



**Hillrom™**

Welch Allyn®  
Vision Express™  
Holter Analysis System  
Clinician's Guide



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**#** 901143 HOLTER ANALYSIS SOFTWARE



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# INTRODUCTION

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## Preface

This guide is intended for qualified health care professionals who want to learn more about the Vision™ Express Holter system methods for analysis. It describes various aspects of the Welch Allyn VERITAS™ algorithm for Holter analysis.

Contents of the Vision Express final report are explained in detail for the interpreting physician's understanding.

A "Quick Reference for the Holter Analyst" section contains representative ECG strips of commonly encountered rhythms and arrhythmias along with widely accepted medical definitions. This section also includes a description of how the Vision Express analysis program interprets each event.

This guide does not cover the user actions such as editing, review and results generation. These instructions are contained in the Burdick Vision Express Holter Analysis System user manual.

## Overview

Vision Express is a high-speed, PC-based Holter scanner that performs analysis on continuous digital ECG data. The Vision Express application provides full-disclosure data for arrhythmia analysis and incorporates Welch Allyn's exclusive VERITAS ECG algorithm for superior beat detection, QT/QTc analysis and ST segment analysis to acquired ECG data.

The Vision Express system is indicated for use in a clinical setting, by qualified medical professionals only, for patients requiring ambulatory (Holter) monitoring. Such monitoring is most frequently used for the purpose of prospective and retrospective cardiac data and arrhythmia analysis. The analysis software package includes detection and reporting features appropriate to the indications below:

- Evaluation of adult patients with symptoms suggesting arrhythmia
- Evaluation of adult patients with pacemakers
- Reporting of time domain heart rate variability
- Evaluation of patient's response after resuming occupational or recreational activities (e.g. after myocardial infarction or cardiac surgery)
- Evaluation of ECG documenting therapeutic interventions in individual patients or groups of patients
- Clinical and epidemiological research studies
- Evaluation of ECGs from infants is limited to QRS detection and heart rate reporting, including infants weighing less than 10 kg (22 lbs) if supported by the Holter recorder device, see specific Holter recorder User Manual.

The Vision Express analysis process consists of the following steps and components:

1. Reading the raw digital ECG data and then processing and storing the digital ECG data
2. Beat detection and creation of templates (QRS shapes) and their group types
3. Beat labeling and creation of navigable events within the following selections:
  - Strips
  - ECG
  - Summary
  - Templates

- 
- Histograms
  - Profile presentation with summary periods of data
  - Trend presentation in five-minute periods of data
4. Creation of summary data to provide totals for each beat and event type

Recording acquisition and the automatic computer analysis of one or more days of recording is completed by the Vision Express program in approximately one minute. Recalculation after an editing change is immediate.

Templates, beats, and events are navigable and can be edited during review. Holter ECG strips are added to the final report manually or automatically.

Holter results can be reported and exported in several different formats. The final report pages are numbered sequentially with examples explained in this guide.

## PROCESSING THE ECG DATA

Accuracy of the Welch Allyn VERITAS analysis algorithm has been measured in accordance with the EC38 and EC57 standards published by the American National Standards Institute and the Association for the Advancement of Medical Instrumentation, as well as the international standard IEC 60601-2-47, who require sensitivity and positive predictivity of ECG analysis algorithms be reported for both QRS and ventricular ectopic beat detection. Tests were performed on all recordings excluding those with ventricular fibrillation and artificial pacemakers of two reference databases: AHA and MIT-BIH. Performance results show that the Burdick Vision Express Holter algorithm has 99.9% QRS detection accuracy, the best performance published by any company.

**Note:** Evaluation of ECGs from infants is limited to QRS detection and heart rate reporting, including infants weighing less than 10 kg (22 lbs) if supported by the Holter recorder device, see specific Holter recorder User Manual.

	<b>AHA Database</b>
<i>Performance Measures</i>	<b>Welch Allyn</b>
QRS Sensitivity %	99.88
QRS Positive Predictivity %	99.91
Ventricular Sensitivity %	93.73
Ventricular Positive Predictivity %	98.40
False Positive Rate %	0.15
	<b>MIT-BIH Database</b>
<i>Performance Measures</i>	<b>Welch Allyn</b>
QRS Sensitivity %	99.95
QRS Positive Predictivity %	99.87
Ventricular Sensitivity %	95.24
Ventricular Positive Predictivity %	97.05
False Positive Rate %	0.22

It is well-known that Holter ECG signals are subject to ambulatory noise and artifacts that can make the data difficult to analyze. Signal processing is performed to remove or lessen the types of noise and artifacts that occur during ambulatory recording such as baseline wander and shifts caused by high electrode impedance, 50/60 Hz AC interference, movement artifact, and muscular noise. The presence of noise and artifact in the recording can be minimized by using high-quality monitoring electrodes with proper skin preparation and electrode placement during patient hook up, explained in each device-specific user manual. Interactive review of the computer analyzed recording by a qualified clinician will ensure a highly accurate final report.

The results of EC 57 testing on the Noise Stress Database testify the resilience of the VERITAS algorithm to noise up to twice the power of the ECG signal itself:

	<b>NST Database</b>
<i>Performance Measures</i>	<b>Welch Allyn</b>
QRS Sensitivity %	87.25
QRS Positive Predictivity %	89.44
Ventricular Sensitivity %	85.76
Ventricular Positive Predictivity %	72.42
False Positive Rate %	3.95

The Vision Express analysis program applies a high pass filter to the data as it is acquired and read where appropriate for the recorder. Each sample is stored accompanied by a status field that contains indicators for diary events, no data, pacemaker spikes, and lead fail for each of the recorded channels.

## Beat Detection

The analysis program checks the signal quality on each beat to determine the best quality channels to be used. Beat detection channels may change dynamically as the analysis progresses. Intermittent periods of lead fail or artifact will cause analysis channel switching to ensure accurate beat labeling. If required, the user can manually exclude channels from being used in the detection algorithm.

## Templates and Beat Labeling

The analysis program groups beats in templates based on shape related information. Template groups such as Normal, Supraventricular\*, Ventricular, Paced, and Unknown are then determined through evaluation of the dominant beat morphology, beat characteristics, prematurity and presence of any pacemaker spikes.

Templates with similar morphologies are merged during the final processing step based on the correlation between them.

Templates are presented in a total of 4 or 5 groups that may also contain other related beat types.

1. Normal
  - Supraventricular\*
  - Bundle Branch Block
  - Aberrant\*
2. Supraventricular\*
  - Supraventricular\*
  - Aberrant\*
3. Ventricular
  - Fusion
  - R-on-T

Once a beat is identified as being Ventricular, it is then compared to the previous beat. If the previous beat is not ventricular, its RR interval is less than 500 ms, and the beat is less than one-half of the previous beat's RR, it is declared an R-on-T beat by the analysis program.

  - Interpolated
  - Ventricular Escape
4. Paced
  - Atrial Paced
  - Ventricular paced
  - Dual Paced
5. Unknown

\* When the user has selected **Enable Supraventricular Template Group**, all normal beats that meet the set SVPB prematurity percent criteria and manually labeled aberrant beats will be in the Supraventricular template group and not included in the Normal template group.

Each individual beat type is color-coded for rapid identification during review.

Automatically applied beat labels by the analysis program:	Manual beat labels:
<ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 15px; border: 1px solid black; background-color: white; margin-right: 5px;"></span> Normal (N)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: blue; margin-right: 5px;"></span> Supraventricular (S)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: red; margin-right: 5px;"></span> Ventricular (V)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: pink; margin-right: 5px;"></span> R on T (R)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: orange; margin-right: 5px;"></span> Ventricular Escape (E)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: lightcoral; margin-right: 5px;"></span> Unknown (U)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: magenta; margin-right: 5px;"></span> Atrial Paced (C)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: green; margin-right: 5px;"></span> Ventricular Paced (P)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: yellow; margin-right: 5px;"></span> Dual Paced (D)</li> </ul>	<ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: teal; margin-right: 5px;"></span> Bundle Branch Block (B)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: cyan; margin-right: 5px;"></span> Aberrant (T)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: orange; margin-right: 5px;"></span> Interpolated (I)</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: darkred; margin-right: 5px;"></span> Fusion (F)</li> <li>Delete Beat</li> <li>Artifact</li> </ul> <p>Note: Deleted beats and beats relabeled as artifact are removed</p>

During review and editing, any applied beat label can be relabeled by the analyst with any one of the 13 beat labels.

Additionally, the analyst may relabel a beat or region of the recording as Artifact to exclude data from being used for analysis, delete a beat or all beats within a template, and insert beat labels as desired. If an entire Template is relabeled Artifact, a short episode of recording containing each beat that is part of the template will be relabeled Artifact.

User-labeled Fusion and Interpolated beats will be classified as a ventricular beat type and used for ventricular calculations. User-labeled Bundle Branch Block beats will be classified as a normal beat type. Supraventricular beat types are identified by the program according to a user-defined prematurity percent setting and are contained within Normal templates or Supraventricular templates when enabled, as their QRS morphology is classified normal according to the dominant beat shape. Beats that are manually labeled as Normal or Supraventricular will not be relabeled on the basis of prematurity. User-labeled aberrant beats will also be classified as a supraventricular beat type.

Ectopic beats are grouped as "single" (one ectopic beat followed by a Normal beat), "couplets" or "pairs" (2 contiguous ectopic beats) and "Runs" (3 or more contiguous ectopic beats).

## Event, Episode and Ectopy Presentation

Rhythm, QT and ST-segment analysis is performed using Welch Allyn's advanced VERITAS™ algorithm to determine isoelectric, Q, R, S and ST measurement points. The beat time, classification family, ST level, noise property,

Q onset and offset, QT interval, template number, and RR interval is analyzed for every beat and is processed by breaking down this information allowing the analyst to rapidly navigate to events and episodes through use of the Vision Express Profile, Histograms, and Trends.

User-defined scan criteria settings can be modified on a per-study basis or set as a default for the following:

- Pacemaker analysis on/off and minimum pacemaker rate
- Automatic atrial fibrillation detection on or off
- Supraventricular prematurity percentage
- Pause duration in msec and if pauses are excluded from minimum HR calculation
- Pauses to use all beats or only normal to normal beats
- ST Segment Depression and Elevation thresholds in  $\mu\text{V}$
- Tachycardia/Bradycardia heart rate thresholds and minimum duration
- Ventricular Tachycardia rate and number of consecutive beats
- Supraventricular Tachycardia rate and number of consecutive beats
- Heart Rate calculation on all beats, or only normal beats
- Heart Rate Variability calculation on normal beats only, or normal and supraventricular beats

The analysis program will identify ventricular bigeminy when the following pattern is present for at least 3 cycles:

NVNVNV... Ventricular trigeminy is identified when the following pattern is present for at least three cycles:

NNVNNVNV... Navigation to these rhythm patterns is best performed in the Profile display.

The analysis program will identify supraventricular bigeminy when the following pattern is present for at least 3

cycles: NSNSNS... Supraventricular trigeminy is identified when the following pattern is present for at least three

cycles: NNSNSNSNS... Navigation to these rhythm patterns is best performed in the Profile display.

Supraventricular or ventricular beats that occur during bigeminy and trigeminy episodes are included in the total ectopic beat count. The profile and summary statistics report the total number of beats that occurred during the bigeminy and trigeminy episodes (ventricular or supraventricular + Normal) in their respective columns.

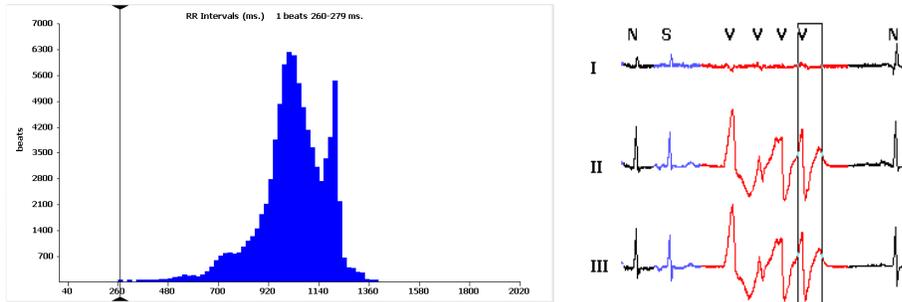
Periods of artifact that occur within a tachycardia or bradycardia episode will be considered to have the same heart rate and will be included in the duration of the event.

A colored Event Bar is selectable for display in the ECG view to indicate the start and end of an episode or event for the types listed below. Users may also define up to three custom event types per Holter study. Some event episodes may overlap and may not be visible. Event episodes are prioritized as follows:

- Exclusion (lead fail, artifact, user-removed)
- Atrial Fibrillation
- User-defined Event 1
- User-defined Event 2
- User-defined Event 3
- ST Depression
- ST Elevation

Vision Express Profile information is broken into one-hour periods with calculated information presented for each period and a summary for the entire recording period.

Vision Express RR Intervals Histogram information is created displaying the number of intervals that fall within 20 ms bins. This feature provides a graphical representation of the interval distribution allowing quick determination of frequency and density of intervals as well as navigation to the most extreme events.



Vision Express Trend information is broken into five-minute periods presenting a minimum, average and maximum graphical representation of events and episodes.

Profile Events	Histogram Events	Trend Events
<ul style="list-style-type: none"> <li>• Beat total</li> <li>• Min/Mean/Max Heart Rate</li> <li>• Bradycardia/Tachycardia</li> <li>• Bundle Branch Block Beats</li> <li>• Aberrant Beats</li> <li>• Interpolated Beats</li> <li>• Unknown Beats</li> <li>• Supraventricular</li> <li>• Atrial Fibrillation percent</li> <li>• Ventricular</li> <li>• Paced events and failures</li> <li>• Min/Max RR</li> <li>• Pauses</li> <li>• ST Elevation/Depression</li> <li>• RR variability calculations</li> <li>• Min/Mean/Max QT/QTc</li> <li>• User-defined episodes (3)</li> </ul>	<ul style="list-style-type: none"> <li>• RR Interval</li> <li>• Supraventricular Prematurity</li> <li>• Pace Spike→QRS</li> <li>• QRS→Pace Spike</li> <li>• Ventricular Run</li> <li>• Supraventricular Run</li> </ul>	<ul style="list-style-type: none"> <li>• Min/Mean/Max Heart Rate</li> <li>• Bundle Branch Block Beats</li> <li>• Aberrant Beats</li> <li>• Interpolated Beats</li> <li>• Unknown Beats</li> <li>• Supraventricular</li> <li>• Atrial Fibrillation percent</li> <li>• Ventricular</li> <li>• Paced events and failures</li> <li>• Min/Max RR</li> <li>• Pauses</li> <li>• ST Elevation/Depression</li> <li>• RR variability calculations</li> <li>• Min/Mean/Max QT/QTc</li> <li>• User-defined episodes (3)</li> </ul>

## Heart Rate Calculation

- Minimum and Maximum HR are calculated in a sliding window of 7.5-second intervals
- Mean HR is calculated on all beats within the time period (hourly, 5-minutes, 24-hours, etc.)

The analysis program calculates a heart rate for every beat based on the RR intervals in a 7.5-second window centered around the beat with a two interval minimum. The minimum and maximum (current) heart rate is then calculated using these heart rates in the defined profile period (e.g. one hour). The Vision Express heart rate measurement range is 20 to 300 BPM.

Minimum and maximum heart rates consider all beats with a valid RR, unless configured to exclude RR intervals greater than the user-defined pause duration. The analysis program can also be configured to use only normal beats (Normal to Normal intervals) for heart rate calculation.

Mean heart rate is calculated on all beats with a valid RR interval within the recording period. This calculation can also be configured to use all beats or only normal beats.

There are two settings in the user defined Scan Criteria window that will affect heart rate calculation:

- 1) [Pause] Normal to Normal Only and 2) Exclude Pause from HR.



A pause is declared when the RR interval is greater than the user defined pause duration in the Scan Criteria window.



The heart rate RMS % error, as measured according to EC57 for the AHA, MIT-BIH and the Noise Stress Test databases are 2.69, 1.72 and 41.53 % respectively.

## Atrial Fibrillation Detection

Atrial fibrillation episode detection is based on RR interval variability and p-wave analysis. Due to the nature of atrial fibrillation, detection is performed on episodes rather than beat-by-beat. The analysis program first divides the ECG into short sections of beats to compute the amount of variation in the RR interval of all beats with a normal morphology and the probability of P-wave presence prior to the QRS. When a criteria threshold is reached, the presence of atrial fibrillation is declared at the time of onset is established. Periods of artifact that occur within an atrial fibrillation episode will be considered to have the same average heart rate and will be included in the duration of the atrial fibrillation event.

In the interest of a high specificity, short (less than a minute) episodes of atrial fibrillation may not be seen by the automatic algorithm. These clinically less important episodes may be added by the user when encountered, usually during the review of supraventricular beats.

Regular (non-chaotic) variability, such as that which can be generated by occasional periods of supraventricular runs with regular rate or atrial flutter with constant AV-conduction, is specifically excluded by the detection algorithm. Irregular rhythm caused by sinus arrhythmia or frequent ectopic beats is also excluded in lieu of the presence of a P-wave in all or the majority of beats.

The analysis program does not automatically detect atrial flutter episodes which tend to present a regular rhythm that is not chaotic or random, as well as a “P-wave” (flutter wave) correlated with the QRS complex. This episode type can be manually classified by the analyst by applying a user-defined event.

The percent of atrial fibrillation is summarized hourly and for the entire recording. An Atrial Fibrillation peak average heart rate value in the summary statistics reports the highest averaged heart rate of all of the atrial fibrillation episodes. This result may be useful when intermittent periods of atrial fibrillation are present.

	MIT-BIH Database
<i>Performance Measures</i>	<b>Welch Allyn</b>
Episode Sensitivity %	74
Episode Positive Predictivity %	76
Duration Sensitivity %	94
Duration Positive Predictivity %	78
Duration False Positive %	N/A
	NST Database
<i>Performance Measures</i>	<b>Welch Allyn</b>
Episode Sensitivity %	N/A
Episode Positive Predictivity %	0
Duration Sensitivity %	N/A
Duration Positive Predictivity %	0
Duration False Positive %	12.9

Performance has also been measured on the Physionet AFDB database (<https://physionet.org/physiobank/database/afdb/>), a database specifically collected to test the performance of atrial fibrillation algorithms. Results are as follows:

	AFDB Database
<i>Performance Measures</i>	<b>Welch Allyn</b>
Episode Sensitivity %	49
Episode Positive Predictivity %	95
Duration Sensitivity %	92
Duration Positive Predictivity %	99
Duration False Positive %	N/A

The AFDB database has also been used in a comparative study, using a slightly different way of measuring performance. The VERITAS results measured in the same way testifies the high specificity of the algorithm and are reported in the table below.

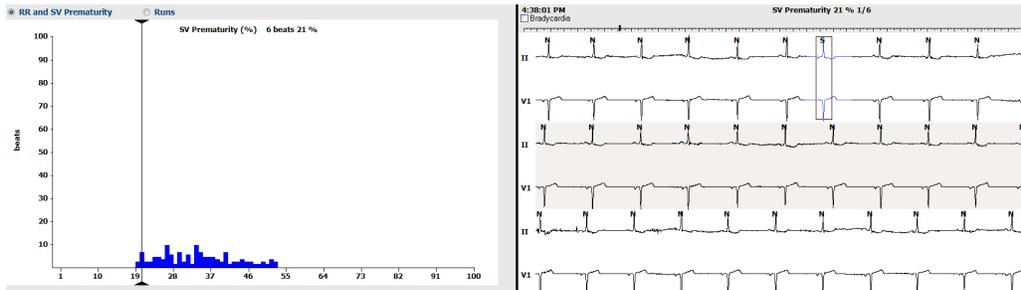
### Comparison with 2011 Comparative Study

Algorithm	Method	Se (%)	Sp (%)	PPV (%)	Err (%)
<b>VERITAS</b>	<b>RRI, AA</b>	<b>91.26</b>	<b>99.48</b>	<b>99.31</b>	<b>4.21</b>
Moody et al.	RRI	87.54	95.14	92.29	7.88
Logan et al.	RRI	87.30	90.31	85.72	10.89
Linker et al.	RRI	97.64	85.55	81.81	9.61
Tatento et al.	RRI	91.20	96.08	90.32	5.32
Cerutti et al.	RRI	96.10	81.55	75.76	16.62
Slocum et al.	AA	62.80	77.46	64.90	28.39
Schmidt et al.	RRI, AA	89.20	94.58	91.62	7.57
Babaeizadeh et al.	RRI, AA	87.27	95.47	92.75	7.80
Couciero et al.	RRI, AA	96.58	82.66	78.76	11.77

Larburu N, Lopetegi T, Romero I, "Comparative Study of Algorithms for Atrial Fibrillation Detection," *Comp. in Cardiol.* 2011; 38: 265-8. RRI = RR Interval; AA = Atrial Activity

## Supraventricular Beat Identification

Supraventricular beats are shaped the same as normal beats, unless they are aberrantly conducted, and are included within the Normal templates and the Normal template group or the Supraventricular template group when the user has enabled it. The SV Prematurity (%) Histogram presents a graph of beats according to prematurity %. This offers a way to locate, review, and adjust prematurity percentage as needed.



