing corresponding peaks at the location of each R wave.

To use the **QRS Detector:**

1) Click on **add function** above a channel with an ECG recording.
2) Select **QRS Detector** from the **Cardiac** functions.
3) The **QRS Detector** computed channel will be added, showing spikes at the location of each R wave. The amplitudes of the spikes correlate with the amplitudes of the actual waves.
4) The **QRS Detector** channel can be used to determine the heart rate. Click **add function** above the **QRS Detector** channel. From the **Periodic** submenu, choose the **Rate** function to open the **Periodic** dialog.

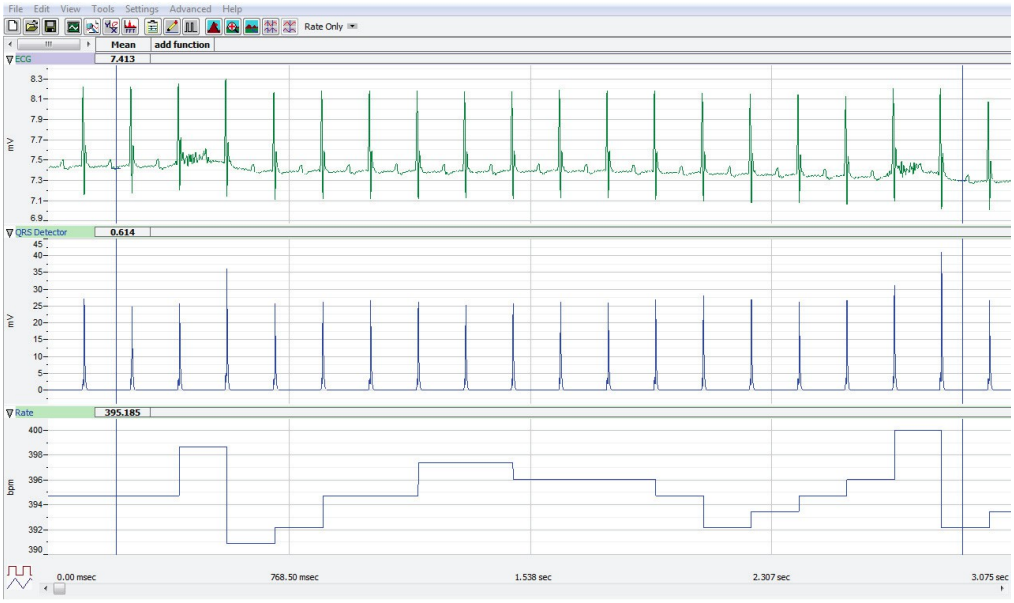


QRS Detection Periodic dialog.

5) In the **Periodic** dialog, each of the detected QRS peaks needs to be detected. There are two ways of configuring this analysis, each using **Threshold** and **Tolerance** values to detect the beats.
   - To **Use percentage of Max and Min Scaling**, enter the **Threshold** and **Tolerance** values directly into the data boxes, or visually determine the value by positioning the two blue horizontal lines on the sample portion of the ECG recording that appears at the bottom of the dialog so that all R waves pass through both lines. If the **Threshold** and **Tolerance** lines are not immediately obvious, check at the very bottom of the ECG window in the dialog. The horizontal scale of this sample can be changed by changing the time scale of the ECG recording itself.

- To **Use absolute values**, enter the absolute **Threshold** and **Tolerance** amplitudes that should trigger detection of a beat directly into the data boxes. These values can be determined from the original ECG.

6) In the **Artifact Removal** data boxes, enter the minimum and maximum heart rates that are likely to be encountered in the data. Events occurring at a slower or faster rate than these, and therefore most likely representing noise or artifacts, will be eliminated from the analysis.
7) Click **OK**, and a new channel will be added, displaying the beat by beat heart rate.
8) To find the average rate over a selected section of the recording, switch to the **Analysis Window**.
9) In the functions bar above **Channel 1**, click on **add function** and choose the **Mean** function in the **General** submenu.
10) Place the left cursor at the start of the chosen section, and the right cursor at the end. In the **Mean** data box above the **Rate** channel, the average rate over the selection will be displayed.



Mouse ECG recording Analysis Window showing QRS Detector and Rate computed channels.

11) Delete the **QRS Detector** and **Rate** channels before continuing.

ECG Advanced Analysis Module: Step by Step

Offline Calculations

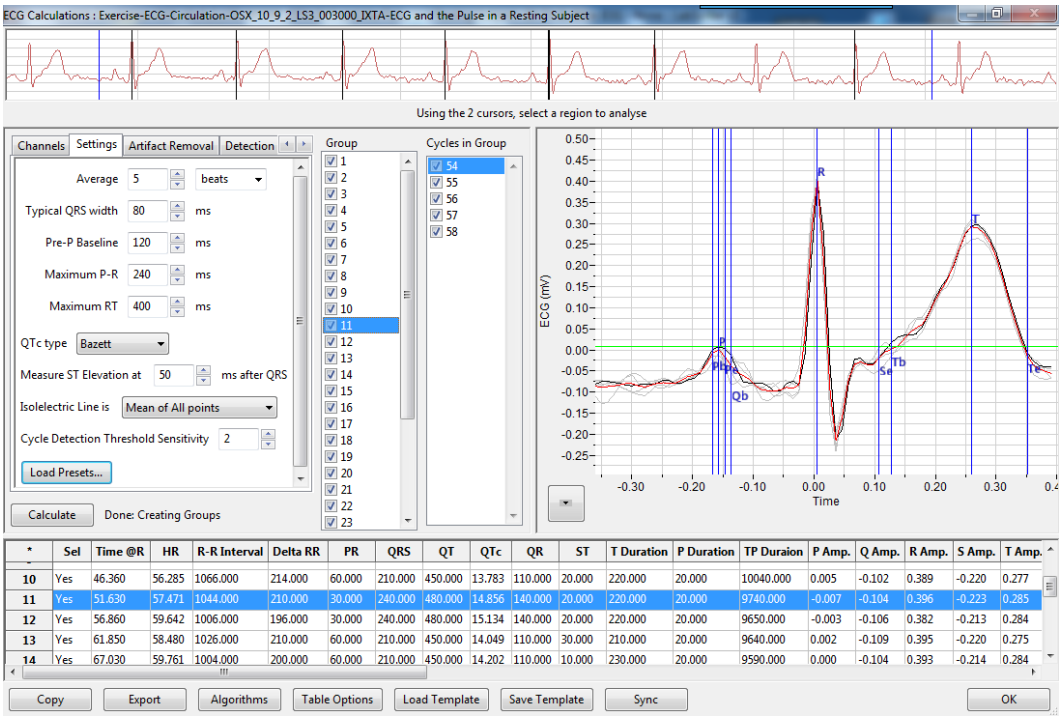
More sophisticated analysis can be done on a previously recorded electrocardiogram using the **Offline Calculations** function of the **ECG Advanced Analysis Module**. This analysis is performed using the offline **ECG Calculations** dialog, so you should first become familiar with this dialog.

The Offline ECG Calculations Dialog

To display the **ECG Calculations** dialog and familiarize yourself with its features:

1) If it is not already open, open the “Tutorial ECG” file you recorded at the start of this guide, or another ECG recording.

