

# Poincaré Graph

Complete ECG record in one sight

# Motivation

Verification of an ECG Holter record is often a big challenge in a medical praxis. This is mainly due to the existence of technical artefacts and noise in the signal. In order to speed-up and simplify this verification, BTL has implemented a special tool in its Holter system BTL CardioPoint-Holter – the Poincaré graph. This graph can summarize a complete Holter record (even several days long) in one picture! Furthermore, BTL has made the Poincaré graph even more useful by making it interactive. Instead of only viewing the graph, it is possible to click in it, make user selections and then browse through the selected events. With such interactivity, the Poincaré graph has become a powerful and fast tool not only in analyzing patients' HRV, but also in revealing rhythm disorders and potentially recorded technical artefacts.

**BTL'S POINCARÉ GRAPH USE CASES:**

- Detection of changes in heart rate variability (HRV)
- Detection of Atrial Fibrillation or Flutter
- Identification of ectopic beats
- Detection of pauses
- Verification of the automatic diagnostics
- ECG record quality analysis

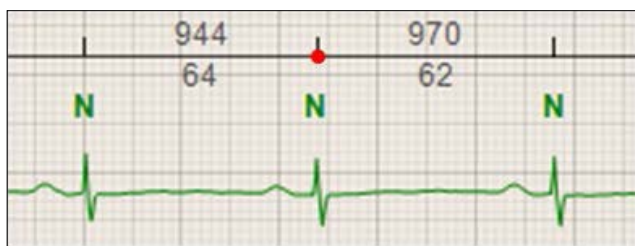


The Poincaré graph was developed by a French mathematician Henri Poincaré in 1890. Besides the medical science, it has found its use in physics and astronomy, geophysics, meteorology and mathematical biology. Synonyms for Poincaré graph are Lorenz plot and Scattergram.

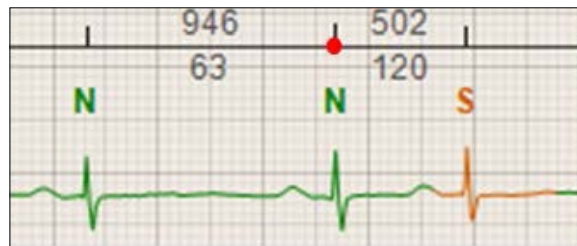
## Constructing a Poincaré graph

The Poincaré graph plots an RR interval against the preceding RR interval. Each couple of RR intervals is then displayed as one dot in the graph. The longer the record, the more dots appear in the graph. These dots usually tend to build one or more clusters, some might however remain isolated. Shape, size and position of these clusters are the main characteristics to be used for HRV and rhythm analysis.

**EXAMPLE:**

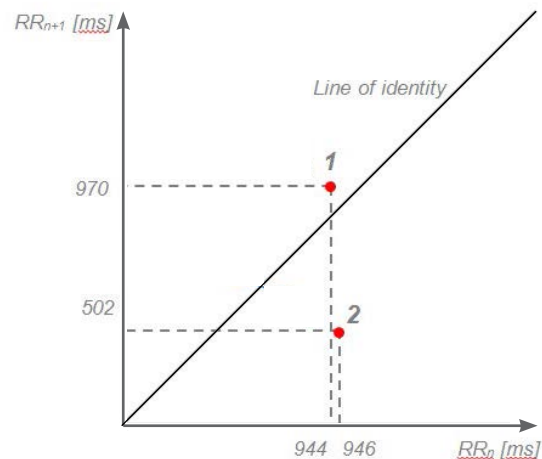


1



2

In the first ECG strip, the first RR is 944 ms (~64 bpm), second RR is 970 ms (~62 bpm). This couple of RR intervals is displayed as point 1 in the graph. In the second ECG strip, the first RR is 946 ms (~63 bpm) and the second one is only 502 ms (~120 bpm) due to an occurrence of supraventricular premature beat. This couple of RR intervals is shown as point 2 in the graph.