The SV Prematurity % value is adjusted through selection of the menu bar Edit and Scan Criteria dialog. The clinician can change the SVPB prematurity percent to adjust when there are false calls. The default is 25%.

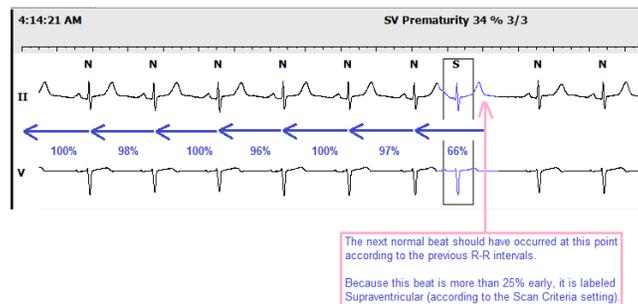
If SVEs are under called, the value can be decreased (20%, 15%, etc.).

If SV beats are overcalled, increase the value (30%, 40%, etc.).

The entire Holter recording is updated immediately after a change to the prematurity % value is made and the OK button is selected.



**Supraventricular Prematurity Calculation:** Supraventricular beat identification is based on the average R-to-R intervals from the previous Normal beats. Each beat is associated with an envelope of 16 preceding normal R-R intervals as demonstrated in the example below.



The Supraventricular Template group, when enabled, and Supraventricular Ectopy columns within in the Profile tab and the Rhythm section are also helpful to quickly navigate to the system identified rhythm events.

**Note:** When a run of SVT approaches or exceeds 16 consecutive beats, the prematurity of the next R-R interval is likely to approach zero, since it is calculated compared to the previous 16 R-R intervals. Therefore, the next beat will be labeled normal (N) and the run is ended. In this case, the clinician may edit the beats of a long run when continuation of the run is determined. If, during a run of SVT, the next R-R interval is less than 400 ms (rate is greater than 150 bpm), it is always labeled supraventricular (S) independent of prematurity and the run is not ended.

## ST Segment Analysis

During analysis, a per-beat measurement of ST level is determined at 60 msec post J for each “normal” beat. ST episode detection is performed by first processing all beats and then averaging the beat ST levels for each channel, excluding aVR, for each five-minute period in the recording.

An ST episode in a channel is found when the user-configured threshold is reached AND a 100  $\mu\text{V}$  step occurred within one hour before the threshold was crossed, using the five-minute averages. Subsequently, the precise channel onset of the episode is found by determining where the individual beat measurements crossed the threshold. If a channel onset is found for more than one channel, the earliest of the channel onsets is used as the episode onset. Starting from the episode onset, the next twelve five-minute episodes (one hour) are evaluated for being below the threshold or showing a 100  $\mu\text{V}$  step back. If the sum of these episodes in the next hour reaches a threshold, meaning that the ST-level has come back consistently, the offset of the episode is declared. This is done on all the channels where an onset was found, and the offset of the episode is determined where the last channel offset was found. The same process is then repeated backward in time, that is, from the last five-minute episode in the recording to the first, interchanging the offset and onset. Lastly, the ST-episodes found in the forward process are merged with those found in the backward process.

The same process is used for ST-depression and ST-elevation.

For each ST episode, the maximum ST values for each channel are calculated and the time at which each occurred is saved. The channel with the largest ST (average) value is labeled as the Primary channel, and the time of its maximum value is declared as the event time of the episode. The average ST value for each channel is calculated.

The ST-segment analysis performance of the VERITAS algorithm has been tested on the European STT database according to EC57. The results are depicted in the table below

	STT Database
<i>Performance Measures</i>	<b>Welch Allyn</b>
Discrepant measurements >100 $\mu\text{V}$ %	7.3
Discrepant measurements >150 $\mu\text{V}$ %	2.2
Discrepant measurements >200 $\mu\text{V}$ %	0.8
Mean absolute error $\mu\text{V}$	49.1
Mean error $\mu\text{V}$	8.5
Standard deviation $\mu\text{V}$	66.1

## QT/QTc Analysis

QT interval evaluation may be beneficial in detection of abnormal prolongation due to drug effects, electrolyte imbalance or genetic diseases, in order to evaluate the risk of serious ventricular arrhythmias that can lead to sudden cardiac death. The VERITAS™ algorithm automatically determines the QT from the interval between the earliest ventricular depolarization activity and the latest “end-of-T” point. This determination utilizes average beats as templates to reduce the effects of noise, but the actual QT interval determination is made on each single beat.

Each single QT value is corrected for previous heart rate (RR-intervals) by one of three formula's chosen by the user: Welch Allyn Linear, Bazett or Fridericia. These formulae correct the QT value for heart rates that differ from 60 bpm (RR intervals of 1 second). The following formulae are used where HR is expressed in beats per minute and QT, QTc and RR are expressed in seconds:

- Welch Allyn Linear:  $QTcL = QT + (1-RR)*S$  (See Note below)
- Bazett:  $QTcB = QT (HR/60)^{1/2} = QT (RR)^{-1/2}$
- Fridericia:  $QTcF = QT (HR/60)^{1/3} = QT (RR)^{-1/3}$

There are three user selectable choices for the RR intervals to be used for QTc calculation:

RRprior	The previous RR interval in seconds; this method shows the immediate effect of the RR interval on the next QT value.
RR16	The sum of the previous 16 RR intervals; this method is most similar to how the QTc is calculated on a 10 second resting ECG.
RRc	A weighted average of the past 256 RR intervals; this method provides the optimal QT-RR correction according to current scientific insight, and is preferred for routine use.

Note: S is 0.143 (=1/7) if RRprior or RR16 is used and is 0.22 if RRc is used.

The use of RRc for QT correction in the ambulatory environment is recommended. The duration of the QT interval is influenced not only by the previous RR-interval, but depends on the history of the heart rate. This is also called QT-RR hysteresis. RRc takes this history into account. The weighting factors used have been calibrated to obtain the best average correction in a wide range of subjects and heart rate histories. It was found that the population average slope of the QT-RR relationship was higher than the traditional "Framingham" value when RRc was used, ranging from 0.19 in a young healthy population to 0.24 in a heart failure population. It should be noted, however, that significant individual differences exist.

The Vision Express analysis program calculates an average QT and QTc duration in milliseconds of the normal beats in a 30-second window, centered on the time of interest. The Maximum, Minimum and Mean 30 second averages within a profile episode are displayed. The measurement of reliable QT/QTc values during ambulatory monitoring can be challenging and is dependent on recording quality. Proper assessment of periods of noise and the patient's ECG features are essential for correlation with any QT/QTc changes.

## Time Domain RR Variability Calculation

During normal sinus rhythm, the heart rate varies from beat to beat. Heart rate variability, also known as RR variability, results from the dynamic interplay between the multiple physiologic mechanisms that regulate the spontaneous heart rate. Since short-term heart rate regulation is predominantly governed by sympathetic and parasympathetic neural activity, examination of heart rate fluctuations provides a window to observe the state and integrity of the autonomic nervous system.

Intervals used for RR variability calculations are those where the current, previous and second previous beats are Normal. The user may configure the program to use both Normal and Supraventricular beats. Intervals within an atrial fibrillation episode are excluded from analysis.

The Vision Express RR Variability program calculates the following intervals in 5-minute periods from the start time of the Holter recording to the end: RMS SD, SDANN, SDNN index, and pNN50.

RMS SD, SDNN index, and pNN50 are calculated using all qualifying 5-minute intervals over the period of interest. In determining hour-by-hour statistics the program uses all qualifying 5-minute intervals for its analysis.

The HRV Triangular Index is calculated on the total number of RR intervals within the time period.

The SDANN value is calculated over a 24-hour period.

The following table contains definitions for each RR variability calculation:

pNN50	The percentage of Successive Differences in RR values greater than 50 ms (independent of sign) during the time period.
RMS SD	Root Mean Square of the Successive Differences in RR values during the time period.
SDNN index	The average of five minute period standard deviations of the RR intervals during the time period. Valid five minute periods are those that have at least two valid RR intervals. Also referred to as Magid SD.
SDANN	Standard Deviation of all five minute average RR intervals during a 24-hour period. Valid five-minute periods are those that have at least two valid RR intervals. Also referred to as Kleiger SD.
HRV Triangular Index	Total number of RR intervals during the time period divided by the height of the histogram of all RR intervals measured on a discrete scale with bins of 7.8125 ms.

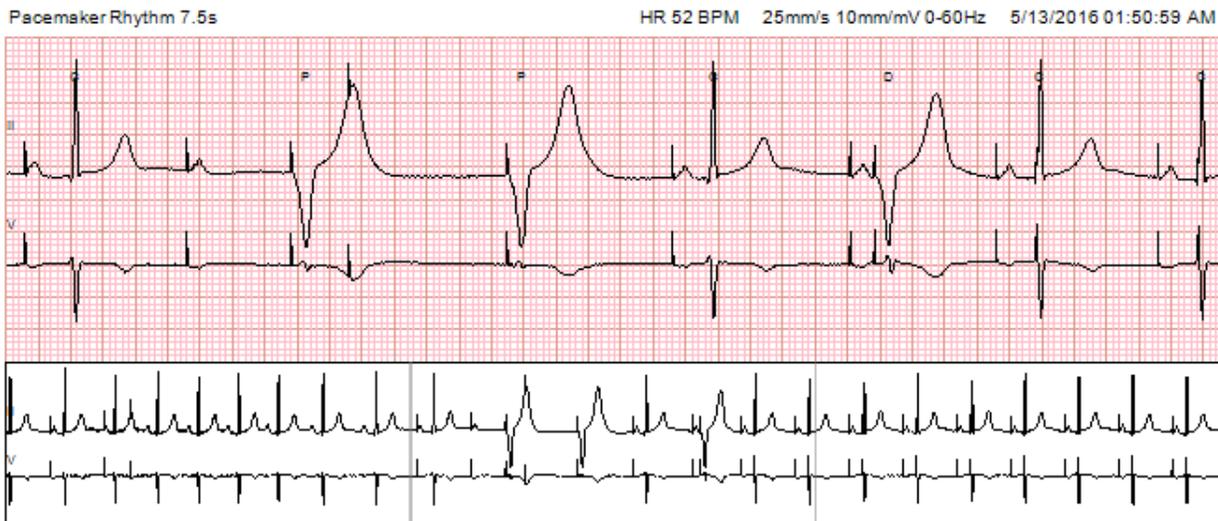
RR variability standard deviation, plotted as “Std” under the Trend tab and printed on the final report trend page is calculated using each 5-minute period representing the standard deviation of all RR intervals within the 5-minute period. This presents a statistical formula for variation.

The measurement of reliable RR variability calculations during ambulatory monitoring can be challenging and is dependent on recording quality. Proper assessment of periods of noise and the patient’s ECG features are essential for correlation with any RR variability changes.

## Pacemaker Analysis

Pacemaker spikes are identified independently for each channel. Spikes that occur in channels with lead fail are ignored.

When pacemaker detection is enabled and pacing has been detected by the Holter analysis system, a spike marker at 500  $\mu$ V amplitude will be present in the displayed waveform and in the final report ECG strips.



The analysis program will declare a beat is Atrial paced when the beat is normal and the pacer spike is within 250 to 125 msec before the beat detection point in any channel. Ventricular paced beats will be declared when the beat is paced and a pacemaker spike is within 60 msec before the beat detection point. Dual paced beats are declared when atrial and ventricular spikes are successive, the atrial spike is at least 60 msec before the ventricular spike and the beat is identified as paced.

Pacemaker failures are identified as follows:

- Capture failure: a beat is not present after the pacer spike with an interval greater than 300 msec.
- Undersense: Pacer spike is earlier than expected and is less than one-third the time from its preceding beat.
- Oversense: The RR interval is greater than 1.2 times the expected paced interval after the beat; the minimum pacemaker rate is used to determine the expected paced interval.

# FINAL REPORTS

## Condensed Report Patient Information with Summary Statistics

The first report page contains patient demographic information, recording information, personnel information, summary statistical with tabular totals for recording events, and conclusions with an optional electronic signature with date signed. Scan criteria used for the recording is located at the bottom of the page. Institution contact information and a logo are customized by the administrative user.

<b>HOLTER REPORT</b>	Children's Clinic 8765 N 86th Street Milwaukee, WI 53224 800-344-7823				
<b>Name:</b> Doe ,Jane <b>Recording Start Date/Time:</b> 1/17/2018 08:07:00 AM					
<b>ID:</b> 486783 <b>Secondary ID:</b> 634-45-3643 <b>Admission ID:</b> 1000567834 <b>Date Of Birth:</b> 10/15/2001 <b>Age:</b> 15.Years <b>Gender:</b> Female <b>Race:</b> Caucasian					
<b>Date Processed:</b> 1/19/2018 <b>Referring Physician:</b> Dr. M. Ray <b>Technician:</b> Mary Adamson, CCVT <b>Procedure Type:</b> 24-Hour Holter <b>Analyst:</b> H. Franks, RN <b>Recorder No:</b> 0					
<b>Indications:</b> palpitations heart hx <b>Medications:</b> None					
<b>Summary Statistics</b>					
<b>ALL BEATS</b> Total QR S: 108430 Normal Beats: 105040 (99%)  Original Duration: 24 hr 1 min Recording Duration: 24 hr 0 min Analyzed Duration: 24 hr 0 min Artifact Duration: 0:00:05	<b>VENTRICULAR ECTOPY</b> Ventricular Beats: 1377 (1%) Singlets: 1370 Couplets: 2 Runs: 1 Fastest Run: 136 at 10:39:10 AM Slowest Run: 136 at 10:39:10 AM Longest Run: 3 at 10:39:10 AM R on T Beats: 0 Interpolated Beats: 0 Escape Beats: 0 VE/1000: 12 Average VE/Hour: 57 <b>VENTRICULAR RHYTHM</b> Ventricular Tachycardia: 1 Bigeminy Episodes: 0 Bigeminy Beats: 0 Bigeminy Duration: 0:00:00 Trigeminy Episodes: 21 Trigeminy Beats: 347 Trigeminy Duration: 0:04:21	<b>SUPRAVENTRICULAR ECTOPY</b> Supraventricular Beats: 13 (<1%) Aberrant Beats: 0 Singlets: 8 Pairs: 0 Runs: 1 Fastest Run: 152 at 12:56:53 PM Slowest Run: 152 at 12:56:53 PM Longest Run: 5 at 12:56:53 PM SVE/1000: 0 Average SVE/Hour: 0 <b>SUPRAVENTRICULAR RHYTHM</b> Supraventricular Tachycardia: 1 Bigeminy Episodes: 0 Bigeminy Beats: 0 Bigeminy Duration: 0:00:00 Trigeminy Episodes: 0 Trigeminy Beats: 0 Trigeminy Duration: 0:00:00			
<b>HEART RATE EPISODES</b> Minimum HR: 51 BPM at 04:22:04 AM Maximum HR: 146 BPM at 08:02:32 PM Average HR: 78 BPM  Longest Tachycardia: 1:09:10, 102 BPMAvg at 06:57:49 AM Fastest Tachycardia: 0:47:11, 124 BPMAvg at 07:33:07 PM Longest Bradycardia: 0:43:06, 59 BPMAvg at 01:19:32 AM Slowest Bradycardia: 0:01:09, 57 BPMAvg at 02:16:58 AM	<b>PAUSES (All Beats)</b> Pauses > 2000 ms: 0 Longest RR: 1.5 s at 01:13:42 AM	Atrial Paced Beats (%): 0 (0%) Vent. Paced Beats (%): 0 (0%) Dual Paced Beats (%): 0 (0%)  Atrial Fib Percent: 0 Atrial Fib Peak Rate: ---			
<b>Conclusions:</b> Essentially normal Holter study with rare supraventricular and occasional ventricular ectopy occurring throughout the recording. Patient was symptomatic with palpitations during the ventricular events. Recommend follow up in 1 year.					
<b>Reviewed by:</b> Nancy Harding, RN		<b>Signed by:</b> Dr. A. Herschel			
<b>Date:</b> 1/24/2018					
<table border="1" style="width: 100%; border-collapse: collapse; font-size: small;"> <tr> <td style="width: 33%;"> <b>Scan Criteria</b>                      Min/Max Heart Rate: All Beats                      Pause Episodes: No                      Pauses: All Beats                      Pauses &gt; 2000 ms                 </td> <td style="width: 33%;">                     Tachycardia: &gt; 100 BPM                      Bradycardia: &lt; 50 BPM                      Tachy/Brad Duration: &gt; 0:01:00                      SVE Prematurity: 25%                 </td> <td style="width: 33%;">                     Vent. Rate: &gt; 100 BPM Beats: &gt; 3                      Supravent. Rate: &gt; 100 BPM Beats: &gt; 3                      Pacemaker Analysis: No                      Automatically Detect Atrial Fibrillation: Yes                 </td> </tr> </table>			<b>Scan Criteria</b> Min/Max Heart Rate: All Beats Pause Episodes: No Pauses: All Beats Pauses > 2000 ms	Tachycardia: > 100 BPM Bradycardia: < 50 BPM Tachy/Brad Duration: > 0:01:00 SVE Prematurity: 25%	Vent. Rate: > 100 BPM Beats: > 3 Supravent. Rate: > 100 BPM Beats: > 3 Pacemaker Analysis: No Automatically Detect Atrial Fibrillation: Yes
<b>Scan Criteria</b> Min/Max Heart Rate: All Beats Pause Episodes: No Pauses: All Beats Pauses > 2000 ms	Tachycardia: > 100 BPM Bradycardia: < 50 BPM Tachy/Brad Duration: > 0:01:00 SVE Prematurity: 25%	Vent. Rate: > 100 BPM Beats: > 3 Supravent. Rate: > 100 BPM Beats: > 3 Pacemaker Analysis: No Automatically Detect Atrial Fibrillation: Yes			
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## Standard Report Patient Information

The first report page contains patient demographic information, recording information, personnel information and conclusions with an optional electronic signature with date signed. Institution contact information and a logo are customized by the administrative user. The layout of this page and the fields included can be customized by Welch Allyn Customer Service.