2) Select **Offline Calculations** from the **ECG Analysis** submenu of the **Advanced** menu. This will open the offline **ECG Calculations** dialog.
3) Familiarize yourself with the offline **ECG Calculations** dialog, pictured above.
   - Across the top of the dialog, in the channel display area, you will see a sample of the raw data channel to be analyzed. By default **Channel 1** is displayed. How much of the ECG appears there can be set by using *LabScribe*'s **Zoom In** and **Zoom Out** features on the original recording.
   - On the left of the middle row are the tabbed dialogs used to configure the analysis.
   - At the right is the XY graph window in which the **ECG Graph** or the **Artifact Graph** can be displayed.
   - Between the configuration dialogs and the graph are the editable lists of the **Groups** and **Cycles in Group** to be analyzed and displayed.
   - Across the lower part of the dialog is the **Data Table** with the calculated average values for each of the analyzed groups of beats.

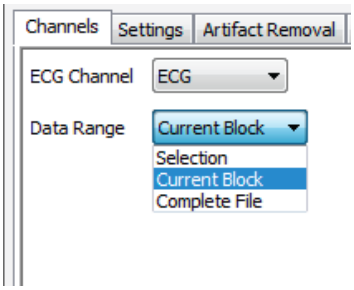


Offline ECG Calculations dialog.

To configure the analysis, the tabbed configuration panels at the left side of the middle row of the dialog are used.

To configure **Channels:**

1) Click the leftmost tab of the configuration dialogs, the one labeled **Channels**.
2) From the **ECG Channel** menu, choose an ECG channel. This could be the human Lead I channel or the ECG you recorded from another species. This is the channel on which the analysis will be performed.

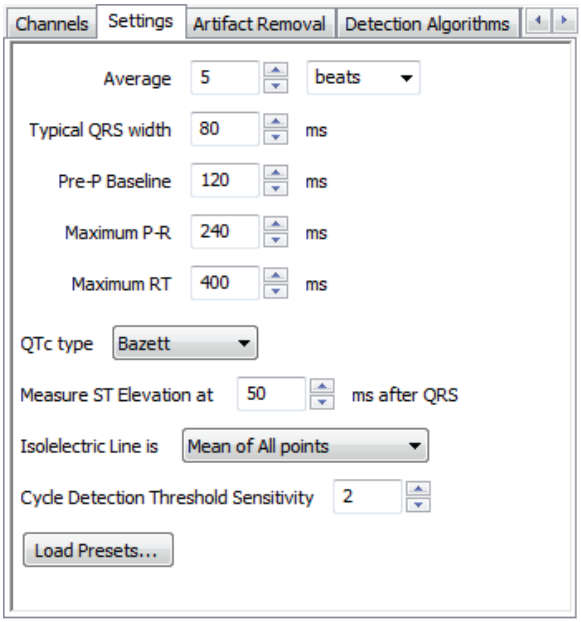


ECG Channels configuration dialog.

3) From the **Data Range** menu, choose **Complete File** to analyze the entire electrocardiogram file. You could instead choose **Selection**, which will analyze a sample of the data between the two vertical cursors in the data sample in the channel display area at the top of the dialog, or **Current Block**, which will analyze all the data in the current recording block.

To configure the **Settings:**

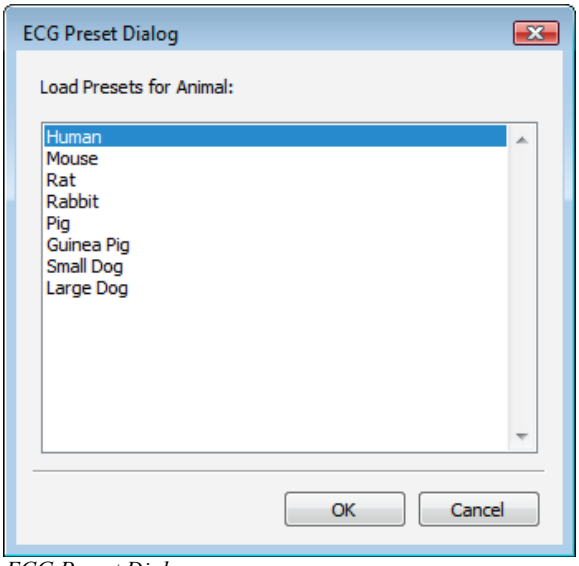
1) Click the **Settings** tab, which is the second tab from the left in the configuration dialogs. The **ECG Settings** configuration dialog will open.



ECG Settings configuration dialog.

2) In the **Average** box, enter **5**, and choose **beats** from the menu to the right. Averaging over a certain number of beats (or seconds) is done to compensate for small cycle by cycle fluctuations, or to average the beats within a specific experimental condition.
3) From the **QTc type** menu, choose **Bazett**. There are a number of options for calculating QTc type, the QT Interval normalized for heart rate. The default calculation is the Bazett formula, but the Fredericia, Framingham, and Hodge formulae are also available options.
4) From the **Isoelectric Line is** menu, choose **Mean of All points**. Alternatively, the isoelectric line can be averaged from only the pre-P points or the absolute zero line.

5) From the **Cycle Detection Threshold Sensitivity** menu, choose **2**. It is important that the cycle detection is set to the correct sensitivity. Adjusting the **Cycle Detection Threshold Sensitivity** number to higher numbers will lower the threshold at which a cycle is detected. Start at a low value; you will be able to adjust this later if you discover that cycles are being missed in the analysis.
6) Click the **Load Presets** button and choose the species from which your ECG was recorded. The remaining data boxes (**Typical QRS width**, **Pre-P Baseline duration**, **Maximum P>R duration**, **Maximum RT duration**, and the **Measure ST Elevation at** value) will be completed using typical values for the designated species. These default values can also be changed manually. *I*t is necessary to choose the correct species from the **ECG Preset Dialog** in order to appropriately display an ECG cycle in the **ECG Graph**.



ECG Preset Dialog.

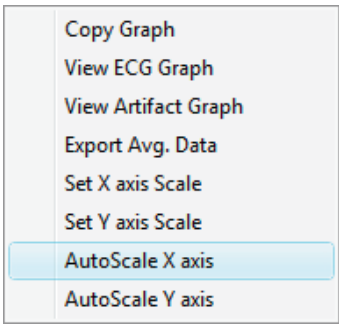
7) Click the **Calculate** button just above the **Data Table** to start the analysis. The **ECG Graph** will appear in the graph window at the right, and the **Data Table** will be populated with values.

Important: *After any configuration settings are changed, click* ***Calculate*** *again, to trigger the revised analysis.*

Once the **Channels** and **Settings** configuration dialogs are completed, it is possible to display the **ECG Graph** and start the analysis.

To display the **ECG Graph:**

1) Choose **View ECG Graph** from the menu at the lower left of the graph window. The **ECG Graph** will be displayed in the XY Graph window, showing the group of cycles specified in the **Groups** and **Cycles in Group** lists to its left.
2) Use the menu indicated by the arrow at the lower left of the graph to **AutoScale** the **X-axis** and the **Y-axis**. The X and Y axes can also be set manually by using the menu items or clicking and dragging the axis numbers themselves.



XY Graph menu.

3) Make sure a complete cycle is visible in the **ECG Graph**. If a complete cycle doesn't appear (from before the P Wave to after the T Wave), go back to the **Settings** configuration dialog, open the **Load Presets** menu, and click on the species from which your ECG was recorded. Click **Calculate** above the **Data Table** and the complete cycle should appear on the **ECG Graph**.
4) Look at the **ECG Graph** and familiarize yourself with its features.
   - Several ECG parameters are automatically indicated by the vertical blue Marks on the graph. Their locations are determined by the algorithms in the configuration dialogs.
   - The graph displays the checked cycles in one selected group from the **Groups** list to the left of the graph. They are superimposed on each other and the cycle mathematically averaged from all of them is highlighted in red. The parameters and calculations from this averaged cycle appear in the **Data Table**. The individual cycles are in grey and the currently selected cycle (from the **Cycles in Group** list) is in black. The number of cycles in a group has been determined in the **Settings** configuration dialog as the **Average**.
5) Change the group of cycles displayed by selecting a different group in the **Group** list. The groups are listed in order of their appearance in the ECG.
6) Select a different cycle in the **Cycles in Group** list. Notice that the cycle displayed in black changes with your selection.
7) Uncheck one of the cycles. Notice that one of the cycles is deleted from the graph. The red averaged cycle will also change to reflect the new mathematical average. Add the cycle back again by checking its check box.