# Reading a Poincaré graph

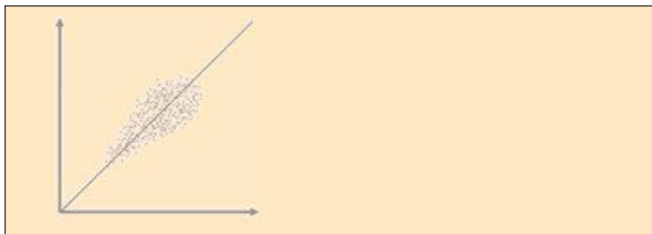
The physician attempting to interpret a Poincaré graph should have the following knowledge:

1. knowing the principle of constructing a Poincaré graph
2. knowing how a Poincaré graph of a healthy person looks like
3. knowing how to interpret deviations from a normal Poincaré graph

While the first point was already discussed in the previous section, the other two will be described in the following text.

## POINCARÉ GRAPH OF A HEALTHY PERSON

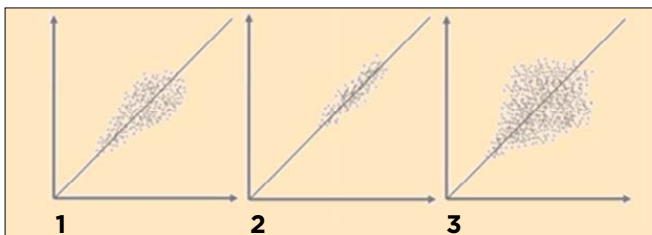
Typically, the Poincaré graph of a healthy person reminds of a comet (narrow at the bottom and gradually getting wider towards the top along the line of identity). Its length is significantly bigger than its width. There is only one main cluster and no others, there are only few separate dots and none of them is very far from the main cluster. The main cluster is located along the line of identity. There are also no dots above 2000 ms on both axes.



Normal graph

## LENGTH AND WIDTH OF THE MAIN CLUSTER:

The first thing to be considered is the length and width of the main cluster (the cluster along the line of identity; length is measured from the zero point of the graph along the line of identity). The length reflects the contribution of non-respiratory components to the total HRV. The longer the cluster, the more is the total HRV affected by nonrespiratory components. The width of this cluster shows how respiratory sinus arrhythmia contributes to the total HRV. Again, the wider this cluster, the higher the effect of respiratory arrhythmia to the total HRV.

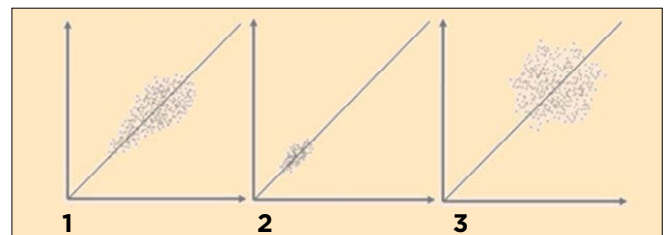


Length & Width

1. normal
2. narrow shape: dominance of the nonrespiratory components regulating the heart rate (sympaticus prevails)
3. wide shape: dominance of the respiratory components regulating the heart rate (parasympaticus prevails)

## POSITION OF THE MAIN CLUSTER

Second important characteristic is the position of the main cluster in the graph. It may indicate which nervous system has a bigger influence on patient's heart rate (sympaticus or parasympaticus). If the location of this cluster is rather at the bottom of the graph, sympaticus prevails and tachycardias may be found in the record. Typically, such cluster also tends to be very narrow, because with shorter RR, the variability becomes smaller. Opposite situation happens with the main cluster appearing in the top right corner. Such appearance is an evidence of parasympaticus having a high impact on patient's heart rate. Bradycardia is then present. Often, the main cluster in the upper right position tends to be rather wide (reflecting the fact that HRV becomes higher with lower heart rates/higher RR).

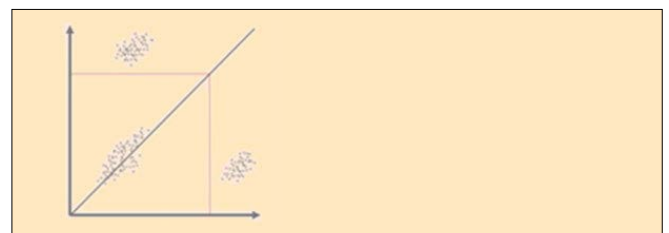


Position

- 1 in the centre: normal
- 2 in the lower part along the line of identity: sympaticus prevails, tachycardia appearance
- 3 in the upper part along the line of identity: parasympaticus prevails, bradycardia appearance

## EXISTENCE OF DOTS OUTSIDE OF THE MAIN CLUSTER:

If there are other clusters (or even individual dots) in the graph that are significantly separated from the main cluster, arrhythmia occurrence can be expected. Typically these clusters (individual dots) represent premature supraventricular or ventricular beats or pauses.