<b>HOLTER REPORT</b>	St. Joseph's Clinic 23 W. 45th St., Milwaukee WI 53223 1-414-567-8901	
<b>Name:</b> 48H Sample ,Report		
<b>Recording Start Date/Time:</b> 6/21/2016 01:36:27 PM		
<b>ID:</b> 483924	<b>Secondary ID:</b> 583-66-2834	<b>Admission ID:</b> 1000986
<b>Date Of Birth:</b> 5/18/1948	<b>Age:</b> 68 Years	<b>Gender:</b> Male
		<b>Race:</b> Caucasian
<b>Indications:</b> Palpitations		
<b>Medications:</b> Antihypertensive, Diuretics, Beta Blockers, None		
<b>Referring Physician:</b> Dr. A. West		<b>Location:</b> Exam Room 6
<b>Procedure Type:</b> 48-Hour Holter		
<b>Date Processed:</b> 6/24/2016	<b>Recording Duration:</b>	
<b>Technician:</b> Tech 2	<b>Recorder:</b> H3+	
<b>Analyst:</b> Wanda Wright, CCVT	<b>Recorder No:</b> 114320224256	
<b>Diagnosis:</b> Abnormalities of heart beat		<b>Notes:</b> Patient did not keep a diary.
<b>Conclusions:</b> No significant episodes of ST segment change, tachycardia or bradycardia events, or ectopic runs or patterns. Rare ventricular and supraventricular ectopic beats all occurring isolated. Normal 48-hour Holter study.		
<b>Reviewed by:</b> John Fernandez, PA		
Electronically Signed by: <u>Dr. R. Everson</u>		
<b>Date:</b> 6/27/2016		
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## Standard Report Summary Statistics

The summary statistical page consists of scan criteria used for the recording at the top of the page and tabular totals for recording events. Page number and page type are printed on this and every following page.

483924		48H Sample, Report, Male, 68 Years, DOB: 5/18/1948		Page 2	
6/21/2016 01:36:27 PM				Summary Statistics	
<u>Scan Criteria</u>					
Min/Max Heart Rate: All Beats Pause Excluded: No		Tachycardia: > 120 BPM Bradycardia: < 50 BPM Tachy/Brady Duration: > 0:01:00		QTc Formula: Linear QTc RR: RRc	
Pauses: All Beats Pauses > 2000 ms		SVPB Prematurity: 25%		ST Segment Elevation (uV): 200 ST Segment Depression (uV): 100	
RR Variability: Normal		Vent. Rate: > 100 BPM Beats: > 3 Supravent. Rate: > 100 BPM Beats: > 3		Pacemaker Analysis: No Automatically Detect Atrial Fibrillation: Yes	
<u>Summary Statistics</u>					
<b>ALL BEATS</b> Total QRs: 175214 Normal Beats: 175185 Unknown Beats: 0 BBB Beats: 0 Fusion Beats: 0 Supraventricular Beats: 13  Original Duration: 48 hr 0 min Recording Duration: 48 hr 0 min Analyzed Duration: 48 hr 0 min Artifact Duration: 0:00:08		<b>VENTRICULAR ECTOPY</b> Ventricular Beats: 16 Singlets: 16 Couplets: 0 Runs: 0 Fastest Run: --- at --- Slowest Run: --- at --- Longest Run: --- at --- R on T Beats: 0 Interpolated Beats: 0 Escape Beats: 0 VE/1000: 0 Average VE/Hour: 0		<b>SUPRAVENTRICULAR ECTOPY</b> Prematurity: 25% Supraventricular Beats: 13 Aberrant Beats: 0 Singlets: 13 Pairs: 0 Runs: 0 Fastest Run: --- at --- Slowest Run: --- at --- Longest Run: --- at --- SVE/1000: 0 Average SVE/Hour: 0	
<b>HEART RATE EPISODES</b> Min/Max Heart Rate: All Beats Pause Excluded: No Minimum HR: 45 BPM at 01:34:59 AM Maximum HR: 115 BPM at 07:29:56 AM(2) Average HR: 61 BPM Tachycardia: > 120 BPM Bradycardia: < 50 BPM Tachy/Brady Duration: > 0:01:00 Longest Tachycardia: ---, --- BPM Avg at --- Fastest Tachycardia: ---, --- BPM Avg at --- Longest Bradycardia: 0:18:02, 49 BPM Avg at 04:00:21 AM Slowest Bradycardia: 0:15:56, 49 BPM Avg at 01:54:07 AM		<b>VENTRICULAR RHYTHM</b> Ventricular Tachycardia: 0 Vent. Rate: > 100 BPM Beats: > 3 Bigeminy Episodes: 0 Bigeminy Beats: 0 Bigeminy Duration: 0:00:00 Trigeminy Episodes: 0 Trigeminy Beats: 0 Trigeminy Duration: 0:00:00		<b>SUPRAVENTRICULAR RHYTHM</b> Supraventricular Tachycardia: 0 Supravent. Rate: > 100 BPM Beats: > 3 Bigeminy Episodes: 0 Bigeminy Beats: 0 Bigeminy Duration: 0:00:00 Trigeminy Episodes: 0 Trigeminy Beats: 0 Trigeminy Duration: 0:00:00  Atrial Fib Percent: 0 Atrial Fib Peak Rate: ---	
<b>PAUSES (All Beats)</b> Pauses > 2000 ms: 0 Longest RR: 1.4 s at 01:35:01 AM		<b>PACED</b> Atrial Paced Beats (%): 0 (0%) Vent. Paced Beats (%): 0 (0%) Dual Paced Beats (%): 0 (0%)		<b>OTHER RHYTHM EPISODES</b> Atrial Flutter: --- (---%) Wide QRS Rhythm: --- (---%) Exercising: --- (---%)	
<b>RR Variability (Normal)</b> pNN50: 13(1); 10(2)% RMSSD: 38(1); 33(2) ms SDNN: 144(1); 131(2) ms SDNN Index: 69(1); 65(2) ms SDANN: 118(1); 108(2) ms Triangular Index: 41(1); 37(2) ms		<b>QT ANALYSIS (QTc Formula: Linear; QTc RR: RRc)</b> Minimum QT: 340 ms at 07:28:08 PM(2) Maximum QT: 459 ms at 04:03:28 AM Average QT: 411 ms Minimum QTc: 388 ms at 11:16:18 AM Maximum QTc: 489 ms at 06:30:13 PM Average QTc: 415 ms			
<b>ST ELEVATION (uV) Value/Time</b> C1 38 / 10:26:27 PM C2 (+) 94 / 01:01:27 AM		<b>ST DEPRESSION (uV) Value/Time</b> C1 (-) -98 / 07:26:27 PM(2) C2 -12 / 07:26:27 PM(2)			
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## Narrative Summary

The narrative page repeats the tabular information in a narrative fashion. This page can be customized through use of the Report Configuration Tool.

483924	48H Sample, Report, Male, 68 Years, DOB: 5/18/1948	Page 3
6/21/2016 01:36:27 PM		Narrative Summary
<p>The monitoring started at 01:36:27 PM and was continued for 48 hr 0 min. The total number of beats was 175214 with a total analysis duration of 48 hr 0 min. The average heart rate was 61 BPM, with the minimum rate, 45 BPM, occurring at 01:34:59 AM, and the maximum rate, 115 BPM, occurring at 07:29:56 AM(2).</p>		
<p>The longest episode of bradycardia was detected with an onset at 04:00:21 AM, duration of 0:18:02 and a heart rate of 49 BPM. The slowest episode of bradycardia was detected with an onset at 01:54:07 AM, duration of 0:15:56 and a heart rate of 49 BPM.</p>		
<p>The longest episode of tachycardia was detected with an onset at ---, duration of --- and a heart rate of --- BPM. The fastest episode of tachycardia was detected with an onset at ---, duration of --- and a heart rate of --- BPM.</p>		
<p>Atrial fibrillation was detected for 0:00:00 of the monitoring period with a total of 0%. The peak average heart rate during atrial fibrillation was --- BPM.</p>		
<p>Supraventricular ectopic activity consisted of 13 beats, which included 13 single beats, 0 pairs, and 0 runs of 3 beats or longer. There were 0 supraventricular bigeminy episodes and 0 supraventricular trigeminy episodes. The SVE/hour was 0 and SVE/1000 was 0.</p>		
<p>The fastest supraventricular run had a rate of --- BPM and occurred at ---. The longest run was --- beats long and occurred at ---. There were 0 episodes of supraventricular tachycardia.</p>		
<p>Ventricular pacing was detected for 0 beats, which is 0% of the total; atrial pacing was detected for 0 beats, which is 0% of the total; dual pacing was detected for 0 beats, which is 0% of the total.</p>		
<p>Ventricular ectopic activity consisted of 16 beats, which included 16 single beats, 0 couplets, 0 R on T events, and 0 runs of 3 beats or longer. There were 0 ventricular bigeminy episodes and 0 ventricular trigeminy episodes. The VE/hour was 0 and VE/1000 was 0.</p>		
<p>The fastest ventricular run had a rate of --- BPM and occurred at ---. The slowest ventricular run had a rate of --- BPM and occurred at ---. The longest run was --- beats long and occurred at ---. There were 0 episodes of ventricular tachycardia.</p>		
<p>The longest R-R interval was 1388 milliseconds at 01:35:01 AM, with 0 R-R intervals longer than 2000 milliseconds.</p>		
<p>The R-R variability measures were: pNN50 of 13(1); 10(2)%, RMSSD of 36(1); 33(2) ms, SDNN Index of 69(1); 65(2) ms, SDNN of 144(1); 131(2) ms, and Triangular Index of 41(1); 37(2) ms.</p>		
<p>The maximum ST Depression of -98 uV was detected in lead C1 at 07:26:27 PM(2), and the maximum ST elevation of 94 uV was detected in lead C2 at 01:01:27 AM.</p>		
<p>The average QT was 411 ms, with a maximum QT of 459 ms occurring at 04:03:28 AM and a minimum QT of 340 ms occurring at 07:26:06 PM(2). The average QTc (Linear, using RRc) was 415 ms, with a maximum QTc of 469 ms occurring at 06:30:13 PM and a minimum QTc of 388 ms occurring at 11:16:18 AM.</p>		
<p>Atrial Flutter was identified for ---% of the recording with a total number of --- beats. Wide QRS Rhythm was identified for ---% of the recording with a total number of --- beats. Exercising was identified for ---% of the recording with a total number of --- beats.</p>		
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# Profiles

Profile pages provide hour-by-hour statistics with a summary of the entire recording in the bottom row. Up to 48 hourly periods are consecutively reported.

483924 48H Sample, Report, Male, 68 Years, DOB: 5/18/1948 Page 4  
6/21/2016 01:36:27 PM Profiles

**RHYTHM PROFILE: GENERAL PERIODIC SUMMARY**

Period Start	Total Beats	Diary Events	Heart Rate			Pauses		JT		User Defined		
			Min	Mean	Max	Max RR	Total	Dep	Elev	1	2	3
13:36:27	3592	0	54	65	102	1.14	0	-34	70	-	-	-
14:36:27	3708	0	53	62	84	1.18	0	1	74	-	-	-
15:36:27	3499	0	50	58	81	1.33	0	-21	83	-	-	-
16:36:27	3516	0	50	59	85	1.24	0	-22	72	-	-	-
17:36:27	3500	0	50	65	103	1.24	0	-54	57	-	-	-
18:36:27	3593	0	53	65	89	1.15	0	-31	69	-	-	-
19:36:27	3504	0	51	58	83	1.21	0	-31	71	-	-	-
20:36:27	3408	0	50	57	71	1.24	0	2	75	-	-	-
21:36:27	3399	0	48	57	92	1.28	0	-25	72	-	-	-
22:36:27	3247	0	49	54	71	1.25	0	18	70	-	-	-
23:36:27	3384	0	50	55	76	1.24	0	1	84	-	-	-
00:36:27	3115	0	45									
01:36:27	3048	0	46									
02:36:27	3201	0	45									
03:36:27	3033	0	46									
04:36:27	3149	0	45									
05:36:27	4055	0	48									
06:36:27	4197	0	53									
07:36:27	4186	0	55									
08:36:27	3879	0	52									
09:36:27	3800	0	50									
10:36:27	3640	0	51									
11:36:27	3544	0	45									
12:36:27	3536	0	52									
13:36:27(2)	3359	0	51									
14:36:27(2)	3336	0	51									
15:36:27(2)	3339	0	48									
16:36:27(2)	3411	0	48									
17:36:27(2)	3306	0	51									
18:36:27(2)	4326	0	54									
19:36:27(2)	3912	0	56									
20:36:27(2)	2956	0	54									
21:36:27(2)	3725	0	51									
22:36:27(2)	3179	0	46									
23:36:27(2)	3481	0	52									
00:36:27(2)	3467	0	51									
01:36:27(2)	3403	0	50									
02:36:27(2)	3390	0	51									
03:36:27(2)	3433	0	47									
04:36:27(2)	3317	0	49									
05:36:27(2)	4128	0	50									
06:36:27(2)	4325	0	54									
07:36:27(2)	4237	0	58									
08:36:27(2)	4071	0	57									
09:36:27(2)	3757	0	53									
10:36:27(2)	3439	0	48									
11:36:27(2)	3842	0	49									
12:36:27(2)	4104	0	50									
Summary	175214	0	46									

483924 48H Sample, Report, Male, 68 Years, DOB: 5/18/1948 Page 5  
6/21/2016 01:36:27 PM Profiles

**RHYTHM PROFILE: SUPRAVENTRICULAR PERIODIC SUMMARY**

Period Start	Diary Events	Heart Rate			Supraventricular Ectopy			Supraventricular Rhythm							
		Min	Mean	Max	Run Length			Total	Tachy (#)	Big (#)	Trig (#)	Aber (#)	BBB (#)	AFib (%)	
					1	2	3+								Max Run
13:36:27	0	54	65	102	0	0	0	0	0	0	0	0	0	0	-
14:36:27	0	53	62	84	0	0	0	0	0	0	0	0	0	0	-
15:36:27	0	50	58	81	0	0	0	0	0	0	0	0	0	0	-
16:36:27	0	50	59	85	1	0	0	0	1	0	0	0	0	0	-
17:36:27	0	50	65	103	0	0	0	0	0	0	0	0	0	0	-
18:36:27	0	53	65	89	0	0	0	0	0	0	0	0	0	0	-
19:36:27	0	51	58	83	0	0	0	0	0	0	0	0	0	0	-
20:36:27	0	50	57	71	0	0	0	0	0	0	0	0	0	0	-
21:36:27	0	48	57	92	3	0	0	0	3	0	0	0	0	0	-
22:36:27	0	49	54	71	0	0	0	0	0	0	0	0	0	0	-
23:36:27	0	50	55	76	0	0	0	0	0	0	0	0	0	0	-
00:36:27	0	45	52	72	1	0	0	0	1	0	0	0	0	0	-
01:36:27	0	46	51	76	0	0	0	0	0	0	0	0	0	0	-
02:36:27	0	45	53	76	0	0	0	0	0	0	0	0	0	0	-
03:36:27	0	46	51	75	0	0	0	0	0	0	0	0	0	0	-
04:36:27	0	45	52	75	0	0	0	0	0	0	0	0	0	0	-
05:36:27	0	48	58	107	0	0	0	0	0	0	0	0	0	0	-
06:36:27	0	53	70	103	3	0	0	0	3	0	0	0	0	0	-
07:36:27	0	55	70	105	0	0	0	0	0	0	0	0	0	0	-
08:36:27	0	52	65	94	0	0	0	0	0	0	0	0	0	0	-
09:36:27	0	50	63	92	0	0	0	0	0	0	0	0	0	0	-
10:36:27	0	51	61	84	1	0	0	0	1	0	0	0	0	0	-
11:36:27	0	45	59	89	0	0	0	0	0	0	0	0	0	0	-
12:36:27	0	52	59	77	1	0	0	0	1	0	0	0	0	0	-
13:36:27(2)	0	51	61	93	0	0	0	0	0	0	0	0	0	0	-
14:36:27(2)	0	51	61	90	0	0	0	0	0	0	0	0	0	0	-
15:36:27(2)	0	48	56	78	0	0	0	0	0	0	0	0	0	0	-
16:36:27(2)	0	48	57	89	0	0	0	0	0	0	0	0	0	0	-
17:36:27(2)	0	51	63	94	0	0	0	0	0	0	0	0	0	0	-
18:36:27(2)	0	54	72	100	0	0	0	0	0	0	0	0	0	0	-
19:36:27(2)	0	56	65	95	0	0	0	0	0	0	0	0	0	0	-
20:36:27(2)	0	54	67	93	0	0	0	0	0	0	0	0	0	0	-
21:36:27(2)	0	51	62	94	0	0	0	0	0	0	0	0	0	0	-
22:36:27(2)	0	46	53	74	2	0	0	0	2	0	0	0	0	0	-
23:36:27(2)	0	52	58	78	0	0	0	0	0	0	0	0	0	0	-
00:36:27(2)	0	51	58	76	0	0	0	0	0	0	0	0	0	0	-
01:36:27(2)	0	50	57	75	0	0	0	0	0	0	0	0	0	0	-
02:36:27(2)	0	51	57	77	0	0	0	0	0	0	0	0	0	0	-
03:36:27(2)	0	47	57	85	0	0	0	0	0	0	0	0	0	0	-
04:36:27(2)	0	49	55	79	0	0	0	0	0	0	0	0	0	0	-
05:36:27(2)	0	50	69	102	0	0	0	0	0	0	0	0	0	0	-
06:36:27(2)	0	54	72	115	0	0	0	0	0	0	0	0	0	0	-
07:36:27(2)	0	58	71	100	0	0	0	0	0	0	0	0	0	0	-
08:36:27(2)	0	57	68	88	0	0	0	0	0	0	0	0	0	0	-
09:36:27(2)	0	53	63	91	0	0	0	0	0	0	0	0	0	0	-
10:36:27(2)	0	48	57	84	1	0	0	0	1	0	0	0	0	0	-
11:36:27(2)	0	49	64	94	0	0	0	0	0	0	0	0	0	0	-
12:36:27(2)	0	50	65	94	0	0	0	0	0	0	0	0	0	0	-
Summary	0	46	61	115	15	0	0	0	15	0	0	0	0	0	0

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48H Sample, Report, Male, 68 Years, DOB: 5/18/1948