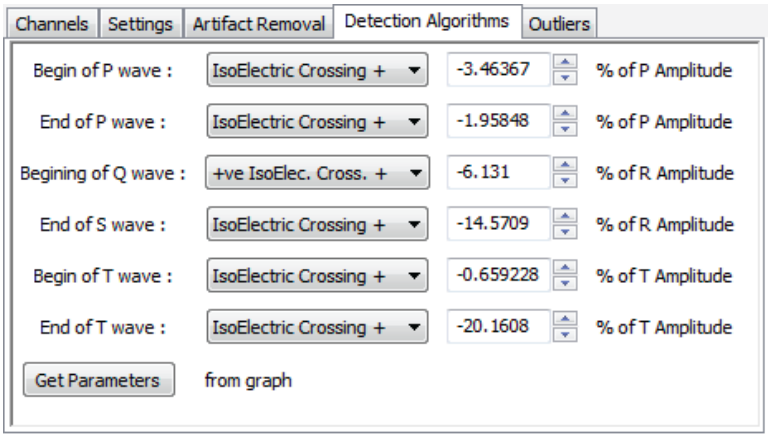
Configure Detection Algorithms

The detection criteria for the parameters displayed on the **ECG Graph** are determined in the **Detection Algorithms** configuration dialog. Default values for the chosen species are entered into the data boxes automatically, and these values can be changed manually.

The parameters marked are the **Beginning (Pb)** and **End (Pe) of the P Wave**, the peak of the **P Wave (P)**, the **Beginning of the Q Wave (Qb)**, the peak of the **R Wave (R)**, the **End of the S Wave (Se)**, and the **Beginning (Tb) and End (Te) of the T Wave**.

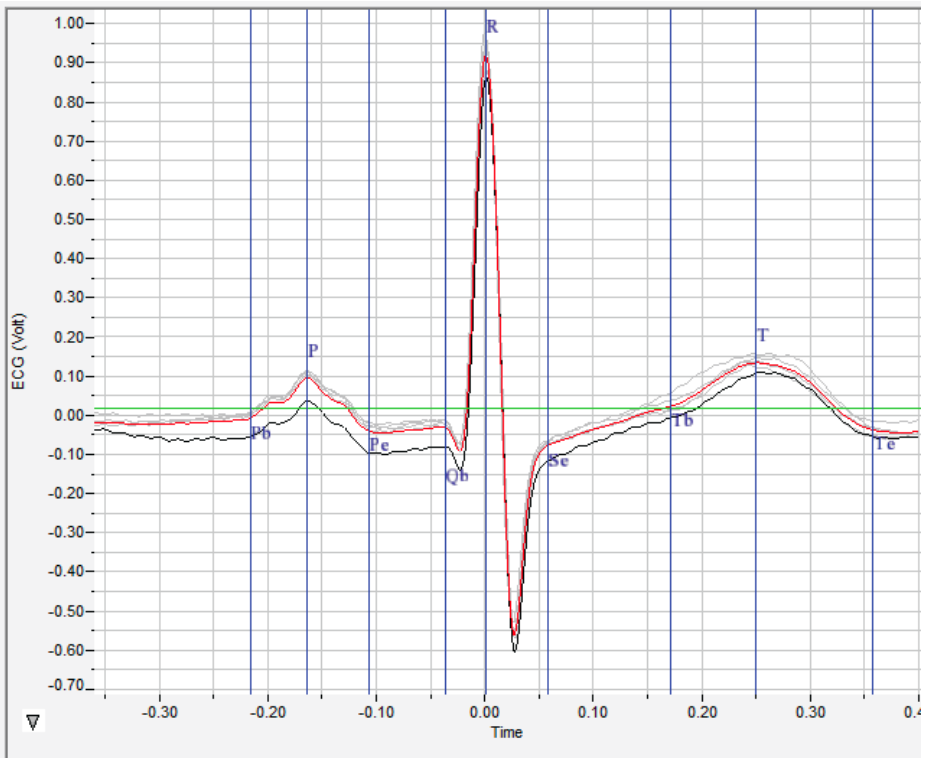
To configure the **Detection Algorithms** dialog:

1) Click on the **Detection Algorithms** tab to open the **Detection Algorithms** configuration dialog.



Detection Algorithms configuration dialog.

2) Examine the **ECG Graph**. Determine if the default locations are correct. Any incorrect locations can be remedied in the **ECG Graph** itself by clicking and dragging the vertical blue parameter Marks to adjust their positions.
3) Adjust the vertical blue parameter markers so that they are in the correct positions. Correct positions for a human electrocardiogram are indicated in the example below. Once the markers are correctly positioned, it is necessary to click **Get Parameters from graph** in the **Detection Algorithms** configuration dialog to enter the mathematical criteria for the values you specified into the dialog's data boxes. The parameters from other cycles to be analyzed will be set according to the revised criteria. Check that the parameter locations are correct and consistent for each group of cycles you analyze.



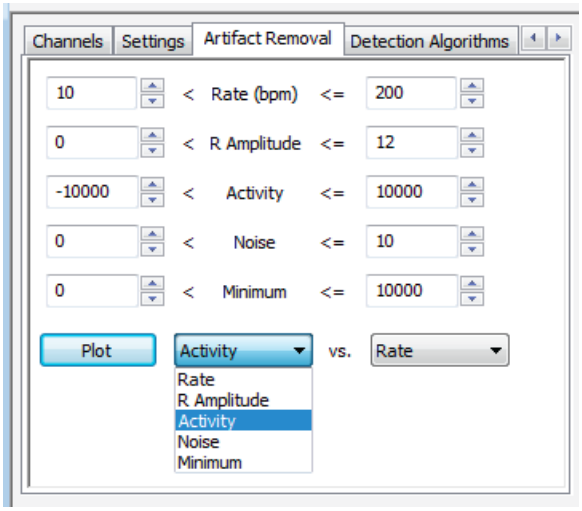
ECG Parameters located on the ECG Graph.

Configure Artifact Removal

Any noise or artifacts from the ECG data that may otherwise be interpreted as beats to be analyzed should be removed. This is accomplished by using the **Artifact Removal** configuration dialog and the associated **Artifact Graph**. In the **Artifact Removal** configuration dialog, acceptable limits for a number of variables are set to default values. These default values can be adjusted with the **Artifact Graph**.