Each dot above the 2000 ms line on both axes should be inspected for a possible pause appearance.

**ECTOPIC BEATS DETECTION:**



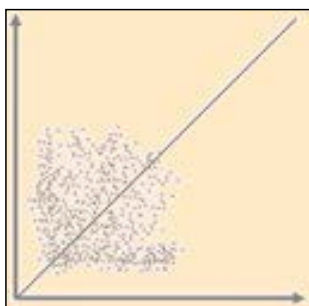
*The ectopic beats in the ECG signal usually create several separate clusters in the Poincaré graph. This example shows how these clusters can be interpreted.*

- 1 Main cluster. Only the RR interval couples that are formed by normal beats (NN) can be found here. Horizontal axis - normal RR interval (normal distance on the horizontal axis) Vertical axis - normal RR interval (normal distance on the vertical axis)
- 2 The dots in this area represent an RR interval formed by normal beats (NN) followed by an ectopic RR (e.g. supraventricular - NS). Horizontal axis - normal RR interval before the ectopic premature beat (normal distance on the horizontal axis) Vertical axis - ectopic RR containing the ectopic premature beat (short distance on the vertical axis)

- 3 This cluster reflects an ectopic RR (e.g. NS) followed by a post-ectopic RR (e.g. SN). Horizontal axis - ectopic RR containing the ectopic premature beat (short distance on the horizontal axis) Vertical axis - post-ectopic RR interval following the ectopic premature beat (long distance on the vertical axis)
- 4 These dots represent a post-ectopic RR (e.g. SN) followed by a normal RR (NN). Horizontal axis - post-ectopic RR interval following the ectopic RR (long distance on the horizontal axis) Vertical axis - normal RR interval following the post-ectopic RR (normal distance on the vertical axis)

**SHATTERED (SPILLED) IMAGE:**

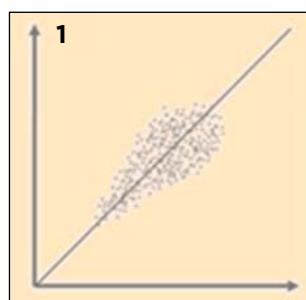
A high amount of dots that do not tend to create clusters and rather seem to be randomly distributed in the graph may often be only a sign of technical artefacts, but sometimes they are a proof of Atrial Fibrillation or Atrial Flutter. The image in the graph then often looks shattered or spilled. Selecting the desired area in such image then allows to reveal a corresponding ECG signal and distinguish between the fibrillation, flutter or noise.



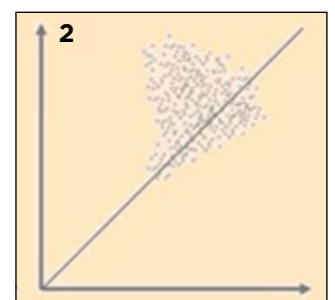
Atrial Fibrillation or Flutter manifests itself as a shattered (spilled) image.

**SYMMETRY:**

Symmetry along the line of identity is the last factor that should be considered in the Poincaré graph analysis. When the main cluster displays signs of asymmetry, occurrence of rhythm disorders is possible.