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Profiles

RHYTHM PROFILE: VENTRICULAR PERIODIC SUMMARY

Period Start	Diary Events	Heart Rate			Ventricular Ecology				Ventricular Rhythm							
		Min	Mean	Max	Run Length			Tachy (P)	Big (P)	Triq (P)	RonT (P)	Fusion (P)	Interp (P)	Escape (P)	Unknown (P)	
					1	2	3+									
13:36:27	0	54	66	102	0	0	0	0	0	0	0	0	0	0	0	0
14:36:27	0	53	62	84	0	0	0	0	0	0	0	0	0	0	0	0
15:36:27	0	50	58	81	1	0	0	0	1	0	0	0	0	0	0	0
16:36:27	0	50	59	88	0	0	0	0	0	0	0	0	0	0	0	0
17:36:27	0	50	66	103	0	0	0	0	0	0	0	0	0	0	0	0
18:36:27	0	53	65	89	0	0	0	0	0	0	0	0	0	0	0	0
19:36:27	0	51	64	83	0	0	0	0	0	0	0	0	0	0	0	0
20:36:27	0	50	57	71	0	0	0	0	0	0	0	0	0	0	0	0
21:36:27	0	48	57	92	0	0	0	0	0	0	0	0	0	0	0	0
22:36:27	0	49	54	71	0	0	0	0	0	0	0	0	0	0	0	0
23:36:27	0	50	56	78	0	0	0	0	0	0	0	0	0	0	0	0
00:36:27	0	45	52	72	0	0	0	0	0	0	0	0	0	0	0	0
01:36:27	0	46	51	76	0	0	0	0	0	0	0	0	0	0	0	0
02:36:27	0	45	53	76	0	0	0	0	0	0	0	0	0	0	0	0
03:36:27	0	46	51	75	0	0	0	0	0	0	0	0	0	0	0	0
04:36:27	0	45	52	78	0	0	0	0	0	0	0	0	0	0	0	0
05:36:27	0	48	60	107	2	0	0	0	0	0	0	0	0	0	0	0
06:36:27	0	53	70	103	0	0	0	0	0	0	0	0	0	0	0	0
07:36:27	0	56	70	105	0	0	0	0	0	0	0	0	0	0	0	0
08:36:27	0	52	65	94	0	0	0	0	0	0	0	0	0	0	0	0
09:36:27	0	50	63	92	0	0	0	0	0	0	0	0	0	0	0	0
10:36:27	0	51	61	84	0	0	0	0	0	0	0	0	0	0	0	0
11:36:27	0	45	59	89	0	0	0	0	0	0	0	0	0	0	0	0
12:36:27	0	52	59	77	0	0	0	0	0	0	0	0	0	0	0	0
13:36:27(2)	0	51	61	83	0	0	0	0	0	0	0	0	0	0	0	0
14:36:27(2)	0	51	61	90	0	0	0	0	0	0	0	0	0	0	0	0
15:36:27(2)	0	48	56	78	0	0	0	0	0	0	0	0	0	0	0	0
16:36:27(2)	0	48	57	89	1	0	0	0	0	0	0	0	0	0	0	0
17:36:27(2)	0	51	63	94	5	0	0	0	0	0	0	0	0	0	0	0
18:36:27(2)	0	54	72	100	0	0	0	0	0	0	0	0	0	0	0	0
19:36:27(2)	0	56	65	96	1	0	0	0	0	0	0	0	0	0	0	0
20:36:27(2)	0	54	67	93	5	0	0	0	0	0	0	0	0	0	0	0
21:36:27(2)	0	51	62	94	0	0	0	0	0	0	0	0	0	0	0	0
22:36:27(2)	0	46	53	74	0	0	0	0	0	0	0	0	0	0	0	0
23:36:27(2)	0	52	58	78	0	0	0	0	0	0	0	0	0	0	0	0
00:36:27(2)	0	51	53	76	0	0	0	0	0	0	0	0	0	0	0	0
01:36:27(2)	0	50	57	75	0	0	0	0	0	0	0	0	0	0	0	0
02:36:27(2)	0	51	57	77	0	0	0	0	0	0	0	0	0	0	0	0
03:36:27(2)	0	47	57	85	0	0	0	0	0	0	0	0	0	0	0	0
04:36:27(2)	0	49	55	79	0	0	0	0	0	0	0	0	0	0	0	0
05:36:27(2)	0	50	59	102	0	0	0	0	0	0	0	0	0	0	0	0
06:36:27(2)	0	54	72	115	0	0	0	0	0	0	0	0	0	0	0	0
07:36:27(2)	0	58	71	100	1	0	0	0	0	0	0	0	0	0	0	0
08:36:27(2)	0	57	68	86	0	0	0	0	0	0	0	0	0	0	0	0
09:36:27(2)	0	53	63	91	0	0	0	0	0	0	0	0	0	0	0	0
10:36:27(2)	0	48	57	84	0	0	0	0	0	0	0	0	0	0	0	0
11:36:27(2)	0	49	64	94	0	0	0	0	0	0	0	0	0	0	0	0
12:36:27(2)	0	50	58	94	0	0	0	0	0	0	0	0	0	0	0	0
Summary	0	46	61	116	18	0	0	0	0	0	0	0	0	0	0	0

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48H Sample, Report, Male, 68 Years, DOB: 5/18/1948

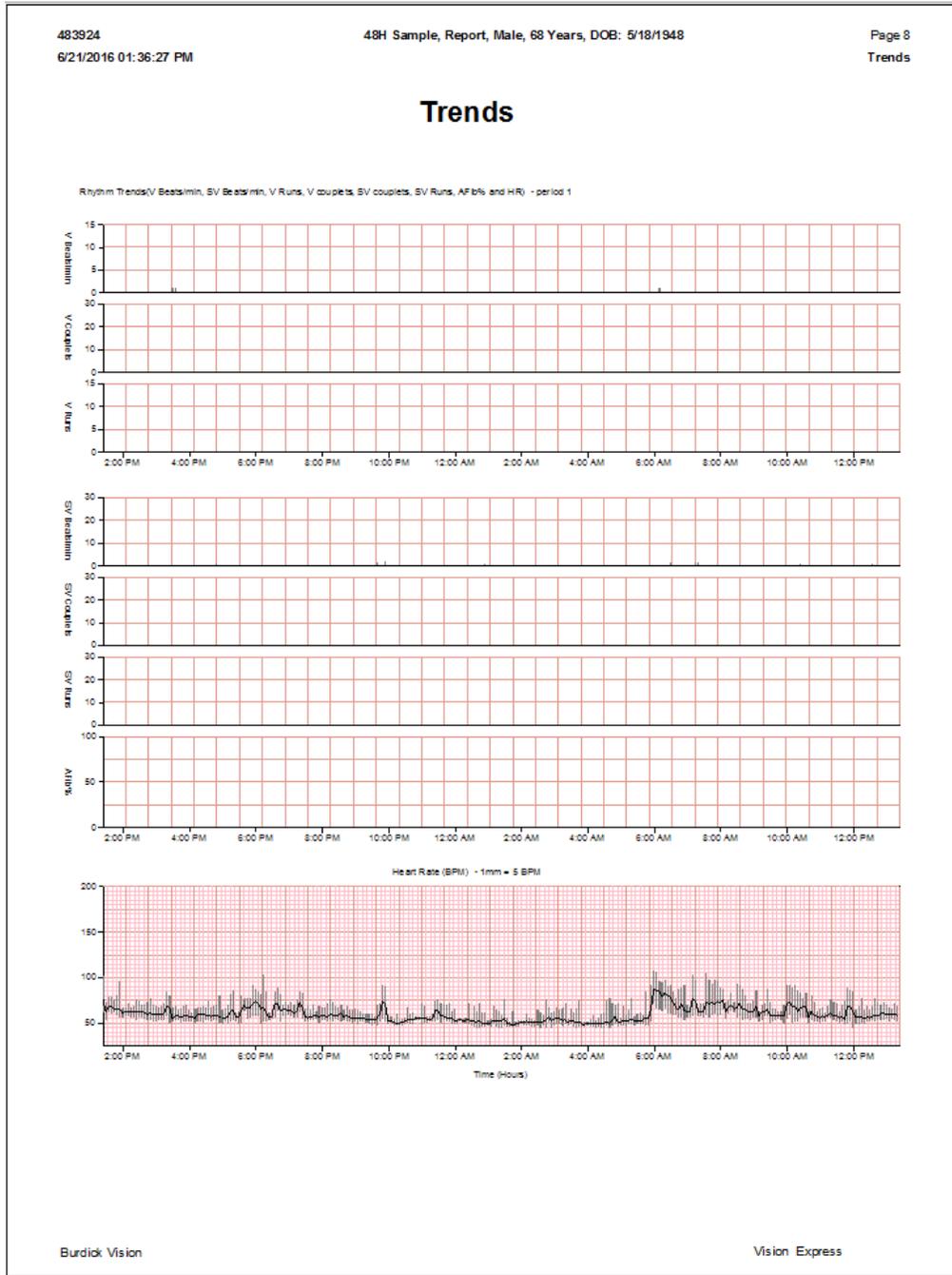
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Profiles

RHYTHM PROFILE: RR AND QT PERIODIC SUMMARY

Period Start	Diary Events	Heart Rate			RR Variability					QT/QTc					
		Min	Mean	Max	pNN50 (%)	rms-SD (ms)	SDNN (ms)	SDANN (ms)	TrI (ms)	QT			QTc/RRc		
										Min	Mean	Max	Min	Mean	Max
13:36:27	0	54	66	102	7	29	82	53	20	384	393	404	399	409	432
14:36:27	0	53	62	84	15	38	69	38	21	380	399	407	396	404	430
15:36:27	0	50	58	81	20	44	68	48	19	383	408	416	393	403	429
16:36:27	0	50	59	88	15	39	80	46	22	384	415	424	398	409	438
17:36:27	0	53	65	103	9	32	93	79	31	389	390	422	409	420	459
18:36:27	0	53	65	89	8	29	59	75	23	387	413	432	409	425	450
19:36:27	0	51	58	83	9	32	83	43	16	383	424	433	412	419	439
20:36:27	0	50	57	71	13	36	57	32	18	417	424	430	401	412	427
21:36:27	0	48	57	92	11	33	59	123	23	371	424	445	399	411	447
22:36:27	0	49	54	71	7	29	39	27	12	408	441	444	404	416	429
23:36:27	0	50	55	76	4	25	50	62	15	413	421	441	411	425	445
00:36:27	0	46	52	72	14	37	69	33	16	420	445	454	401	412	425
01:36:27	0	46	51	76	16	37	48	35	15	427	450	456	403	412	424
02:36:27	0	46	53	76	13	37	67	39	19	431	446	454	409	418	430
03:36:27	0	46	51	75	16	39	52	27	15	443	451	459	411	416	423
04:36:27	0	48	52	78	17	40	77	46	18	423	443	457	408	414	427
05:36:27	0	48	60	107	10	31	79	197	33	341	397	442	408	420	440
06:36:27	0	53	70	103	4	25	80	51	31	345	386	408	404	416	430
07:36:27	0	55	70	105	6	28	86	58	29	345	386	406	401	415	431
08:36:27	0	52	65	94	11	33	78	53	24	382	389	402	393	404	424
09:36:27	0	50	63	92	15	39	83	81	26	388	395	412	392	406	439
10:36:27	0	51	61	84	19	41	71	63	23	380	399	405	388	402	425
11:36:27	0	45	59	89	23	45	90	75	27	375	410	423	393	405	421
12:36:27	0	52	59	77	25	49	72	26	18	402	410	420	388	406	418
13:36:27(2)	0	51	61	93	18	41	78	29	21	372	402	411	388	407	427
14:36:27(2)	0	51	61	90	14	36	66	38	18	373	404	416	397	406	426
15:36:27(2)	0	48	56	78	28	51	51	18	19	408	418	428	398	402	421
16:36:27(2)	0	48	57	89	25	48	74	92	25	371	424	434	399	410	433
17:36:27(2)	0	51	63	94	18	39	66	63	33	368	407	423	407	415	437
18:36:27(2)	0	54	72	100	7	27	64	102	34	340	399	417	411	422	445
19:36:27(2)	0	56	65	96	8	31	69	58	19	351	396	417	402	413	433
20:36:27(2)	0	54	67	93	9	33	72	44	23	351	397	410	404	418	430
21:36:27(2)	0	51	62	94	8	30	76	90	37	351	407	432	403	414	432
22:36:27(2)	0	46	53	74	15	37	60	46	19	429	442	450	399	414	435
23:36:27(2)	0	52	58	78	3	25	56	54	14	409	438	447	421	430	445
00:36:27(2)	0	51	58	76	4	27	50	57	19	408	440	456	408	432	442
01:36:27(2)	0	50	57	75	1	22	42	37	9	423	450	458	430	437	445
02:36:27(2)	0	51	57	77	2	24	48	42	10	423	449	457	429	435	446
03:36:27(2)	0	47	57	85	7	31	67	60	22	432	444	453	418	429	444
04:36:27(2)	0	49	55	79	4	28	39	35	13	423	438	448	410	420	429
05:36:27(2)	0	50	59	102	2	21	67	147	31	352	395	434	405	424	441
06:36:27(2)	0	54	72	115	3	23	75	78	32	350	383	407	402	419	462
07:36:27(2)	0	58	71	100	3	22	62	35	16	358	383	393	397	416	

## Trends

The trends pages consist of 5-minute rhythm trends, QT trends, RR variability trends, and ST trends. Episodes of ST elevation and ST depression will be listed on the ST trends page. The heart rate trend is repeated in each trend for correlation. Each trend page will represent a 24-hour period.

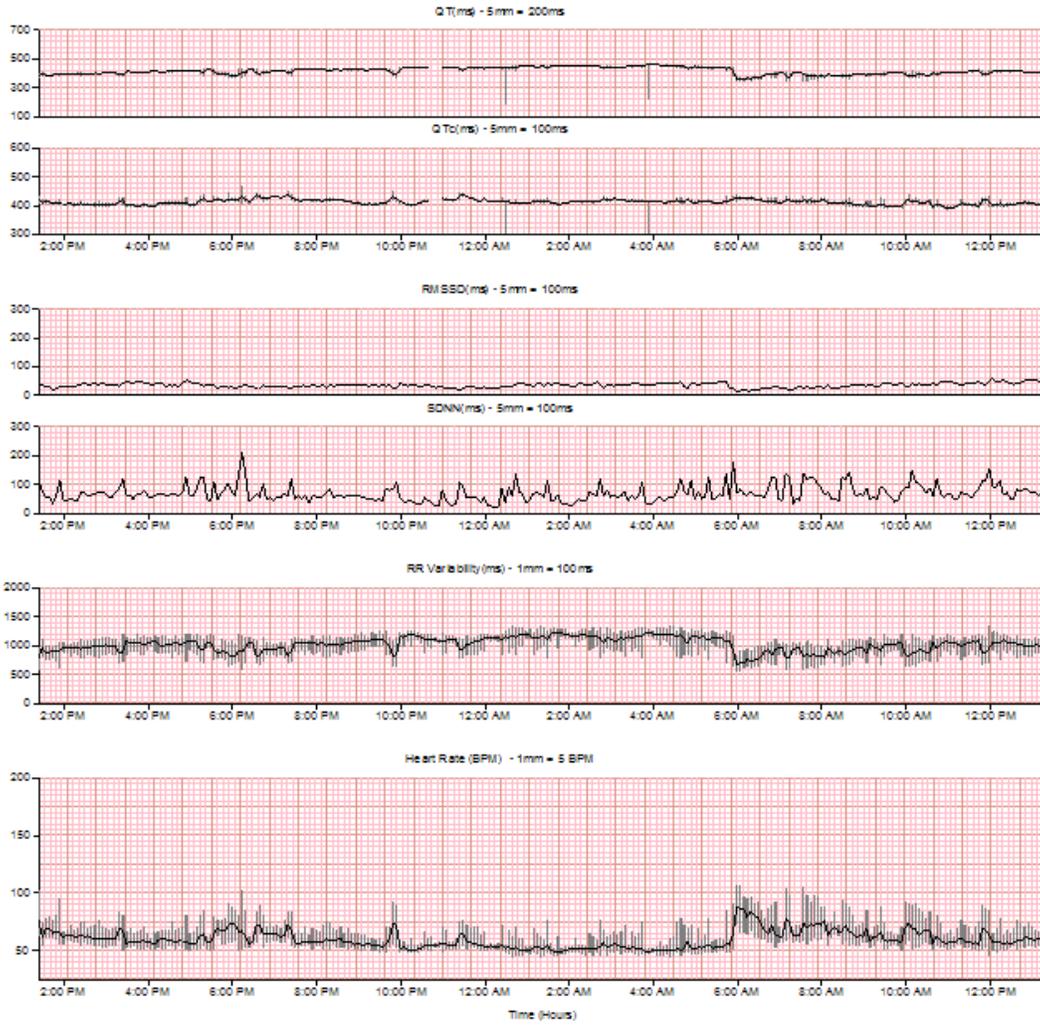


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48H Sample, Report, Male, 68 Years, DOB: 5/18/1948

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Trends

QT Trends (QT, QTc, RRc, RMSSD, SDNN, RR Variability and HR) - period 1



Burdick Vision

Vision Express

483924

48H Sample, Report, Male, 68 Years, DOB: 5/18/1948

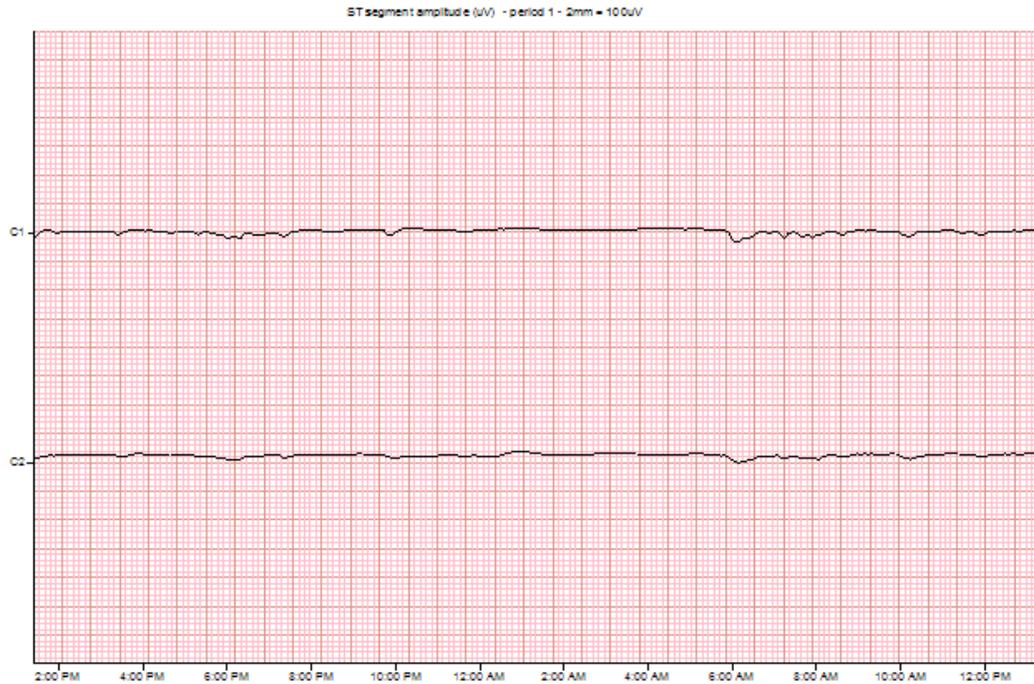
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Trends

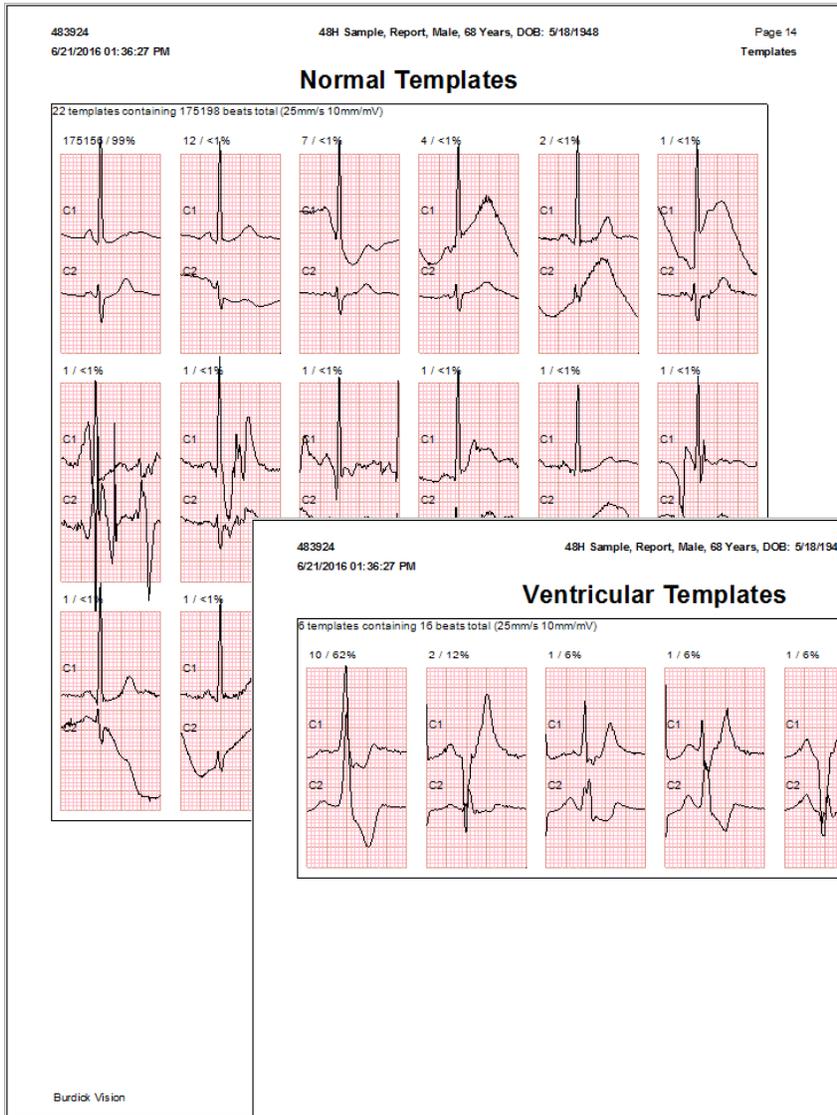
ST Summary and Trends

ST Analysis Criteria = 200  $\mu$ V ST segment elevation; 100  $\mu$ V ST segment depression



# Templates

Templates pages consist of one page for each template group present within the recording. Each beat shape shows the total number of matched beats and the percent of that beat shape within the template group.