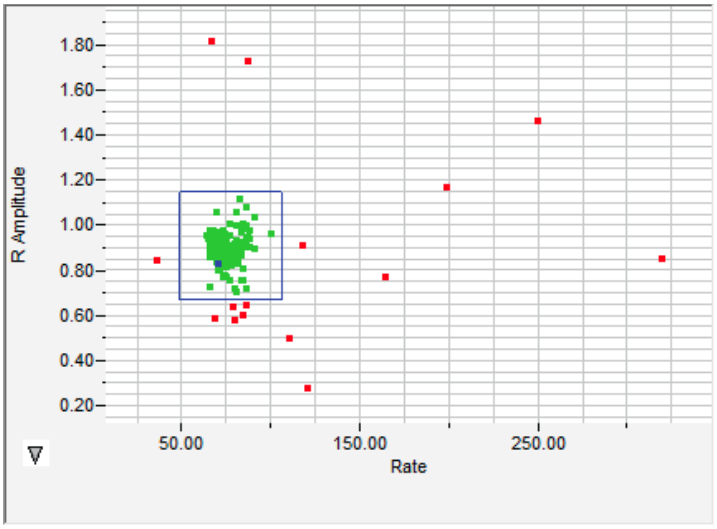
To use the **Artifact Removal** configuration dialog and the **Artifact Graph** for artifact detection and elimination:

1) Click the **Artifact Removal** tab to open the **Artifact Removal** configuration dialog. Initial default values are automatically entered into the data boxes.



Artifact Removal configuration dialog.

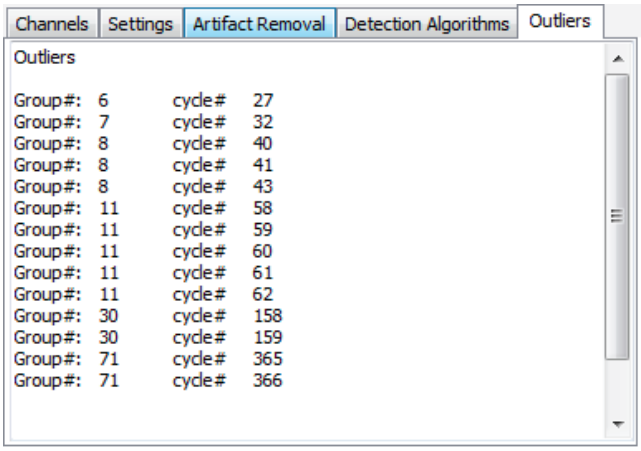
2) Choose **Artifact Graph** from the XY Graph menu at the lower left of the graph window.



Artifact Graph

3) Use the menu at the lower left to **Autoscale** the **X-axis** and the **Y-axis**.

4) In the **Artifact Removal** dialog, choose **Rate** and **R Amplitude** from the two menus next to the **Plot** button. Click **Plot**.
5) Look at the **Artifact Graph**. Each dot represents one cycle from the data. The green dots are those currently included in the analysis. The red dots are those that have already been removed by the default **Artifact Removal** settings. The currently selected cycle from the **Cycles in Group** list is highlighted in blue.
6) Select another cycle from the **Cycles in Group** list, and notice that the blue dot changes.
7) Click on any dot in the graph, and notice that it becomes blue, and the selected group and cycle indicated in the two lists change.
8) Notice that the dots are clustered in one area of the graph. The most representative ECG cycles will be clustered in one area of the graph, and will probably be surrounded by a number of outlying values that represent cycles characterized by values of one graphed variable or the other that are well outside the typical values.
9) Look at the **Rate** axis and see if there are any dots outside the cluster. Click on one of these dots; this represents a cycle that has been determined to be much shorter or longer than typical. Choose **View ECG Graph** (in the menu to the lower left of the graph) to display the group of cycles to which that cycle belongs. The selected cycle will be in black and may differ from the other cycles in the graph.
10) Look at the **R Amplitude** axis and repeat Step 9.
11) In the **Artifact Graph**, resize the blue box around the cluster of cycles and all cycles represented by dots outside the box will be removed from the analysis and will turn red after you click **Calculate** to update the analysis. Adjusting the size of the blue box will adjust the values in the data boxes of the **Artifact Removal** configuration dialog that determine the **Artifact Removal** criteria for the two graphed variables.
12) Repeat the process for other variables in the **Artifact Removal** dialog by plotting those variables and repeating the process. In this way outlying values can be excluded for any or all of the variables. Any **Outliers** will be removed from all calculations.
13) Click on the **Outliers** tab (to the right of **Detection Algorithms**) to see a list of all **Outliers**, described by **Group** and **Cycle** number.



Outliers dialog.

Data Table

All the data for each averaged group will be included in the **Data Table**. Each row of the **Data Table** contains the averaged ECG parameters for one of the checked cycle groups in the **Groups** list.

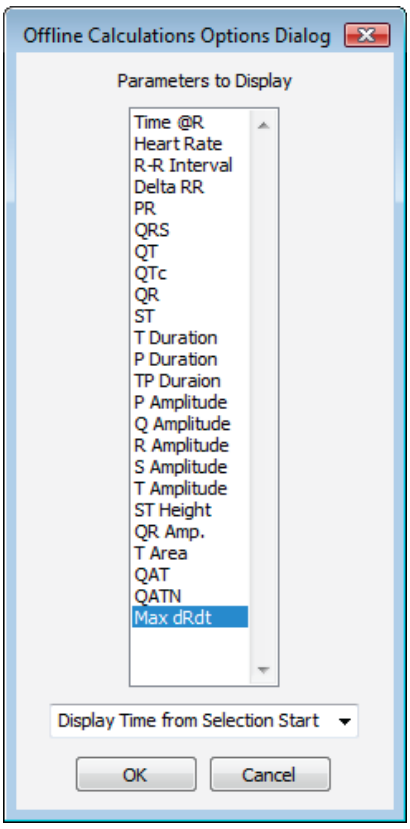
*	Sel	Time @R	HR	R-R Interval	Delta RR	PR	QRS	QT	QTc	QR	ST	T Duration	P Duration	TP Duraion	P
1	Yes	0.870	35.864	836.500	276.000	110.000	206.000	430.000	14.867	102.000	56.000	168.000	82.000	1092.900	0.
2	Yes	5.002	37.764	794.400	156.800	108.000	206.000	440.000	15.611	102.000	40.000	194.000	72.000	1002.000	0.
3	Yes	8.998	40.021	749.600	142.400	102.000	206.000	420.000	15.340	102.000	10.000	204.000	76.000	954.800	0.
4	Yes	12.658	40.584	739.200	149.600	114.000	206.000	430.000	15.816	102.000	50.000	174.000	84.000	932.400	0.
5	Yes	16.372	42.301	709.200	139.600	86.000	208.000	440.000	16.522	102.000	76.000	156.000	42.000	856.800	0.
6	Yes	19.872	42.397	707.600	144.800	120.000	208.000	420.000	15.789	102.000	14.000	198.000	94.000	880.400	0.
7	Yes	23.456	42.931	698.800	132.400	52.000	230.000	516.000	19.520	156.000	56.000	230.000	12.000	815.300	0.
8	Yes	26.872	43.956	682.500	171.500	70.000	200.000	446.000	17.072	136.000	2.000	244.000	36.000	800.900	0.
9	Yes	30.308	44.883	668.400	186.000	210.000	134.000	368.000	14.234	30.000	178.000	56.000	120.000	928.400	0.
10	Yes	33.912	36.946	812.000	172.000	112.000	206.000	446.000	15.652	102.000	80.000	160.000	90.000	1121.600	0.
11	Yes	38.050	34.981	857.600	172.000	102.000	206.000	454.000	15.503	102.000	52.000	196.000	76.000	843.100	0.
12	Yes	42.368	51.948	577.500	100.667	118.000	278.000	430.000	17.893	122.000	120.000	32.000	120.000	1080.300	0.
13	Yes	46.634	29.331	1022.800	180.000	108.000	208.000	428.000	13.383	104.000	64.000	156.000	86.000	1356.800	0.
14	Yes	50.960	34.642	866.000	173.600	106.000	206.000	434.000	14.748	102.000	60.000	168.000	78.000	1176.400	0.

Copy | Export | Algorithms | Table Options | Load Template | Save Template | OK | Cancel

The Data Table.