1 - symmetric

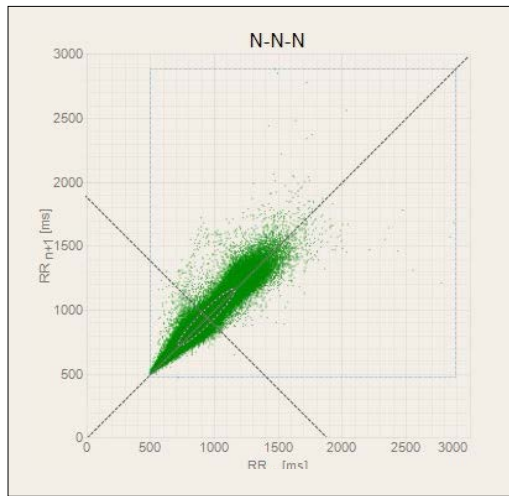


2 - asymmetric

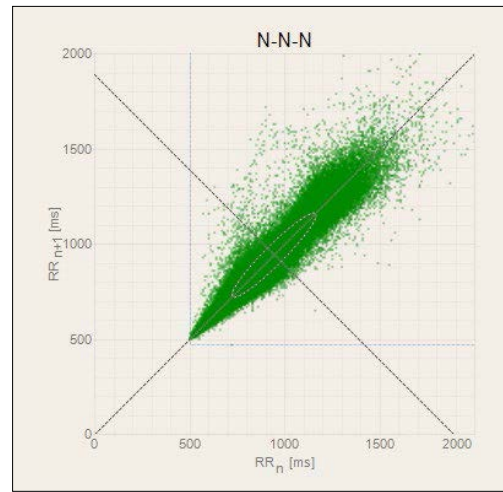
**IMPORTANT NOTE**

It is very important to pay attention to the scale on both axes of the graph when making the analysis. The image of the same data (same examination record) will look different (bigger/smaller, also might be shifted towards one of the ends of the line of identity) depending on this scale.

Example: The same ECG record visualized in Poincaré graphs with different scales.



1 - 3000 ms

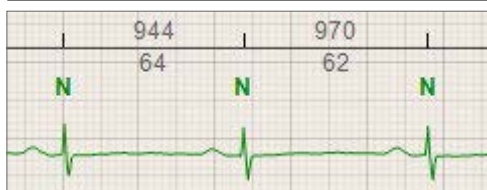
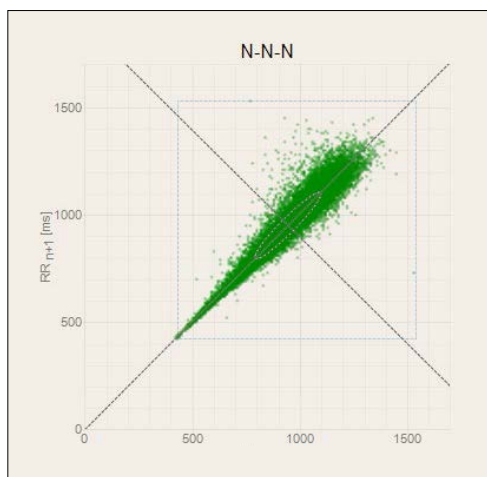


2 - 2000 ms

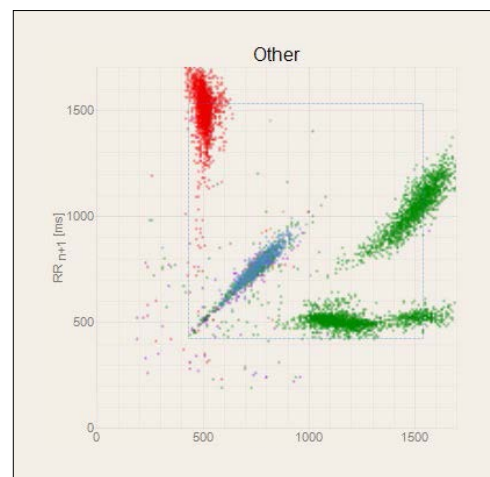
## Poincaré graph views

There are two views with the Poincaré graphs in the BTL CardioPoint-Holter. The first one, called “N-N-N”, is only formed by RR couples with normal beats (normal morphology). It is useful mainly for HRV diagnostics as the HRV can only be analyzed on normal beats. Furthermore it can be used to detect pauses. Ectopic premature beats, atrial fibrillation or flutter may also appear in this graph if they are undetected by the automatic diagnostics. The second graph, called “Other”, shows all abnormal RR couples. Typically it can be used to easily detect ectopic premature beats or intervals of Atrial Fibrillation or Flutter. The dots in this graph may be coloured depending on the automatic diagnostics (green- normal, red - ventricular premature beats, yellow - supraventricular premature beat, blue - Atrial Fibrillation or Flutter, violet - unknown).