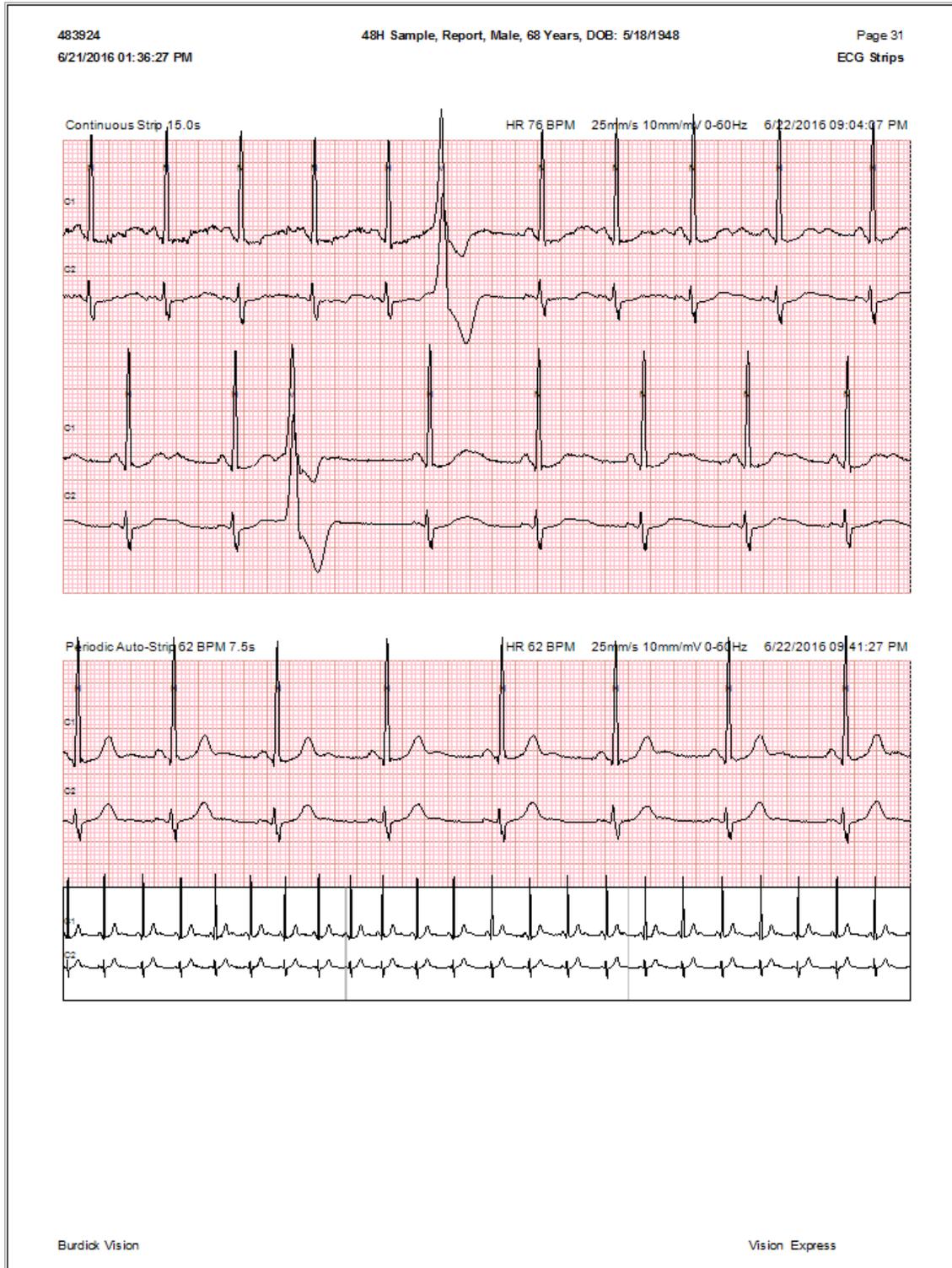


## ECG Strip List and ECG Strips

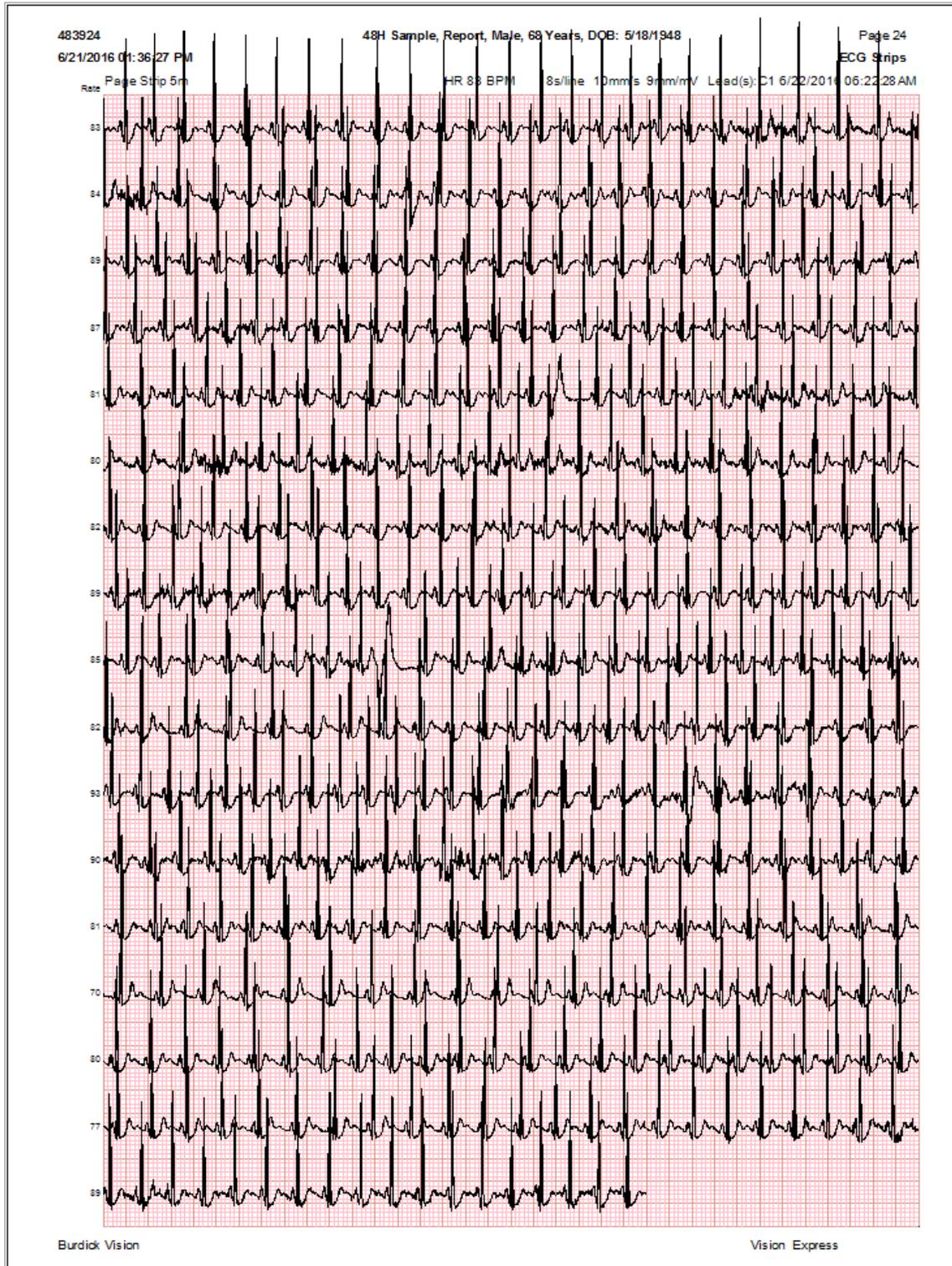
An index of all included strips in the final report shows duration of each strip, ECG leads, annotations and page numbers precede the actual strips. Beginning after the initial 24-hours, each following 24-hour period is numbered and enclosed in parentheses.

<u>Time</u>	<u>Duration</u>	<u>Leads</u>	<u>Strip Annotation</u>	<u>Page</u>
01:36:52 PM	7.5s	C1, C2	Recording Start	17
01:41:27 PM	7.5s	C1, C2	Periodic Auto-Strip 67 BPM	17
03:46:52 PM	7.5s	C1, C2	Isolated Ventricular Beat	18
05:04:35 PM	7.5s	C1, C2	Isolated SV Beat	18
05:41:27 PM	7.5s	C1, C2	Periodic Auto-Strip 57 BPM	19
09:41:27 PM	7.5s	C1, C2	Periodic Auto-Strip 50 BPM	19
09:54:50 PM	7.5s	C1, C2	Isolated SV Beat	20
10:10:39 PM	7.5s	C1, C2	Isolated SV Beat	20
01:34:55 AM	7.5s	C1, C2	Minimum Heart Rate 45 BPM	21
01:34:57 AM	7.5s	C1, C2	Longest RR 1.388 s	21
01:41:27 AM	7.5s	C1, C2	Periodic Auto-Strip 53 BPM	22
01:54:03 AM	7.5s	C1, C2	Slowest Bradycardia 00:15:57 49 BPM	22
04:00:17 AM	7.5s	C1, C2	Longest Bradycardia 00:18:03 49 BPM	23
05:41:27 AM	7.5s	C1, C2	Periodic Auto-Strip 53 BPM	23
06:23:46 AM	7.5s	C1, C2	Shortest RR 0.404 s	24
06:23:46 AM	7.5s	C1, C2	Isolated Ventricular Beat	24
06:24:55 AM	7.5s	C1, C2	Isolated Ventricular Beat	25
09:41:27 AM	7.5s	C1, C2	Periodic Auto-Strip 70 BPM	25
01:41:27 PM(2)	7.5s	C1, C2	Periodic Auto-Strip 58 BPM	26
05:06:34 PM(2)	7.5s	C1, C2	Isolated Ventricular Beat	26
05:41:27 PM(2)	7.5s	C1, C2	Periodic Auto-Strip 56 BPM	27
05:52:52 PM(2)	7.5s	C1, C2	Isolated Ventricular Beat	27
05:53:53 PM(2)	7.5s	C1, C2	Isolated Ventricular Beat	28
09:41:27 PM(2)	7.5s	C1, C2	Periodic Auto-Strip 62 BPM	28
11:07:56 PM(2)	7.5s	C1, C2	Isolated SV Beat	29
11:09:07 PM(2)	7.5s	C1, C2	Isolated SV Beat	29
01:41:27 AM(2)	7.5s	C1, C2	Periodic Auto-Strip 55 BPM	30
05:41:27 AM(2)	7.5s	C1, C2	Periodic Auto-Strip 61 BPM	30
07:29:53 AM(2)	7.5s	C1, C2	Maximum Heart Rate 115 BPM	31
10:53:16 AM(2)	7.5s	C1, C2	Isolated SV Beat	31
01:36:13 PM(2)	7.5s	C1, C2	Recording End	32

15-second, 2-channel continuous ECG strip followed by a 7.5-second, 2-channel ECG strip with a 22.5-second context ECG strip

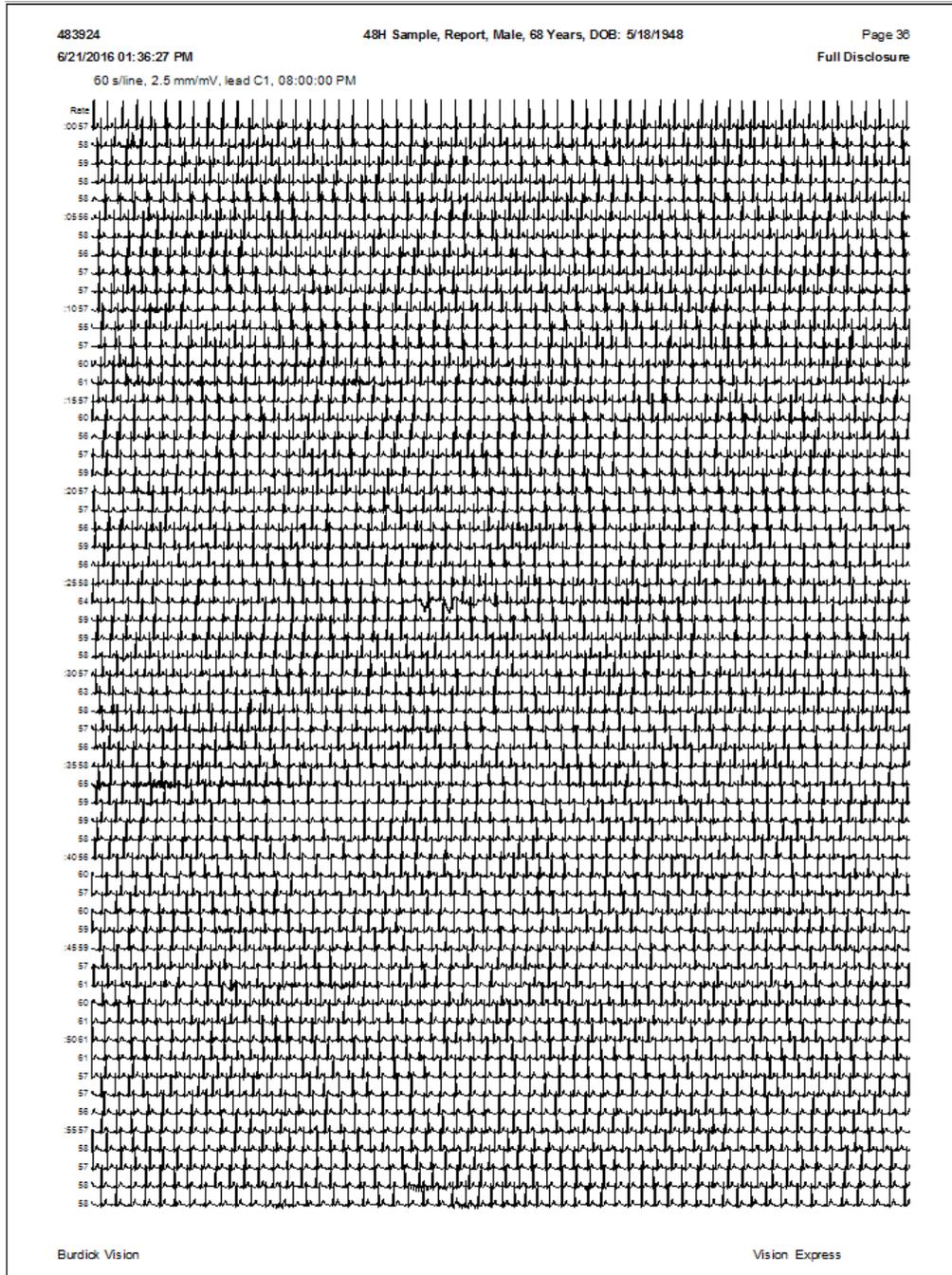


5-minute, single-channel page strip



# Full Disclosure

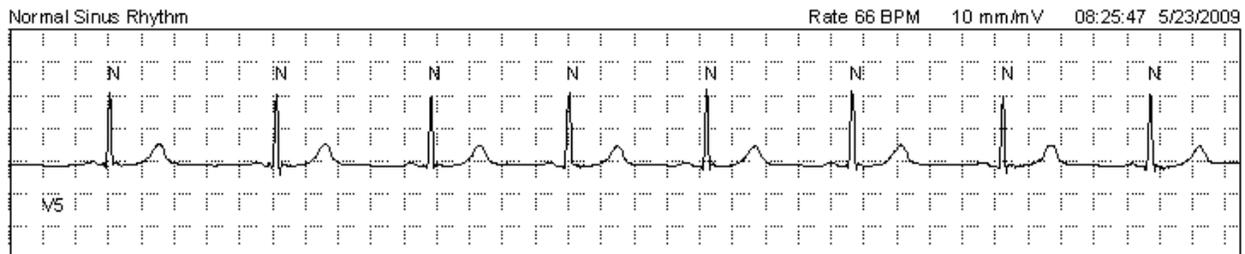
Each full disclosure page contains 60 minutes of miniature ECG at 2.5 mm/mV



# QUICK REFERENCE FOR THE HOLTER ANALYST

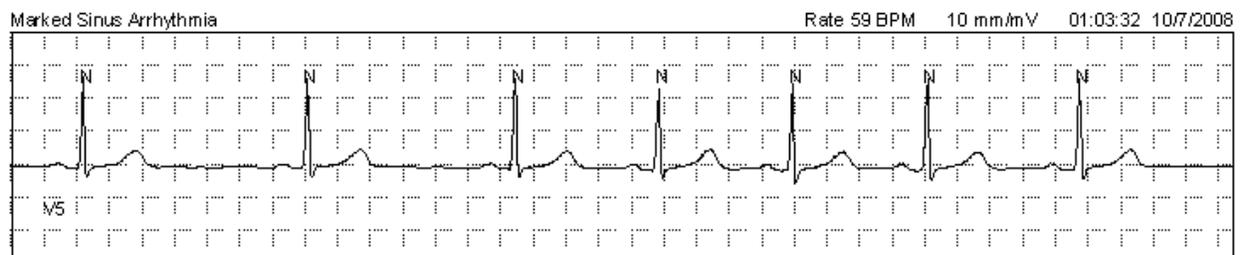
## Rhythm and Conduction

**Normal Sinus Rhythm** – Sinus Rhythm consists of an electrical impulse originating in the Sino-atrial (SA) node and radiating through both atria, traveling through the Atrio-ventricular (AV) node, continuing through the Bundle of His, both the left and right bundle branches, the Purkinje fibers and finally depolarizing the ventricular myocardium. When the SA node paces the heart at a rate between 60 and 100 BPM, the rhythm is called **NORMAL SINUS RHYTHM**; at a rate of 100 BPM or more, **SINUS TACHYCARDIA**; at a rate below 60 BPM, **SINUS BRADYCARDIA**.



*Vision Express Approach* – Our system chooses the predominant rhythm to be that patient’s “normal”. The analyst simply allows the underlying rhythm to be identified as “Normal”. The highest HR and the lowest HR ECG times are reported automatically. The analyst may add and annotate these strips as Sinus Tachycardia or Sinus Bradycardia as desired.

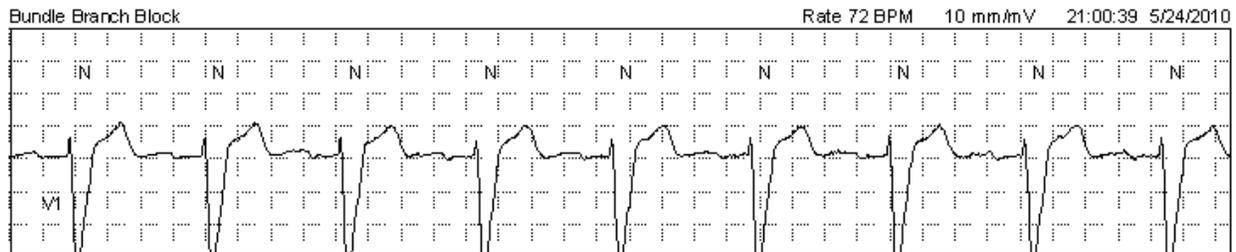
**Sinus Arrhythmia** – When the SA Node paces the heart irregularly, typically a rhythmic increase and decrease in rate that corresponds to respiration, the rhythm is called **Sinus Arrhythmia**. This is typically a normal rhythm and shows that there is a good balance between the parasympathetic and sympathetic nervous system (reflected in heart rate variability calculations).



*Vision Express Approach* – When the sinus arrhythmia is pronounced (or marked), some beats may be incorrectly identified as supraventricular when the prematurity percentage is set at 25, which is appropriate for most recordings. It is recommended that the percent value be increased to prevent false SVPB calls.