To use the **Data Table** and export values to the **Journal:**

1) Click **Table Options** at the bottom of the dialog to see a list of all the ECG parameters that can be displayed in the **Data Table**. These parameters and calculations are all defined in the **ECG Advanced Analysis Module: Reference** section.



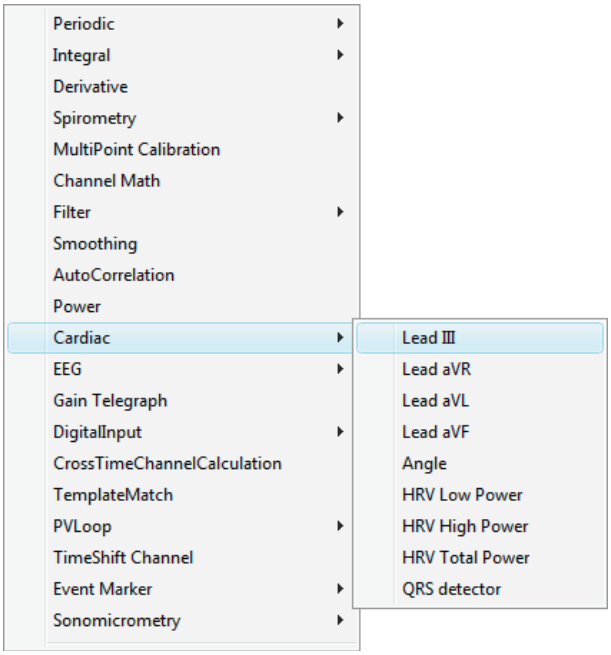
Offline Calculations Options dialog.

2) Choose the options you wish to include in the analysis and display in the **Data Table**. Choose whether you wish to display the **Time from the Start of the Selection** or the **Time of Day** of the recording. Click **OK**.
3) Click the asterisk in the upper left corner of the **Data Table**. The **Autosize** option adjusts the size of the cells for optimal display. The **Copy Selection** option will copy any selected cells to the clipboard.
4) Click **Algorithms** to see the definitions of the parameters and calculations.
5) To copy all the calculated data in the **Data Table** to the clipboard, click the **Copy** button, or click the **Export** button to export the data. The data are exported in a tab (*.txt) or comma (*.csv) separated text file, and the graph can be exported as a Portable Network Graphics (*.png) or JPEG (*.jpg) image.
6) To load the analysis configuration for the current analysis, click **Save Template** to name and save the settings. Clicking **Load Template** when the module is reopened will display the list of previously saved templates.

ECG Analysis: Reference

Basic Cardiac Functions: Reference

LabScribe's **Cardiac** functions can be accessed by clicking **add function** on the channel of an ECG recording and selecting one of the **Cardiac** functions.



The Cardiac submenu.

The limb lead **Cardiac** functions are specifically used for the analysis of human electrocardiograms (ECGs). Four of the **Cardiac** functions calculate limb **Leads: III, aVR, aVL** and **aVF** from recordings of **Lead I** and **Lead II**. The channels corresponding to **Lead I** and **Lead II** should be chosen in the **Cardiac Setup** dialog.

LabScribe can be programmed to do these calculations because all the points of view in a 6- lead ECG are in the same plane (frontal) of the body and each lead can be considered as a vector. So if any two of the limb leads are recorded, the other four leads can be calculated from them.

The **Cardiac** submenu also includes other functions. The cardiac **Angle** function is also specific to human cardiograms and calculates the vector of the cardiac depolarization that passes through the interventricular septum, and can indicate abnormalities in electrical conduction, or the actual anatomical orientation of the heart.

Three **Power** functions, which are special cases of the general **Power** function and can be used in the analysis of any species, are also available. These three power functions are useful for heart rate variability (**HRV**) analysis. **HRV Low Power** (0.04-0.15 Hz), which shows low frequency cyclic fluctuations in heart rate, **HRV High Power** (0.18-0.4 Hz), which shows high frequency cyclic fluctuations in heart rate, and **HRV Total Power** are each calculated from a tachogram transformation of one of the ECG raw data channels, or from the **QRS detector** channel.

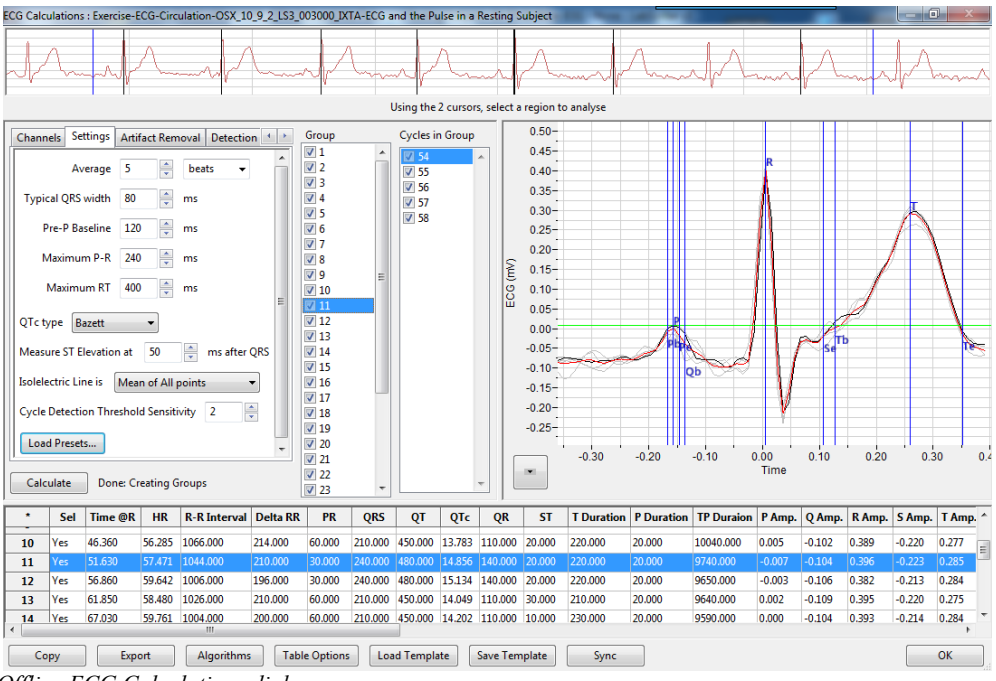
The **QRS detector** displays a trace of peaks representing the QRS complexes with amplitudes reflecting the amplitudes of the individual QRS complexes. Heart rate can be determined from this function and the relative amplitudes of the R waves can be compared.

ECG Advanced Analysis Module: Reference

Offline Calculations

Sophisticated ECG analysis can be accomplished by selecting **Offline Calculations** from the **ECG Analysis** submenu and opening the offline **ECG Calculations Dialog**. The panels of this dialog can be resized by moving the mouse cursor over the boundaries until a double-headed arrow appears, and dragging the boundaries to resize the panels.

The Offline ECG Calculations Dialog



Offline ECG Calculations dialog.

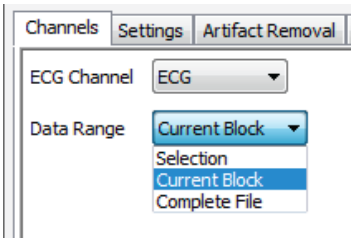
Across the top of the dialog, in the channel display area, is the raw data channel to be analyzed. On the left of the middle row are the windows used to configure the analysis. At the right is a window in which the **ECG Graph** and **Artifact Removal** graphs can be displayed. Between them is an editable list of the cycles to be analyzed and displayed. Across the lower part of the dialog is a **Data Table** with the calculated average parameter values for each of the analyzed groups of beats.