**TYPES OF POINCARÉ GRAPHS:**



N-N-N

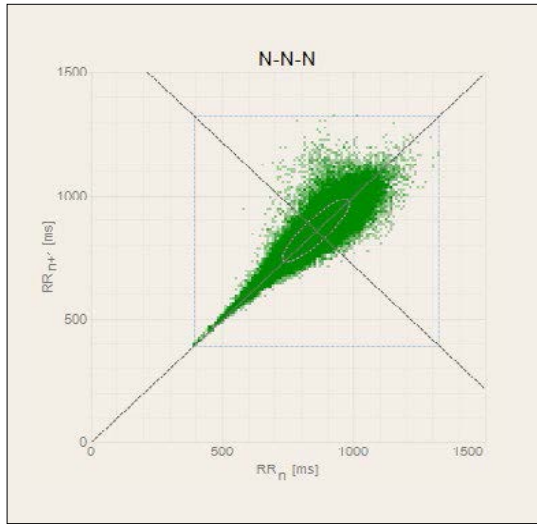


N-V-N sequence (Other)

# Examples

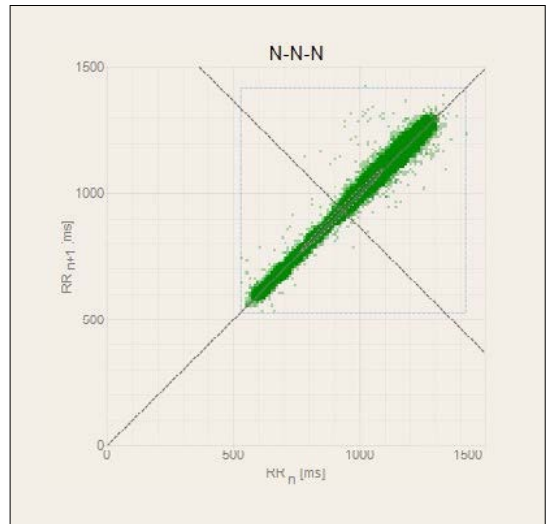
This section shows several examples of real ECG recordings and their Poincaré graphs. Versatility of this tool will be demonstrated.

## NORMAL ECG

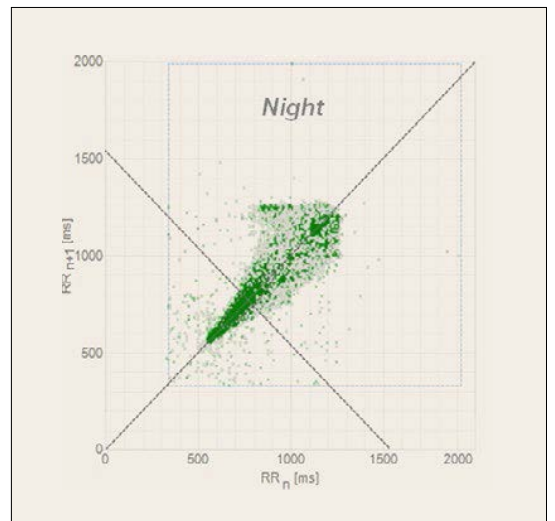
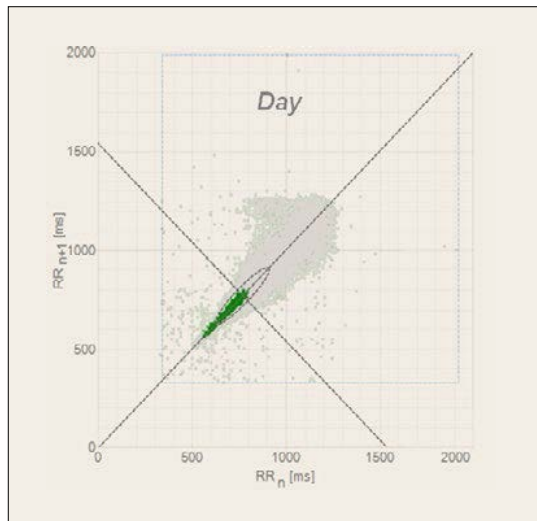


This image shows how a typical Poincaré graph of a healthy person might look like.