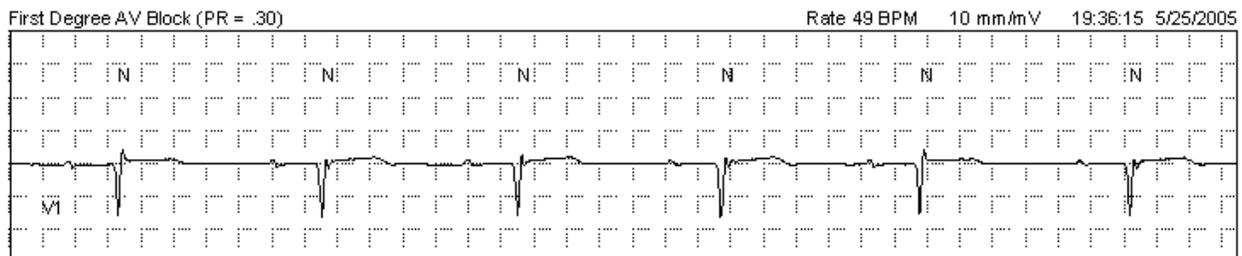
You may first try 30% to see if beat labels are adequate and if not, increase the value in 5% steps until labeling is satisfactory.

**Bundle Branch Block (BBB) or Intraventricular Conduction Defect (IVCD)** – When a block exists along either of the bundle branch pathways, the electrical impulse travels through the right or left bundle branch to stimulate one ventricle and then through the septum to stimulate the other ventricle. The P-wave and PR interval are normal, but because one ventricle is stimulated later than the other, the QRS complex is wider than normal and is usually 0.12 seconds in duration or more. BBB or IVCD may also occur intermittently during the recording.



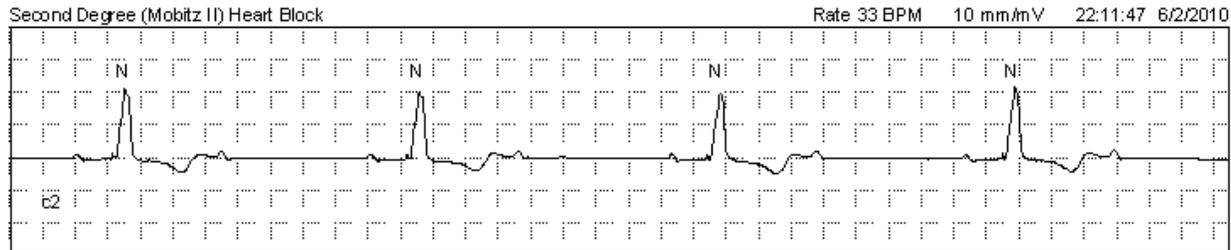
*Vision Express Approach* – The template corresponding to the QRS can be identified as normal or Bundle Branch Block so the Vision Express analysis program will consider any properly-timed QRS of this morphology in normal beat calculations. Because Vision Express updates the predominant morphology, any conduction changes will be reflected in the Template view as well as the ECG and superimposition views.

**First Degree AV Block** – If a block exists in the AV node so that the electrical impulse is held for a longer than normal period of time, the rhythm is called **FIRST DEGREE AV BLOCK**. This rhythm is characterized by a PR interval prolonged to greater than 0.20 seconds.



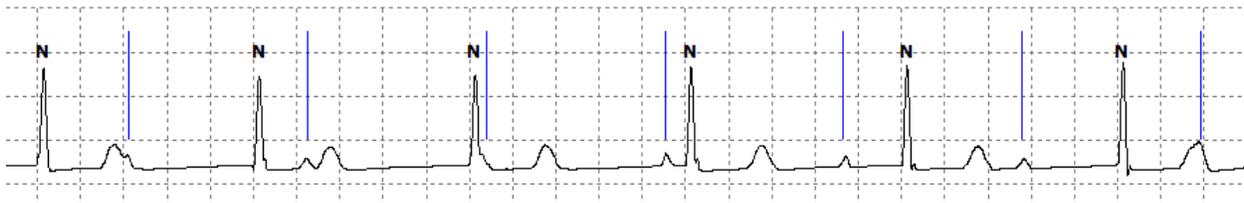
*Vision Express Approach* – Since the Vision Express analysis program detects only the QRS, no lengthening of the PR interval will be detected by the system alone. The Superimposition display allows easy detection of changes in the PR interval. A PR interval within the normal range will be superimposed with the P-wave preceding the QRS, while the onset of a first degree block causes the P-wave to slide farther to the left side of the superimposition display.

**Second Degree AV Block** – Two types of **SECOND DEGREE AV BLOCK** are caused by blocks in the AV node with only some of the electrical impulses from the atria conducting through to the ventricles. **MOBITZ I**, also called **WENCKEBACH**, holds the impulse within the AV node for longer than the preceding electrical impulse until the electrical impulse does not conduct through the AV node at all. This block is characterized by a gradual prolongation of the PR interval followed by a non-conducted P wave. **MOBITZ II** blocks impulses intermittently and PR intervals with conduction are normal. When a beat is dropped, a normally timed P-wave occurs and is not followed by a QRS.



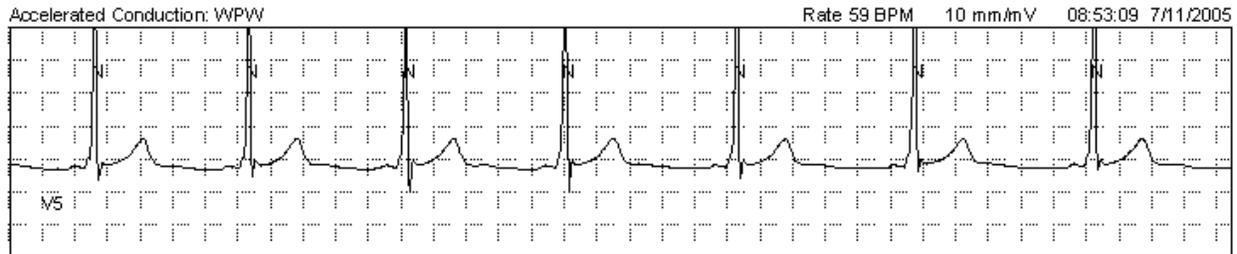
*Vision Express Approach* – Our system will report the RR interval of the dropped beat in the Profile display as a long RR interval or as a pause if it exceeds the set criteria. The RR interval histogram will show a characteristic shape of more than one peak depending on frequency of the blocked beats.

**Third Degree (Complete) AV Block** – When none of the atrial impulses are conducted through the AV node, the rhythm is called a **COMPLETE AV BLOCK**. Typically, a lower portion of the AV node or a ventricular site takes over pacing function at a slow BPM rate. This is referred to as an “Escape Rhythm”. The atria and ventricles will pace independently and there is no relationship between the P waves and the QRS complexes.



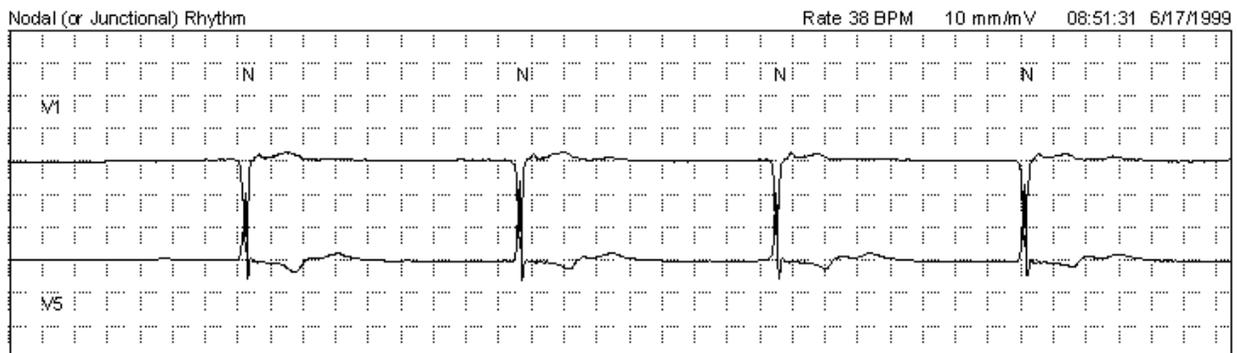
*Vision Express Approach* – Whether the escape rhythm is nodal (sometimes called junctional) or ventricular in origin, the analysis program will identify the predominant rhythm as “Normal” with a slow heart rate. Intermittent episodes will be found in the Profile (Min HR, Bradycardia episodes, Max RR, or Pauses), the RR interval Histogram with a wide distribution, and can be observed in the superimposition display characterized by P-waves that appear to float forward or backward relative to the QRS. Users can “march out” the calipers for assistance in the identification of hidden P-waves as shown in the example above.

**Accelerated Conduction** – Wolf-Parkinson-White (WPW) and Lown-Ganong-Levine (LGL) are both types of accelerated conduction defects. Rather than the electrical impulse being delayed in the AV node, there is pre-excitation of the ventricles by means of abnormal conduction fibers that parallel and bypass the normal conduction pathway. LGL presents as a shorter than normal PR interval (< 0.08 seconds). WPW presents as a slurring of the onset of the QRS making it appear wider than normal; this slurring is called a delta-wave. Accelerated conduction defects may lead to re-entry tachycardia, sometimes mimicking ventricular tachycardia.



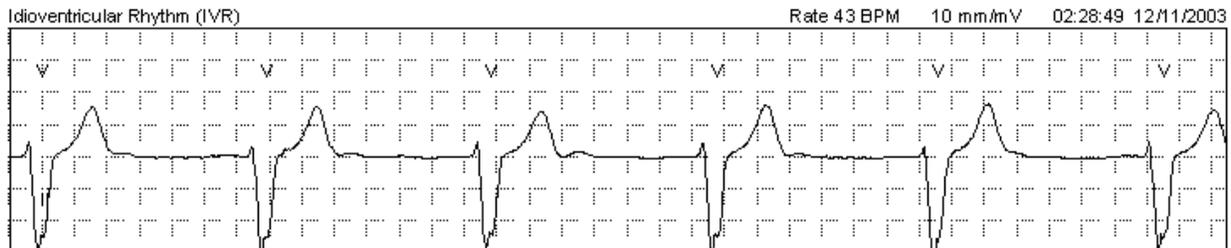
*Vision Express Approach* – These abnormalities can be easily detected by routine measurements of the PR interval using the on-screen caliper tool. Intermittent changes will be apparent in the Superimposition scanning mode.

**Nodal or Junctional Rhythm** – When the predominant pacemaker is the AV node rather than the SA node, the rhythm is called nodal or junctional. This rhythm is characterized by normal conduction and an inverted P-wave, sometimes seen after the QRS complex or the absence of a P-wave altogether. The ventricular rate is typically 40 – 50 BPM, but can be accelerated with a faster rate.



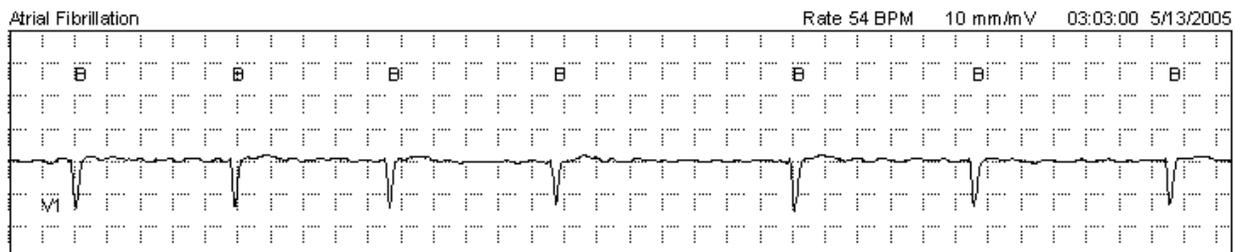
*Vision Express Approach* – A change or absence of the P-wave is easily observed in the superimposition display. Onset of this rhythm is seen as either the appearance of a negative P-wave or the disappearance of the P-wave. Intermittent episodes may be found in the Profile under minimum HR.

**Idioventricular Rhythm (IVR) and Accelerated Idioventricular Rhythm (AIVR)** – When the predominant pacemaker is ventricular in origin, rather than the SA node or another supraventricular focus, the rhythm is considered IVR if the rate is 50 BPM or less. AIVR is called if the rate is 50 to 100 BPM. These rhythms are characterized by the absence of P-wave and a QRS of ventricular morphology.



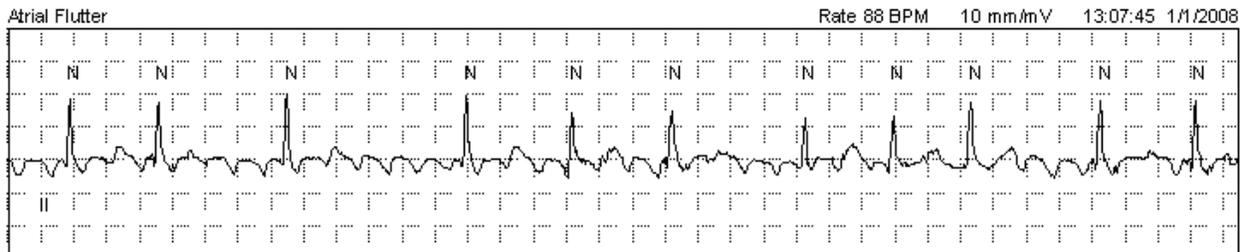
*Vision Express Approach* – When a ventricular focus is the predominant rhythm, the rhythm will be identified as “Normal”. If the ventricular rhythm is transient, the episodes will be quantified in the ventricular run length summary and can easily be found in the Profile view. Since the Vision Express cannot distinguish between a sinus rhythm with Bundle Branch Block and Idioventricular Rhythm, the user should inspect the Normal templates and rename templates with Idioventricular Rhythm to “Ventricular”.

**Atrial Fibrillation** – When the electrical activity in the atria is chaotic and many ectopic foci are firing erratically, the atria are said to be “fibrillating”. Some impulses conduct through the AV node and stimulate the ventricles. This rhythm is characterized by a chaotic baseline with no distinct P-wave and highly irregular RR intervals.



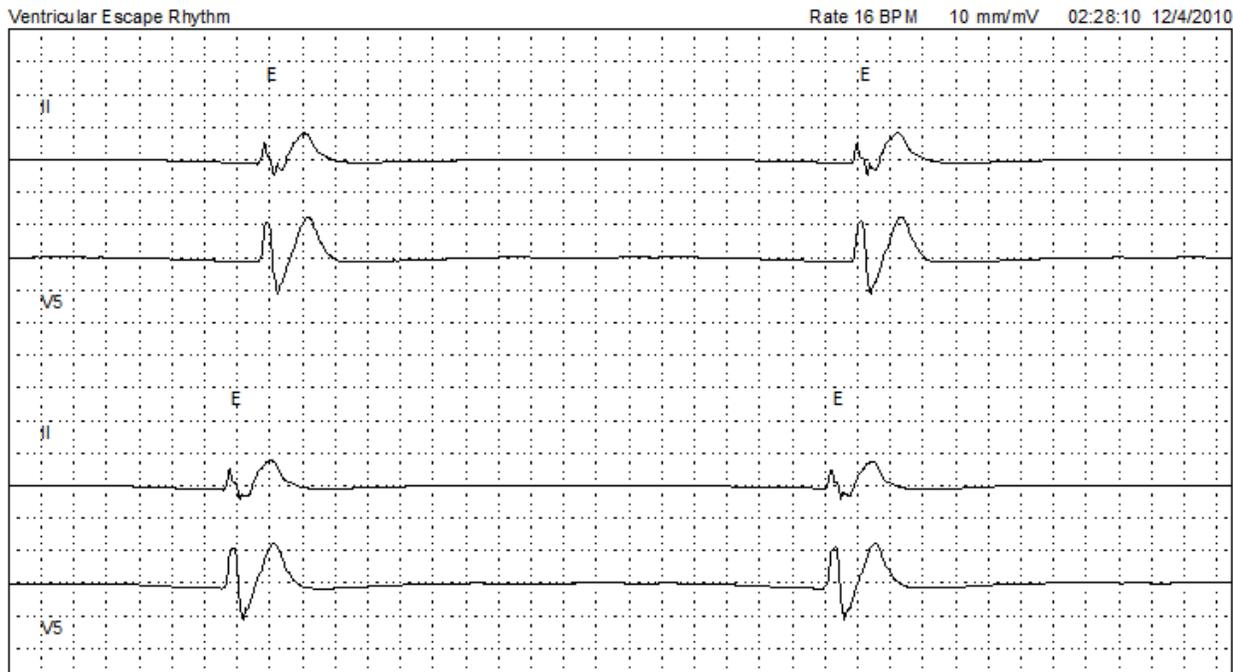
*Vision Express Approach* – Atrial fibrillation (Afib) is detected by irregular RR intervals and will be identified automatically when “Detect Atrial Fibrillation” has been enabled. When intermittent, Afib episodes can be navigated in the Profile display and by episode bars in the ECG view.

**Atrial Flutter** – When one atrial focus fires repeatedly and regularly at a rate between 220 and 350 BPM, the rhythm is called atrial flutter. Not all of the atrial impulses are conducted through the AV node so the ventricular rate is typically much lower. The baseline appears “saw-toothed” and the RR intervals can be regular or irregular, dependent on the variability of blocked impulses.



*Vision Express Approach* – Atrial flutter is not automatically detected by the Vision Express analysis program. This rhythm is easily detected in the Superimposition display and will likely be seen when reviewing Min/Max HR, Min/Max RR interval, and Pause ECG strips. Often the RR-histogram shows distinct peaks.

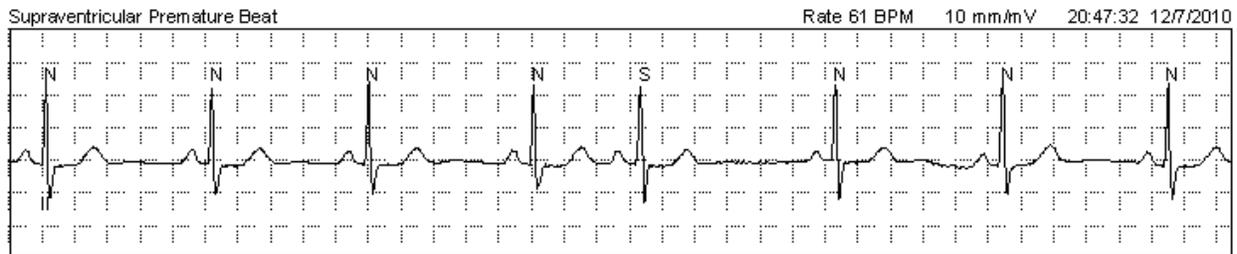
**Escape Rhythms** – Nodal and ventricular myocardial cells of the heart have inherent pacemaking ability with a different intrinsic rate. Normal nodal foci fire between 40 and 60 beats per minute (BPM), normal ventricular foci at 40 and lower BPM. These foci may provide an “escape rhythm” should the SA node fail to pace. Escape rhythms are not infrequent in trained athletes during sleep; single escape beats also occur after a sinus or AV block.



*Vision 5 Approach* – Any escape mechanism following an RR interval will most likely be seen when reviewing minimum HR, maximum RR, and Pause events in the Profile display.

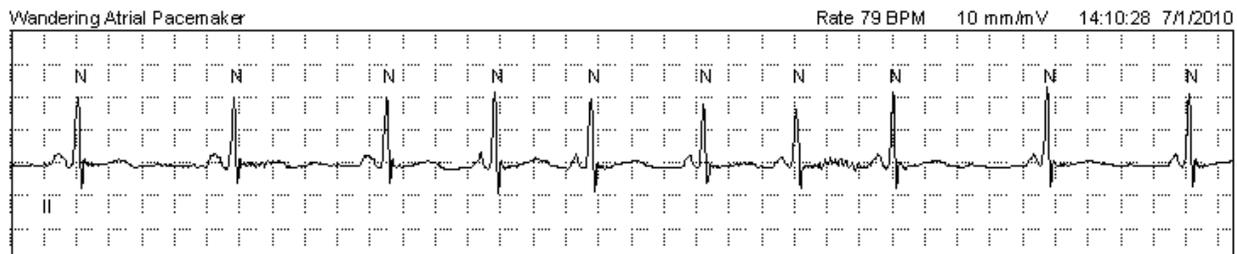
## Premature Beats

**Supraventricular Premature Beats (SVPB)** – SVPB is a beat initiated by an irritable focus in one of the atria. The beat looks normal in morphology with a slight difference in the P-wave morphology, occurs early compared to the normal sinus rhythm preceding it, and resets the SA node so that the next beat is slightly later than the normal sinus rate.