The Channel Display Area: In the channel display area, the two vertical blue lines can be adjusted to designate a section of the recording for analysis.

The Configuration Dialogs

There are five tabbed dialogs used to configure the analysis: **Channels, Settings, Artifact Removal, Detection Algorithms,** and **Outliers.**

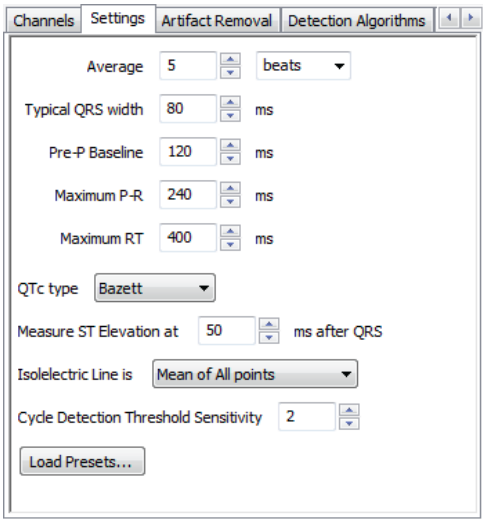
The Channels Configuration Dialog



Channels configuration dialog.

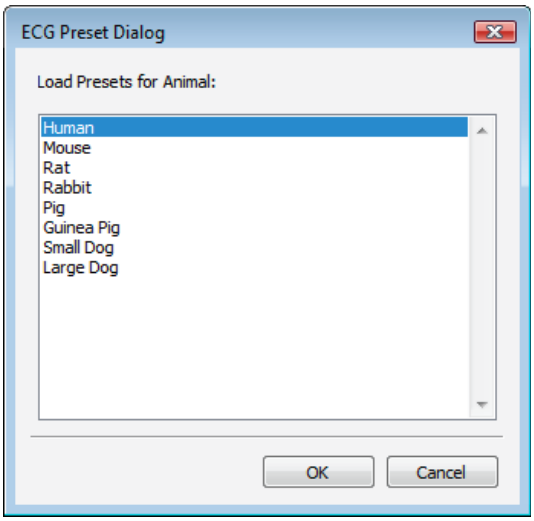
- The ECG channel you wish to analyze from the data file can be selected from the **ECG Channel** menu.
- It is possible to select whether you want to analyze the complete file, the current block or the selection between the cursors on the data sample in the channel display area at the top of the dialog from the **Data Range** menu.

The Settings Configuration Dialog



Settings configuration dialog.

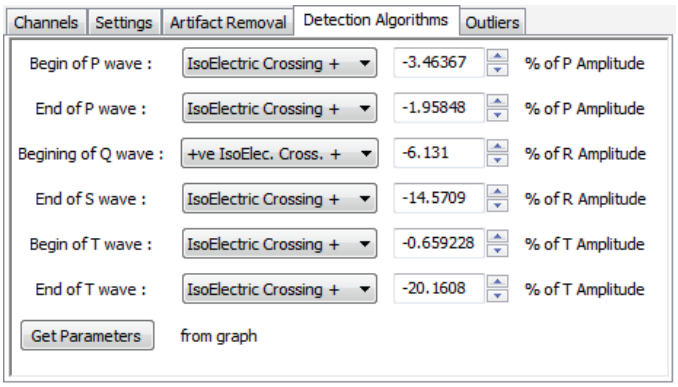
- In order to compensate for variation from cycle to cycle, or to compare different experimental conditions, it is possible for *LabScribe* to average a user-selected number of sequential cycles. This number should be entered in the **Average** text box.
- The number of cycles that should be used to determine the **Cycle Detection Threshold Sensitivity** should be entered in the **Cycle Detection Threshold Sensitivity** data box. If each cycle is not being detected properly, the sensitivity can be adjusted. As the numbers increase, the threshold for beat detection is lowered and more cycles are detected.
- The desired type of QTc analysis and how you would like the isoelectric line to be calculated are chosen from the **QTc type** and **Isoelectric Line is** menus.
- Clicking **Load Presets...** will open the **ECG Preset Dialog**, from which the species from which the analyzed ECG has been recorded can be chosen.



ECG Preset Dialog.

- The remaining data boxes will be loaded with values appropriate to the ECG of the selected species.
- Changes to the default values can also be entered manually into the appropriate boxes of the **Settings** dialog.

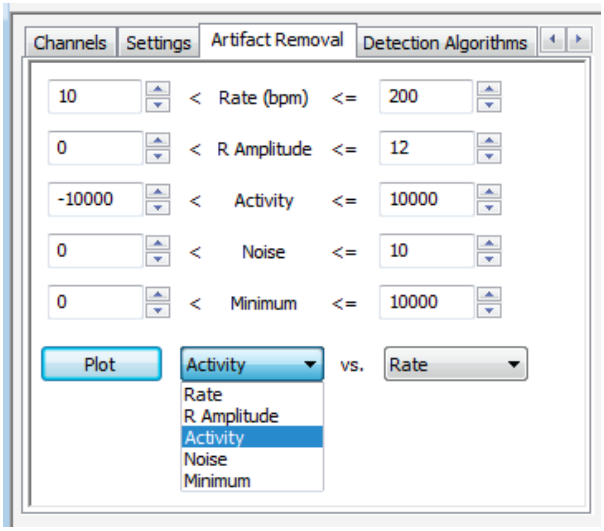
The Detection Algorithms Configuration Dialog



Detection Algorithms configuration dialog.

- The default algorithms used to place markers at specific locations in the ECG are displayed.
- The positions of the markers can be set manually by adjusting the markers in the **ECG Graph** and clicking **Get Parameters from graph**. The revised parameters will be used in the analysis of other ECG groups to be analyzed.

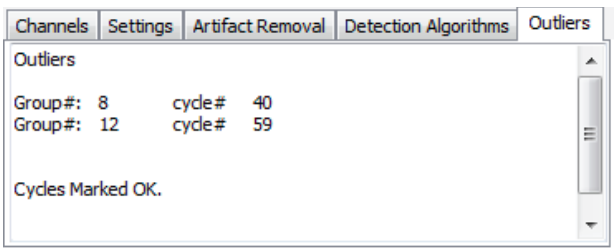
The Artifact Removal Configuration Dialog



Artifact Removal configuration dialog.

- *LabScribe* can remove cycles that are likely to be misinterpreted due to artifacts or noise in the recording. Individual cycles that fall outside expected values for **Rate**, **R Amplitude**, **Activity, Noise**, and **Minimum** will not be displayed or included in the averaged values. **Activity** (for example, from movement artifacts) and **Noise** are both measures of fluctuation from a continuous trace.
- Default values are automatically entered in the **Artifact Removal** dialog.
- These values can be changed by entering new values in the text boxes manually, or by clicking on the **Plot** button to display the **Artifact Graph** in the graph area to the right of the dialog (see the Artifact Graph section below for details). The parameters that are graphed are those entered in the two **Plot** menus of the **Artifact Removal** dialog.