## LOW HRV

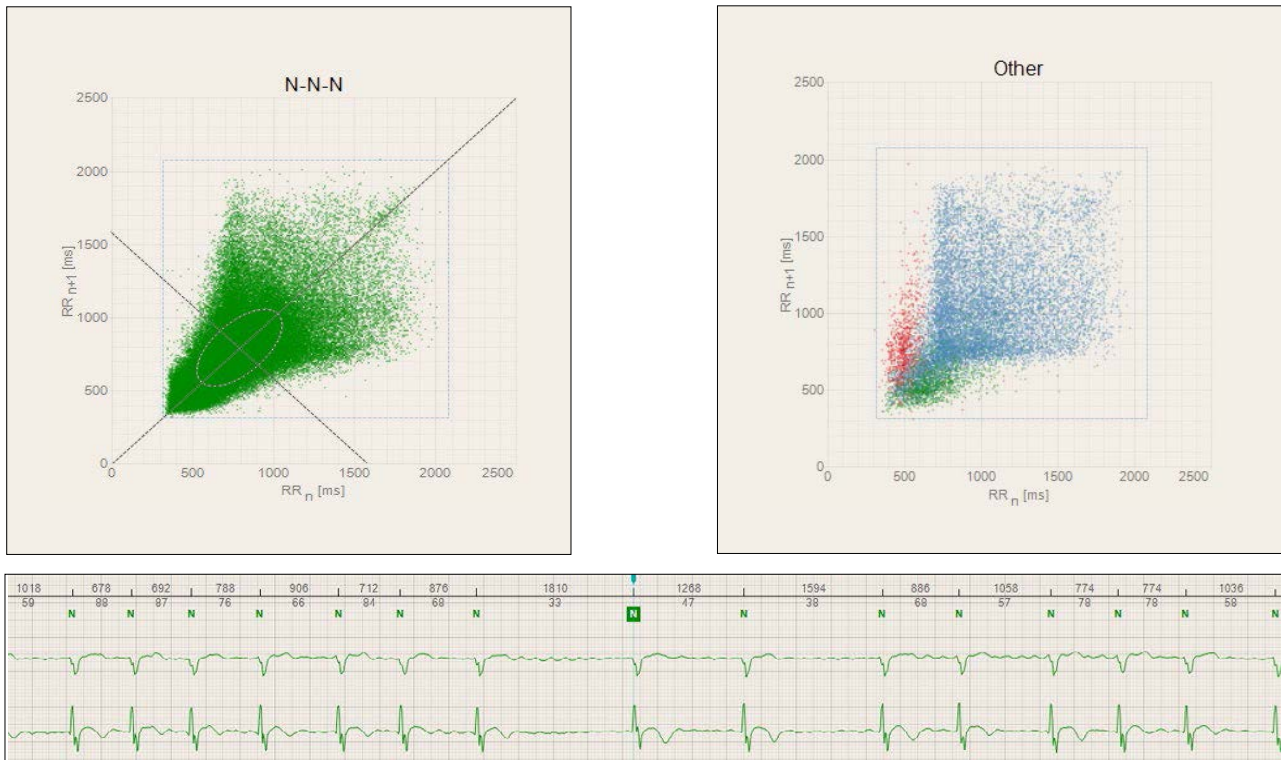


## LOW HRV DURING THE DAY, NORMAL HRV AT NIGHT:



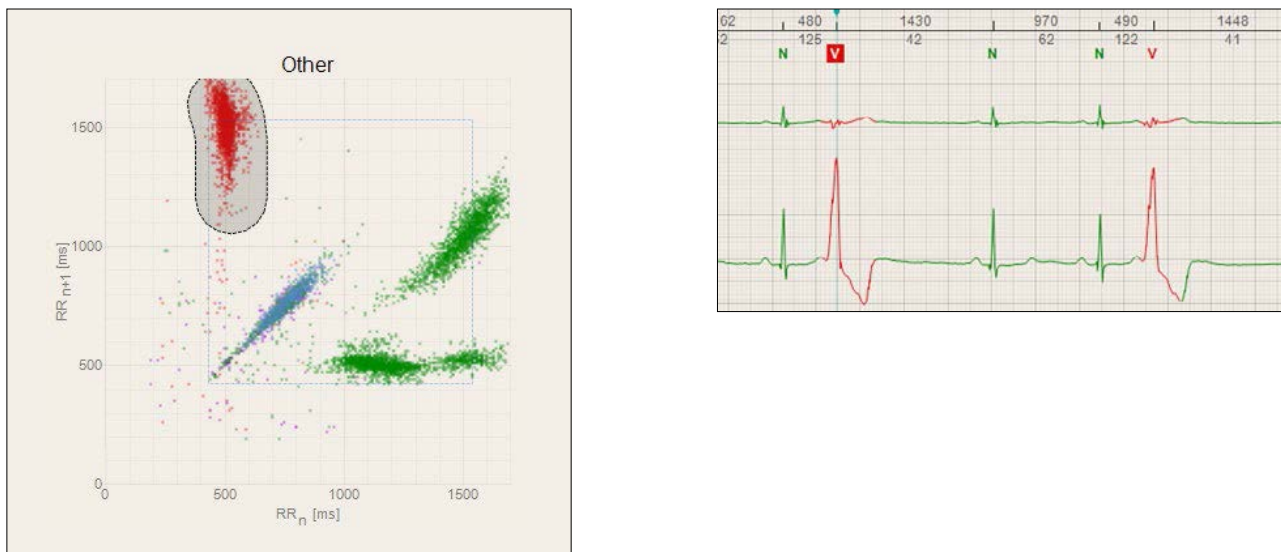
The BTL CardioPoint software doesn't only show the Poincaré graph as an image of the whole record. It can also show only a particular interval, such as selected 30 minutes, 6 hours, 12 hours etc. Hence it is possible to see how the HRV changes in time or when the arrhythmias start to appear or when they fade out. Pictures above clearly show that the day variability is rather small, while the night one is normal.