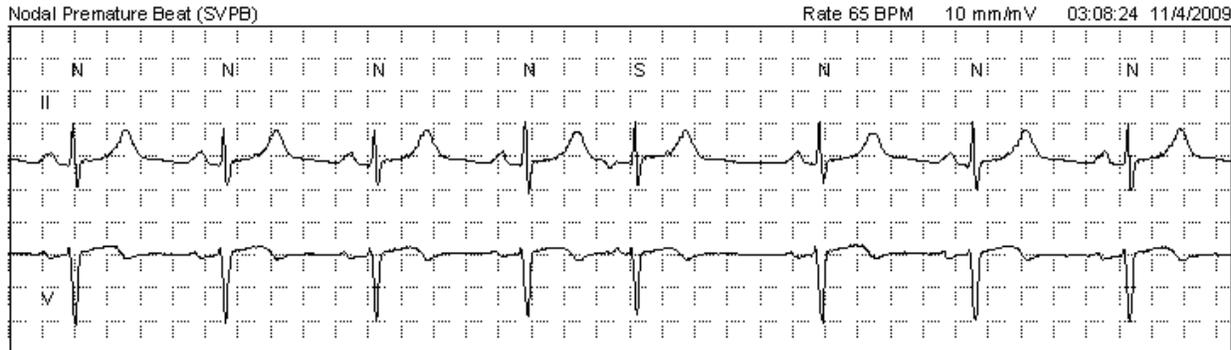
*Vision Express Approach* – An early beat (at least 10% early compared to the preceding rhythm) that is either normal in morphology or matches a morphology that the analyst has determined is supraventricular in origin will be labeled an SVPB. The SVPB prematurity % criterion is typically set to 25 and can be adjusted by the analyst depending on the prematurity of the supraventricular ectopy and regularity of the rhythm. SVPBs are best found in the Profile display and are presented as isolated, in pairs and runs with the longest and fastest run reported in the summary. When the Supraventricular template group has been enabled in the Scan Criteria dialog, beats identified as supraventricular can be quickly reviewed and edited as necessary.

**Wandering Atrial Pacemaker** – When the predominant atrial pacemaker is not limited to the SA node, but instead varies from one atrial focus to another, the phenomenon is called wandering atrial pacemaker. The PR intervals and conduction are usually normal with slightly irregular RR intervals and slightly varying P-wave shapes.



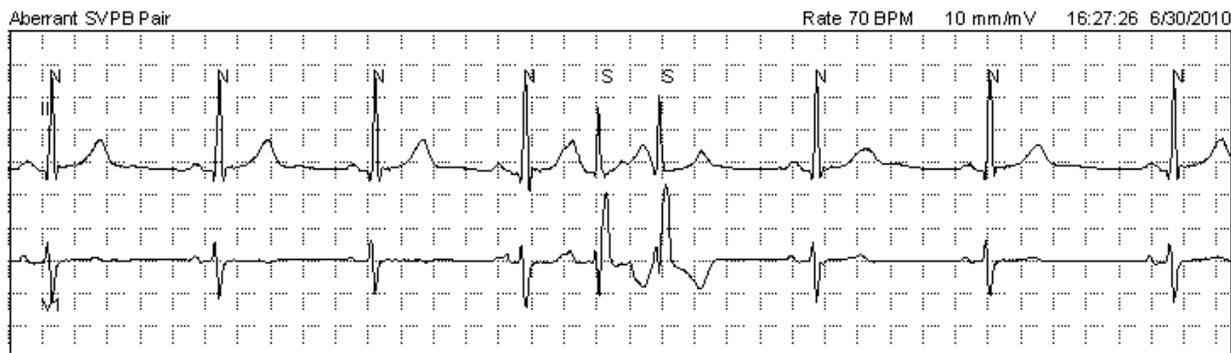
*Vision Express Approach* – Changes of the primary pacemaker are easily detected in the superimposition display as varying P-wave morphologies. The RR Histogram may be used to find irregularity.

**Nodal or Junctional Premature Beat (SVPB)** – When an irritable site in the tissue surrounding the AV node fires prematurely, the conducted beat is normal in morphology except for the P-wave. An inverted P-wave preceding the QRS implies that the site is high-nodal; if the P-wave follows the QRS, the site is low-nodal; the absence of a P-wave indicates that atrial depolarization is occurring during the QRS and that the site is mid-nodal.



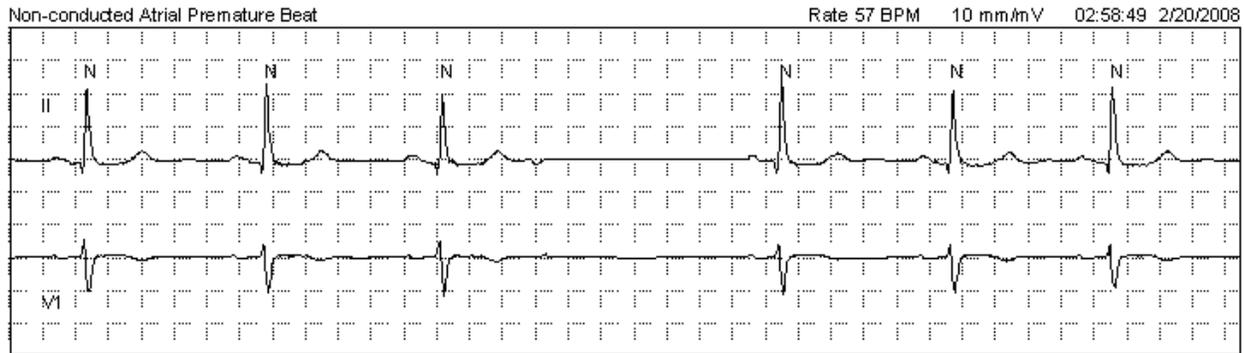
*Vision Express Approach* – Our analysis program determines that the QRS is normal in morphology and early. The analyst must determine that the P-wave is either non-existent or retrograde and can annotate the sample strip precisely.

**Aberrant Supraventricular Premature Beat (SVPB)** – When an irritable supraventricular site fires early enough that the connective tissue is still partially refractory (has not completely repolarized), conduction is abnormal and the beat is called an aberrant SVPB. This is characterized by an early P-wave followed by a normal PR interval and a wide QRS.



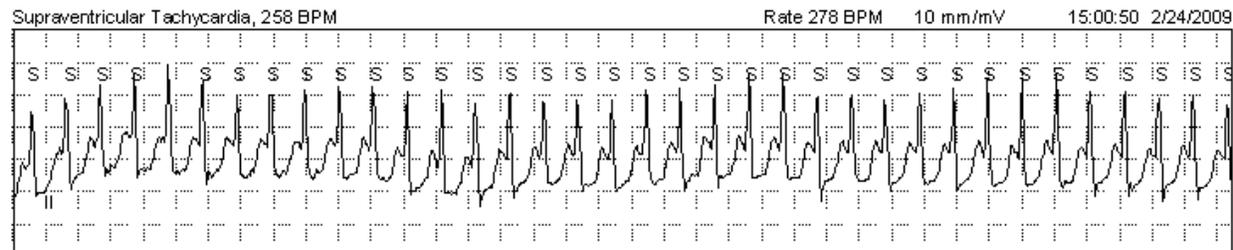
*Vision Express Approach* – Our analysis program will often identify an aberrant SVPB as a ventricular premature beat because of the different QRS morphology between normal and the aberrancy. If the analyst determines that the beat is an aberrant supraventricular premature beat because a P-wave can be seen, the beat can be relabeled “Aberrant” and will be included in Supraventricular calculations.

**Non-Conducted Atrial Premature Beat (APB)** – When an irritable atrial focus fires early and the electrical impulse does not conduct through the AV node because the conduction system is still completely refractory, the missing beat is called a non-conducted APB. This is characterized by the presence of an early P-wave without a subsequent QRS resulting in a longer than normal RR interval.



*Vision Express Approach* – Any long RR intervals will be seen when reviewing maximum RR and Pause events in the Profile and the RR Histogram displays. On-screen calipers can be used to see if the sinus rhythm is reset after the long RR interval.

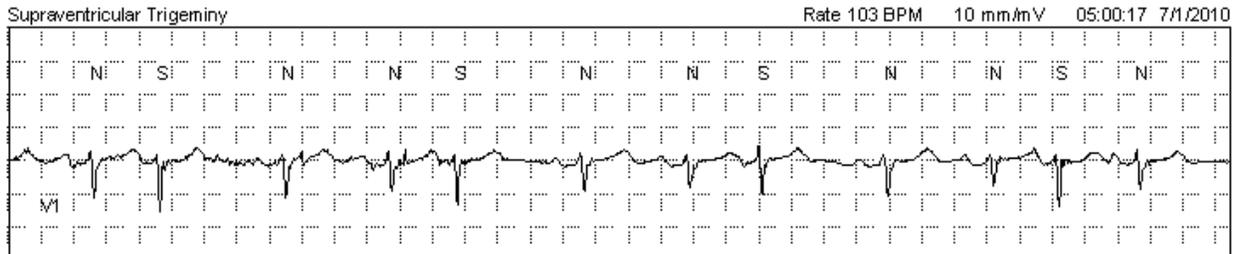
**Supraventricular Tachycardia (SVT) and Runs** – When one or more supraventricular foci fire in succession (three or more beats) and the impulses conduct through to the ventricles, the ectopic event is called SVT when it occurs at a heart rate of 100 BPM or more and is called a supraventricular run when it occurs at a heart rate of less than 100 BPM. SVT can be sub-divided into Paroxysmal Atrial Tachycardia (PAT), when only one focus is firing and the RR intervals are regular, and Multifocal Atrial Tachycardia (MAT) when more than one focus is firing and the RR intervals are irregular.



*Vision Express Approach* – Any run of three or more supraventricular premature beats is identified by the analysis program as a supraventricular run that can be navigated through use of the Profile display. The analyst may choose to annotate the Supraventricular runs with a rate of greater than 100 BPM as SVT, PAT or MAT.

**Note:** When a run of SVT approaches or exceeds 16 consecutive beats, the prematurity of the next R-R interval is likely to approach zero, since it is calculated compared to the previous 16 R-R intervals. Therefore, the next beat will be labeled normal (N) and the run is ended. In this case, the clinician may edit the beats of a long run when continuation of the run is determined. If, during a run of SVT, the next R-R interval is less than 400 ms (rate is greater than 150 bpm), it is always labeled supraventricular (S) independent of prematurity and the run is not ended.

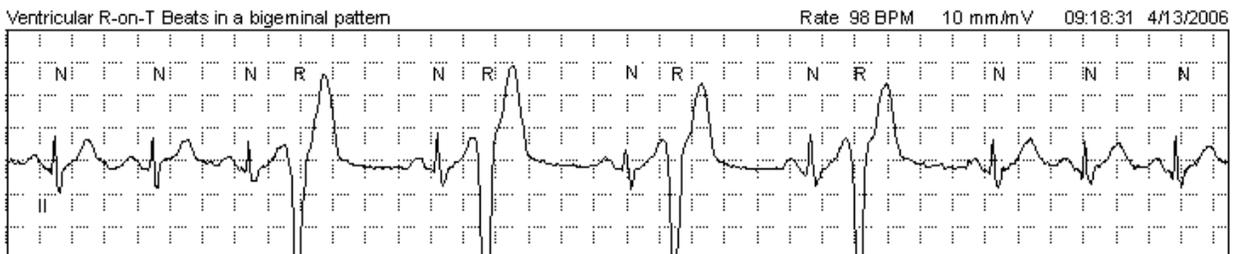
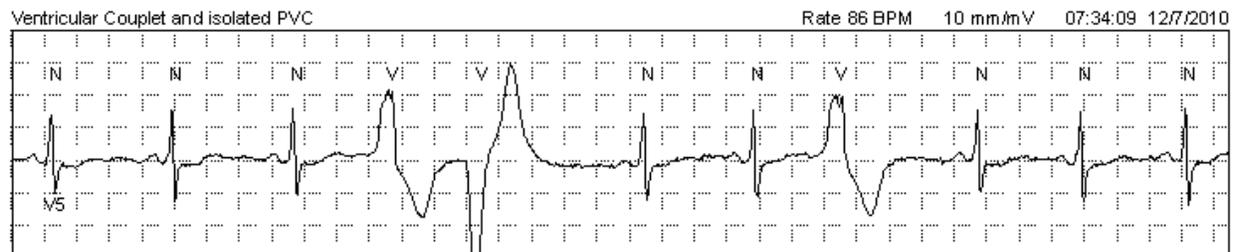
**Supraventricular Bigeminy and Trigeminy** – When supraventricular premature beats occur alternating with normal beats so that every other beat is a supraventricular beat, the rhythm is called bigeminy. When every third beat, the rhythm is trigeminy.



*Vision Express Approach* – The analysis program will identify bigeminy when the following pattern is present for at least 3 cycles: NSNSNS... Trigeminy is identified when the following pattern is present for at least three cycles: NNSNNSNNS... Navigation to these rhythm patterns is best performed in the Profile display.

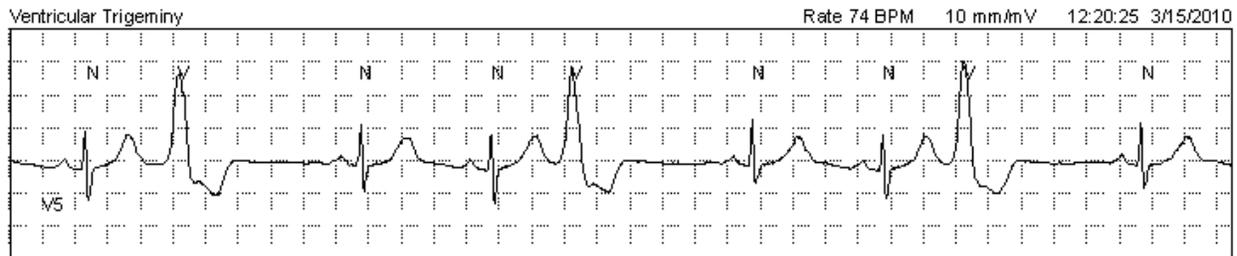
**Ventricular Premature Beat or Premature Ventricular Complex (VPB or PVC)** – An irritable ventricular focus that fires prematurely is called a VPB or PVC. It is characterized by the absence of a P-wave, a QRS that is wide and bizarre in morphology, and typically is followed by a full compensatory pause (does not reset the SA node). These beats can occur as single isolated beats, in couplets (or pairs), or in runs of 3 or more. An R-on-T is a very early VPB that occurs on, or near, the peak of the T-wave of the previous beat, a very vulnerable period during repolarization, that could initiate ventricular tachycardia and other lethal arrhythmias.

Clinicians may quantify VPB frequency on a per hour basis or per 1,000 beats (average number of VPBs per 1,000 normal beats) to classify occurrence as rare, occasional or frequent during the Holter monitoring period. The Lown classification scale from 0 to 5 may also be used. This quantification may be helpful to gauge effects of antiarrhythmic drugs.



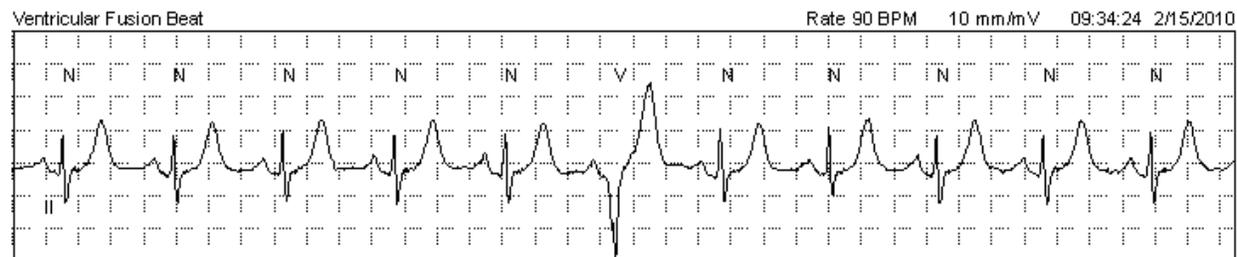
*Vision Express Approach* – The analysis program will identify an abnormal beat that does not match the dominant beat shape and is not paced as a Ventricular beat type. When this beat type exceeds a prematurity threshold as compared to the preceding rhythm, the beat is identified as an R-on-T beat. These beats and runs are easily navigable in the Profile display.

**Ventricular Bigeminy, Trigeminy** – When ventricular beats occur alternating with normal beats so that every other beat is from the same ventricular focus, the rhythm is called bigeminy. When every third beat is ventricular, the rhythm is trigeminy.



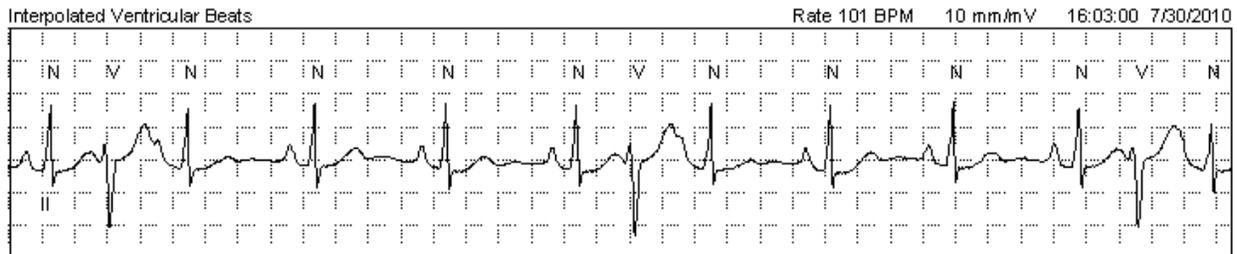
*Vision Express Approach* – The analysis program will identify bigeminy when the following pattern is present for at least 3 cycles: NVNVNV... Trigeminy is identified when the following pattern is present for at least three cycles: NNVNNVNV... Navigation to these rhythm patterns is best performed in the Profile display.

**Fusion Beat** – When a ventricular focus fires after the SA node has fired but before the impulse has been conducted through to the ventricles, a fusion beat occurs. Its morphology is a combination of the normal and ventricular morphologies with a normally-timed P-wave and a shortened PR interval.



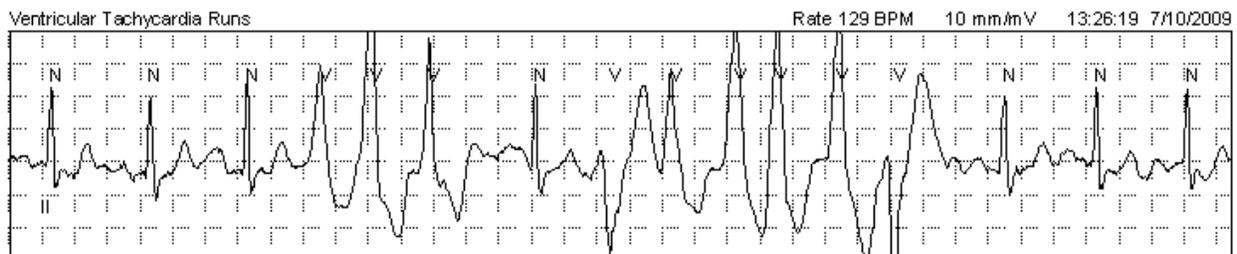
*Vision Express Approach* – The analysis program will identify the fused sinus and ventricular beats as ventricular if the morphology is different enough from the dominant normal morphology. The analyst can relabel the fused beat templates or individual beats as “Fusion” and they will be included in ventricular calculations.