The Outliers Configuration Panel

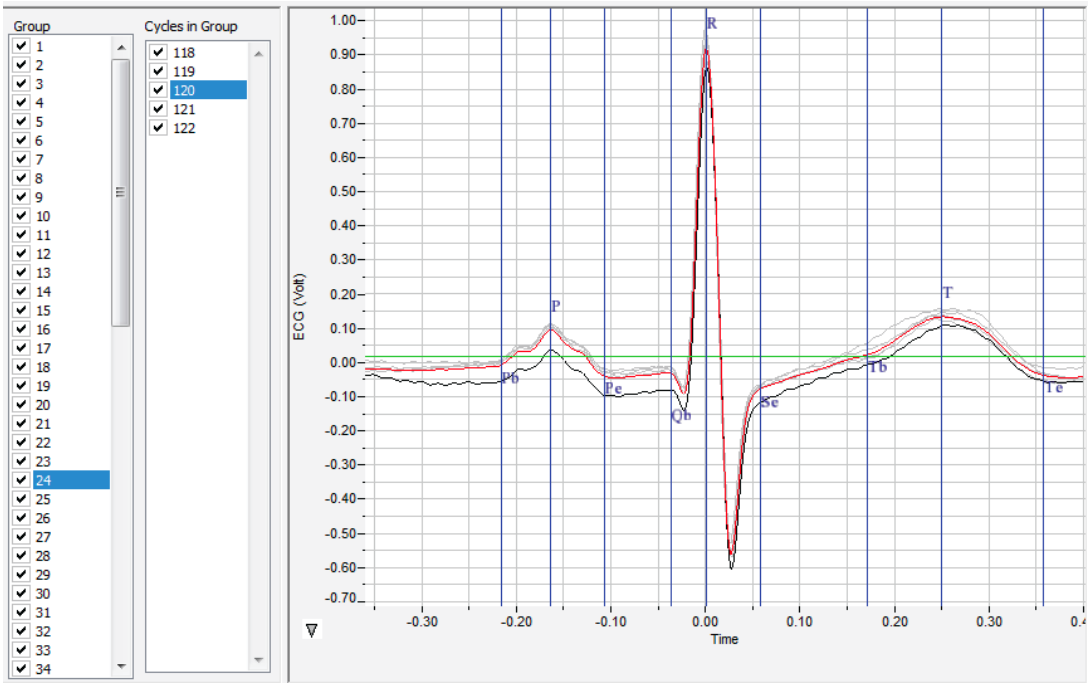


Outliers configuration dialog.

- The specific outlying cycles determined by the **Artifact Removal** process are listed.

The ECG Graph

Once the **Settings** configuration dialog is completed, clicking **Calculate** just above the **Data Table** will display the **ECG Graph** in the XY graph window.



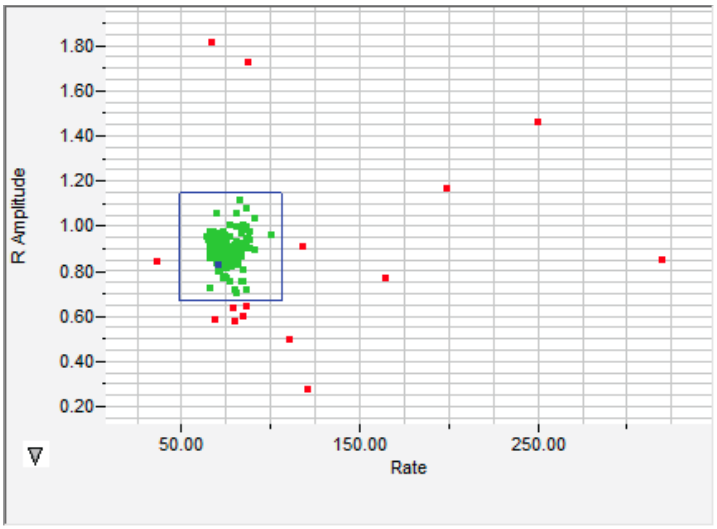
The XY Graph. with the Groups and Cycles in Group checklists to its left.

A group of cycles is displayed at a time. The number of cycles displayed is determined by the number entered in the **Average** box of the **Settings** dialog. The group being displayed is indicated in the **Group** window, and the individual cycles in that group are indicated in the **Cycles in Group** window. The UP and DOWN arrows on the computer keyboard can be used to move quickly through the individual groups or cycles. In the graph, the currently selected cycle is in black, and the average of the group is in red. Any others are in grey. The calculated values displayed in the **Data Table** are the averages of each group.

The parameters marked are the **Beginning (Pb) and End (Pe) of the P Wave**, the peak of the **P Wave (P)**, the **Beginning of the Q Wave (Qb)**, the peak of the **R Wave (R)**, the **End of the S Wave (Se)**, and the **Beginning (Tb) and End (Te) of the T Wave**. Their locations are set by the default values for the species chosen in the **ECG Preset** dialog. Incorrect locations can be remedied by manually moving the vertical blue Marks to the correct location and clicking on **Get Parameters from graph** in the **Detection Algorithms** dialog.

The Artifact Graph

The **Artifact Graph** is accessed in the menu at the lower left of the XY Graph window. In the **Artifact Graph**, each dot represents one cycle from the data. The green dots are those currently included in the analysis. The red dots are those that have already been removed by the default **Artifact Removal** settings. The currently selected cycle from the **Cycles in Group** list is highlighted in blue.



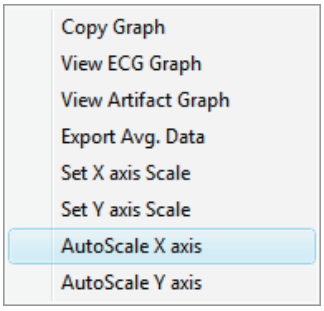
Artifact Graph.

The blue box in the **Artifact Graph** can be resized to exclude cycles represented by outlying data points.

Clicking **Calculate** after adjusting the size of the box will update the analysis and the newly excluded data points will be red. The values in the data boxes of the **Artifact Removal** configuration dialog wll also be adjusted.

The XY Graph Menu

Clicking the arrow to the lower left of the XY graph window displays the XY graph menu.



XY Graph menu.

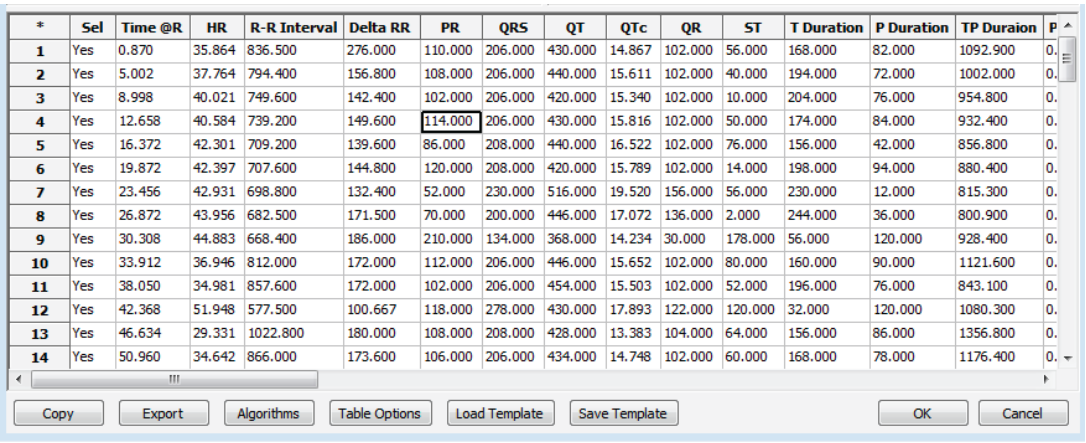
XY Graph menu options:

- **Copy graph**: Copies the current XY graph to the clipboard. It can then be pasted into the **Journal** or an external application.
- **View ECG Graph**: Displays the beats determined by the checked **Group** and **Cycles in Group**. The group's signal-averaged ECG is also displayed in red.
- **View Artifact Graph**: Displays the graph configured in the **Artifact Removal** tabbed dialog.
- **Export Avg. Data**: Exports the data points representing the averaged ECG as a tab (*.txt) or comma (*.csv) separated text file.
- **Set X-axis Scale**, **Set Y-axis scale**: Allows the user to set the X-axis and Y-axis scales. The axes can also be rescaled by clicking and dragging the X-axis or Y-axis numbers.

- **AutoScale X-axis**, **AutoScale Y-axis**: Optimizes display scale of the X-axis or Y-axis of the XY graph.

The Data Table

All the data for each averaged group is included in the **Data Table**. Each row of the **Data Table** contains the averaged ECG parameters for one of the checked cycle groups in the **Groups** list.



*	Sel	Time @R	HR	R-R Interval	Delta RR	PR	QRS	QT	QTc	QR	ST	T Duration	P Duration	TP Duraion	P
1	Yes	0.870	35.864	836.500	276.000	110.000	206.000	430.000	14.867	102.000	56.000	168.000	82.000	1092.900	0.
2	Yes	5.002	37.764	794.400	156.800	108.000	206.000	440.000	15.611	102.000	40.000	194.000	72.000	1002.000	0.
3	Yes	8.998	40.021	749.600	142.400	102.000	206.000	420.000	15.340	102.000	10.000	204.000	76.000	954.800	0.
4	Yes	12.658	40.584	739.200	149.600	114.000	206.000	430.000	15.816	102.000	50.000	174.000	84.000	932.400	0.
5	Yes	16.372	42.301	709.200	139.600	86.000	208.000	440.000	16.522	102.000	76.000	156.000	42.000	856.800	0.
6	Yes	19.872	42.397	707.600	144.800	120.000	208.000	420.000	15.789	102.000	14.000	198.000	94.000	880.400	0.
7	Yes	23.456	42.931	698.800	132.400	52.000	230.000	516.000	19.520	156.000	56.000	230.000	12.000	815.300	0.
8	Yes	26.872	43.956	682.500	171.500	70.000	200.000	446.000	17.072	136.000	2.000	244.000	36.000	800.900	0.
9	Yes	30.308	44.883	668.400	186.000	210.000	134.000	368.000	14.234	30.000	178.000	56.000	120.000	928.400	0.
10	Yes	33.912	36.946	812.000	172.000	112.000	206.000	446.000	15.652	102.000	80.000	160.000	90.000	1121.600	0.
11	Yes	38.050	34.981	857.600	172.000	102.000	206.000	454.000	15.503	102.000	52.000	196.000	76.000	843.100	0.
12	Yes	42.368	51.948	577.500	100.667	118.000	278.000	430.000	17.893	122.000	120.000	32.000	120.000	1080.300	0.
13	Yes	46.634	29.331	1022.800	180.000	108.000	208.000	428.000	13.383	104.000	64.000	156.000	86.000	1356.800	0.
14	Yes	50.960	34.642	866.000	173.600	106.000	206.000	434.000	14.748	102.000	60.000	168.000	78.000	1176.400	0.

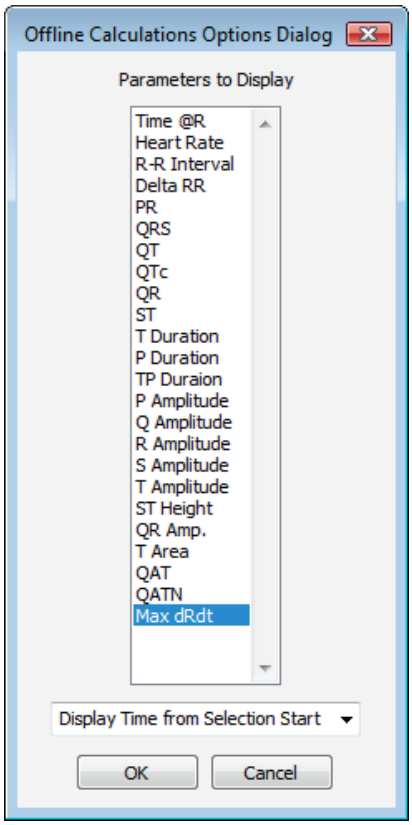
Copy | Export | Algorithms | Table Options | Load Template | Save Template | OK | Cancel

Data Table.

Clicking the asterisk at the upper left of the **Data Table** displays the **Autosize** or **Copy Selection** options. Clicking **Autosize** will optimize the size of the **Data Table** boxes, and **Copy Selection** will copy any selected cells from the **Data Table** to the clipboard.

There are six buttons beneath the Data Table: **Copy, Export, Algorithms,Table Options, Load Template,** and **Save Template.**

- All the calculated data in the **Data Table** can be copied to the clipboard by clicking the **Copy** button, or exported by clicking the **Export** button. The data are exported in a tab (*.txt) or comma (*.csv) separated text file, and the XY graph can be exported as a Portable Network Graphics (*.png) or JPEG (*.jpg) image
- *LabScribe* is able to calculate a large number of ECG calculations for each group of cycles. By clicking **Table Options** at the bottom of the offline **ECG Calculations Dialog**, the **Offline Calculations Options Dialog** opens and calculations to be displayed in the **Data Table** can be chosen from the list of all possible calculations. The **Display Time** to be used (**from Selection Start** or **Time of Day** of recording) is also chosen here.



Data Table parameter options.

- Clicking **Algorithms** opens an information window describing the mathematical equations used to compute a number of the offline parameters.
- Clicking **Save Template** allows you to name and save a template for future analysis. **Load Template** allows a choice from previously saved templates.
- Clicking **OK** saves the current configuration. The next time the offline **ECG Calculations** dialog is opened, it opens with these settings.

Offline Calculation Algorithms: The offline calculations (averaged over the cycles in the group unless indicated otherwise) include:

- **Time @ R**: The time at the peak of the averaged R wave.
- **Heart Rate**: 60/period of each cycle averaged over the cycles in the group.
- **R-R Interval**: Average of the R-R intervals (peak to peak) of the cycles in the group.
- **Delta RR**: Change of the current R-R interval from the R-R interval of the preceding group.
- **PR**: Time from the beginning of the P wave to the peak of the R wave.
- **QRS**: Time from the beginning of the Q wave to the end of the S wave.
- **QT**: Time from the beginning of the Q wave to the end of the T wave.
- **QTc**: Rate-corrected **QT Interval (QTc = QT Interval**/square root of preceding **R-R interval).**
- **QR**: Time from the beginning of the Q wave to the peak of the R wave.
- **ST**: Time from the end of the S wave to the start of the T wave.
- **P Duration**: Time from the beginning to the end of the P waves.
- **T Duration**: Time from the beginning to the end of the T wave.

- **TP Duration**: Time from the beginning of the T wave to the end of the P wave.
- **P Amplitude**: Amplitude of the P wave (from the baseline).
- **Q Amplitude**: Amplitude of the Q wave (from the baseline).
- **R Amplitude**: Amplitude of the R wave (from the baseline).
- **S Amplitude**: Amplitude of the S wave (from the baseline).
- **T Amplitude**: Amplitude of the T wave (from the baseline).
- **ST Height**: The height of the point at the beginning of the ST segment (from the baseline).
- **QR Amplitude**: Lowest point of the Q wave to the peak of the R wave.
- **T Area**: Area between the T wave and the baseline from the start to the end of the T wave.
- **QAT** (Q alpha T): The time from the Q wave to the peak of the T wave.
- **QATN** (Q alpha T normalized): Time between the Q wave and the lowest point between the end of the S wave and the end of the T wave.
- **Max dRdt**: Maximum derivative between Qbegin and R.