**Interpolated VPB** – When a VPB occurs early enough that the normally-timed impulse from the SA node conducts through to the ventricles immediately following the VPB, the VPB is called “interpolated”. Rather than replacing the normal QRS, the VPB occurs between two normally-timed sinus beats and is not followed by a compensatory pause.



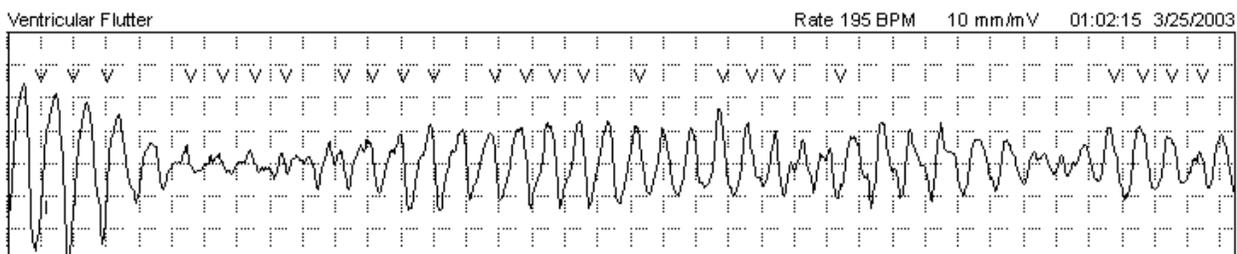
*Vision Express Approach* – The analysis program will identify ventricular beats as usual and they will be found in the Ventricular templates and in the Profile display. The analyst can relabel these ventricular beats individually as “Interpolated” and they will be included in ventricular calculations.

**Ventricular Tachycardia (VT, VTAC, or VTach) and Ventricular Runs** – When one or more ventricular foci fire in succession (three or more beats), the ectopic event is called VT when it occurs at a heart rate of 100 BPM or more and is referred to as an idioventricular or accelerated ventricular rhythm when it occurs at a heart rate of less than 100 BPM.



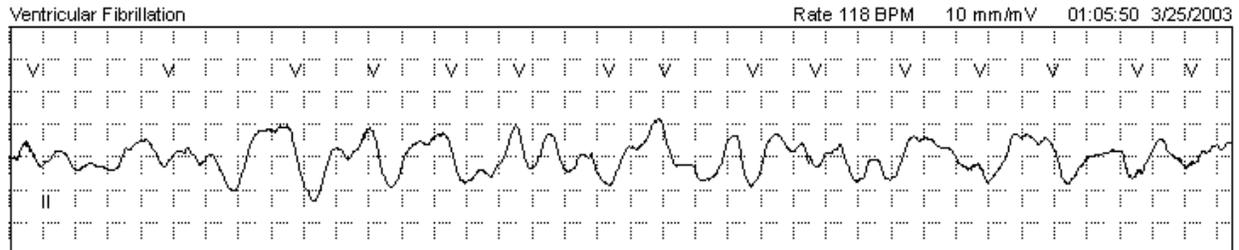
*Vision Express Approach* – Three or more consecutive ventricular beats will be identified by the analysis program as a ventricular run that can be navigated through use of the Profile display. The analyst may choose to annotate the ventricular runs with a rate of greater than 100 BPM as VT; with a rate of less than 100 BPM as IVR or AIVR.

**Ventricular Flutter (VFlut)** – When a single ventricular focus fires repeatedly and rapidly enough to prevent even a reduced cardiac output, the event is called ventricular flutter. Rather than having the distinct QRS morphology of VT, VFlut is identified by its sinusoidal appearance.



*Vision Express Approach* – Ventricular runs that degenerate into ventricular flutter will continue to be identified as a ventricular run with most flutter waves counted as ventricular beats if the amplitude is large enough, otherwise a pause will be detected.

**Ventricular Fibrillation (VFib)** – When many ventricular foci are firing in rapid succession, the electrical activity in the ventricles is chaotic and the myocardium is twitching rather than contracting, the heart is in ventricular fibrillation. There is no cardiac output. The ECG waveform is distinctively chaotic.



*Vision Express Approach* – The electrical impulses of VFib will continue to be identified as ventricular runs if the system can find any possible QRS complexes or will be identified as a pause according to the set pause criteria. An entire event showing the onset of VT and degeneration into VFlut and VFib can be documented and annotated with continuous strips.

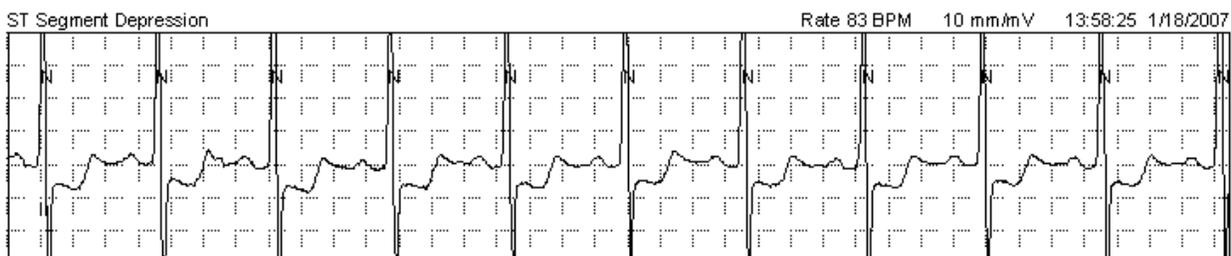
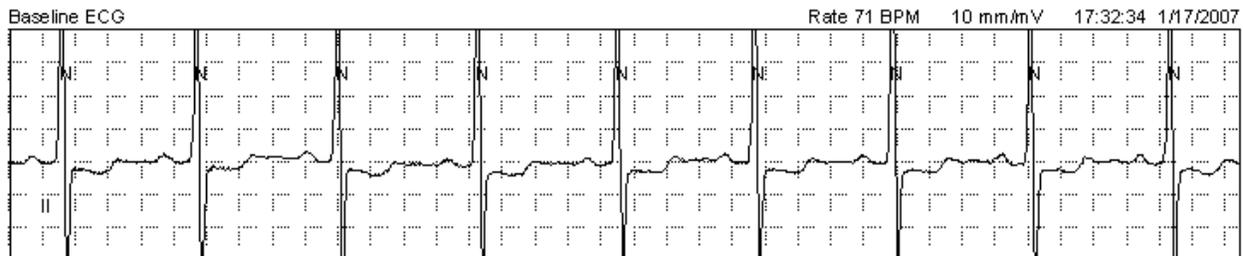
## ST Segment Analysis

An analysis of the ST segment is used in the diagnosis of ischemia, an inadequate supply of oxygen to the ventricular myocardium. Ischemia, whether accompanied by pain or not (termed “silent ischemia”), is indicated when the ST segment voltage change at the J-point is typically greater than or equal to  $100\ \mu\text{V}$  and the morphology of the ST segment is either flat or downsloping, rather than steeply upsloping. ST elevation can be attributed to early repolarization, pericarditis, acute injury, and acute infarction. Holter monitoring records ST segment changes in an ambulatory setting where episodes may occur with a variety of causes.

**ST Baseline** – The change in voltage of the ST segment should be measured relative to the normal ECG baseline; normal is defined as the stable voltage measurement relative to isoelectric before the onset of the possible ST depression or elevation event.

*Vision Express Approach* – The analysis program performs a per-beat measurement of ST offset determined at 60 msec post J. ST depression and elevation episodes are declared by locating a persisting ST level that is beyond the user-configured threshold and following a change of at least  $100\ \mu\text{V}$ . Only beats identified as “Normal” are used for this analysis.

**ST Depression** – ST segment depression is typically defined as 1 millimeter ( $100\ \mu\text{V}$ ) or more of negative change from the baseline ST segment. To be considered ischemic, the slope of the ST segment usually must be flat or downsloping.



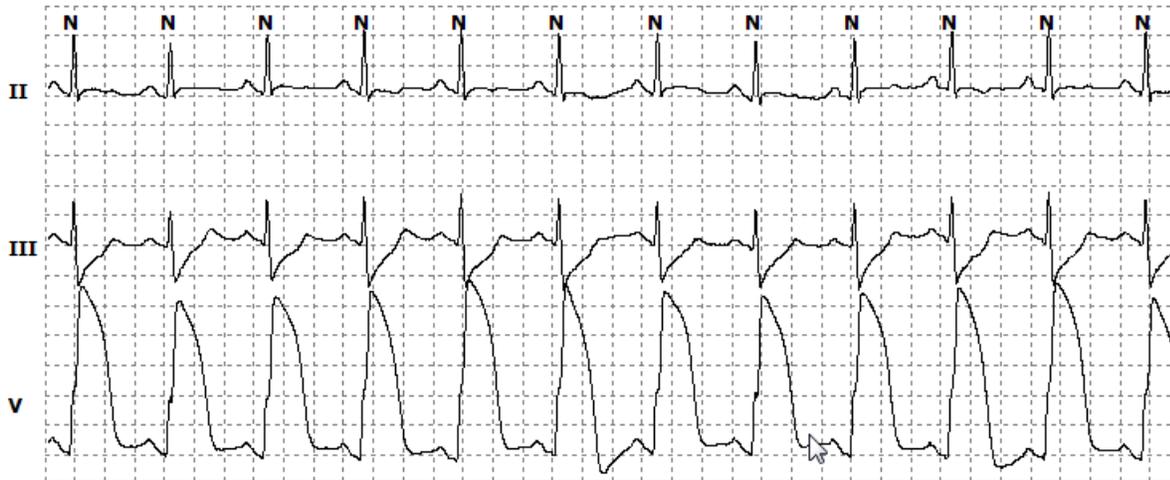
*Vision Express Approach* – After eliminating artifact and ensuring all ectopic beats are labeled appropriately, the analysis program measures the ST segment for each normal beat and averages the measurements. The Profile and Trend displays will show any change in ST segments and depression episode onset, offset and durations will be reported according to user-defined thresholds.

**ST Elevation** – ST segment elevation is typically defined as 1 millimeter (100  $\mu$ V) or more of positive change from the baseline ST segment.

In the example below, a baseline ECG is selected for comparison.



The ST episode below lasted for a period of approximately 2 minutes that may have been missed if only lead II had been observed and the patient were asymptomatic.

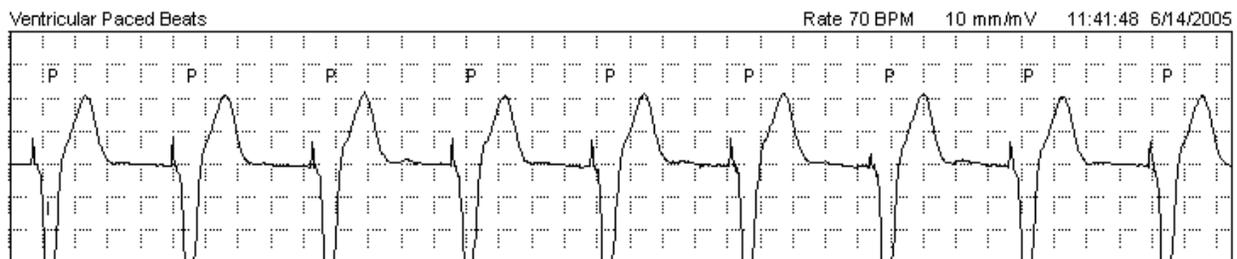


*Vision Express Approach* – After eliminating artifact and ensuring all ectopic beats are labeled appropriately, the analysis program measures the ST segment for each normal beat and averages the measurements. The Profile and Trend displays will show any change in ST segments and elevation episode onset, offset and durations will be reported according to user-defined thresholds.

## Pacemaker Analysis

Pacemakers fall into categories that are identified by three-letter abbreviations that describe their pacing, sensing, and response mechanisms. The first letter identifies the location of the pacing electrode(s); the choices are “A” for atrial, “V” for ventricular, and “D” for dual (both atrial and ventricular). The second letter identifies the location of the sensing electrode(s); again the choices are “A”, “V”, and “D”. The third letter identifies the appropriate response of the pacing electrode(s): the choices are “I” for inhibited, “T” for triggered, and “D” for dual (both inhibited and triggered).

**Ventricular Demand Pacemaker (VVI)** – A VVI pacemaker senses in and paces only the ventricles. Pacing of the ventricles is inhibited when the pacemaker senses ventricular activity. When the pacemaker senses that no ventricular activity has occurred in a certain pre-defined time period (for example one second, corresponding to 60 beats per minute), it will fire to initiate a beat. This results in a paced escape rhythm whenever the patient’s intrinsic rate drops below the rate of the pacemaker.



*Vision Express Approach* – When pacemaker detection is turned on, ventricular paced beats are declared when the beat is paced and a pacemaker spike is immediately before the beat.

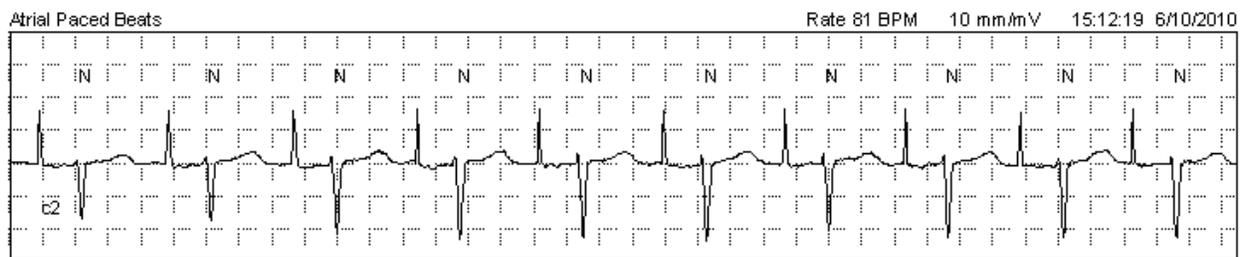
**AV Sequential Pacemaker (DVI)** – A DVI pacemaker paces both atrial and ventricular chambers whenever it does not sense ventricular activity during a certain pre-defined time period. Functionality is similar to that of a VVI, but the patient has a higher cardiac output by also pacing the atria.



*Vision Express Approach* – When pacemaker detection is turned on, the analysis program will declare a beat is Atrial paced when the beat is normal and the pacer spike precedes the beat. Ventricular paced beats (P) are declared when the beat is paced and a pacemaker spike is immediately before the beat. Dual paced beats (D) are declared when atrial and ventricular spikes are successive and the beat is identified as paced.

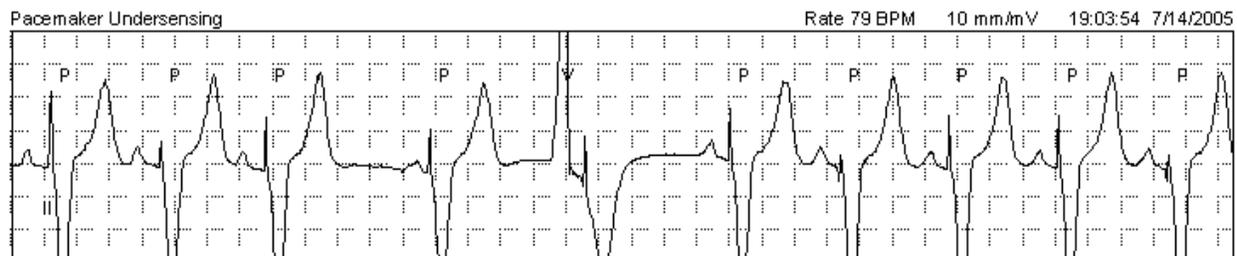
**Dual Demand Pacemaker (DDD)** – A DDD pacemaker independently paces and senses in both atrial and ventricular chambers. This results in three different modes of pacing:

1. Atrial pacing by sensing no atrial or ventricular activity has occurred. If conduction is normal, the impulse travels through the ventricles;
2. Atrial tracking by sensing atrial activity but no ventricular response, the pacemaker initiates electrical activity at the ventricular lead;
3. Dual-chambered pacing by sensing no atrial or ventricular activity, the pacemaker initiates electrical activity at the atrial lead. If the impulse does not conduct through normally and there is no ventricular response, the ventricular lead initiates the electrical impulse in the ventricles.



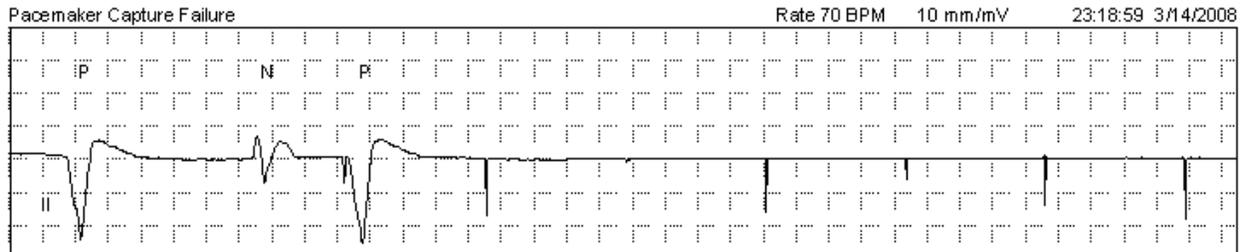
*Vision Express Approach* – When pacemaker detection is turned on, the analysis program will declare a beat is Atrial paced when the beat is normal and the pacer spike precedes the beat. Ventricular paced beats are declared when the beat is paced and a pacemaker spike is immediately before the beat. Dual paced beats are declared when atrial and ventricular spikes are successive and the beat is identified as paced.

**Pacemaker Failure to Sense** – If either an atrial or a ventricular sensing electrode does not sense either a P-wave or a QRS complex that occurs, the failure is called a “sense failure”. This is sometimes also referred to as undersensing. Failure of the ventricular-inhibited lead to sense a QRS results in an early paced beat. Failure of an atrial-triggered lead to sense a P-wave results in a non-tracked P-wave.



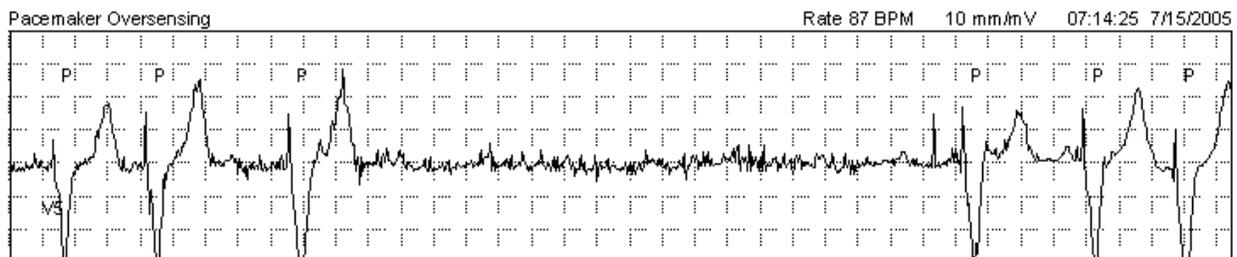
*Vision Express Approach* – The analysis program will identify when a pacer spike is earlier than expected and is less than one-third the time from its preceding beat. This failure can be found in the Pacer Profile display.

**Pacemaker Failure to Capture** – When any pacing electrode fires and fails to initiate depolarization, the failure is called a “capture failure”. This is characterized by either an atrial or a ventricular spike not followed by a subsequent P-wave or QRS complex.



*Vision Express Approach* – The analysis program will identify when a beat is not present after the pacer spike with an interval greater than 300 msec. This failure can be found in the Pacer Profile display.

**Pacemaker Oversensing** – When either an atrial or a ventricular sensing electrode senses a P-wave or a QRS complex that does not occur, the failure is called inappropriate inhibition or “oversensing”. If a ventricular-inhibited lead senses inappropriately and fails to fire, the result is a longer than programmed RR interval; oversensing often happens during exercise and may be caused by sensing of the muscle activity.



*Vision Express Approach* – The analysis algorithm will identify when the RR interval is greater than 1.2 times the expected paced interval after the beat. This failure can be found in the Pacer Profile display and also under maximum RR/Pause events.