**ATRIAL FIBRILATION:**



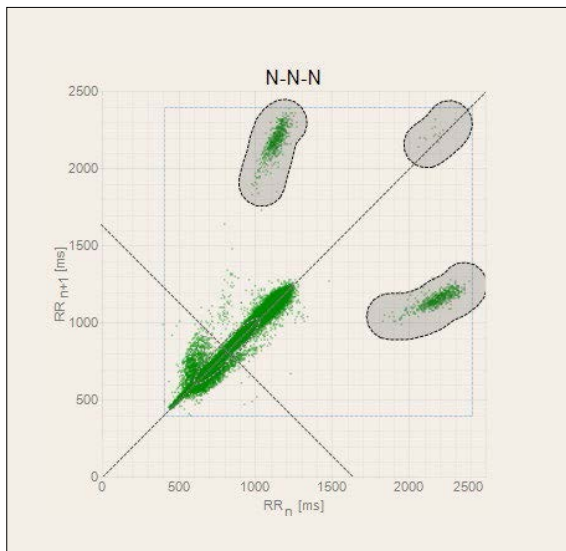
Atrial Fibrillation manifests itself as shattered image in the Poincaré graph due to permanent and radical changes in RR. In the CardioPoint software, this image can appear in both graphs (N-N-N and Other) depending on whether the Atrial Fibrillation was automatically recognized (if so, blue points appear in the Other graph) or not (shattered image in the N-N-N graph).

**VENTRICULAR PREMATURE BEATS:**



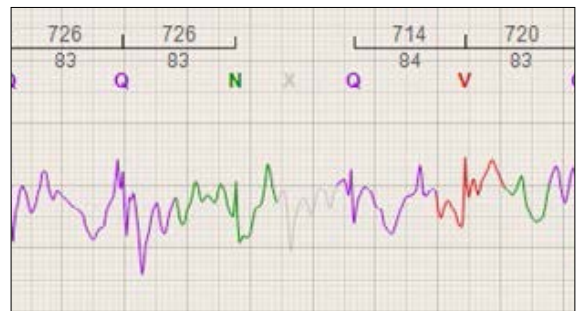
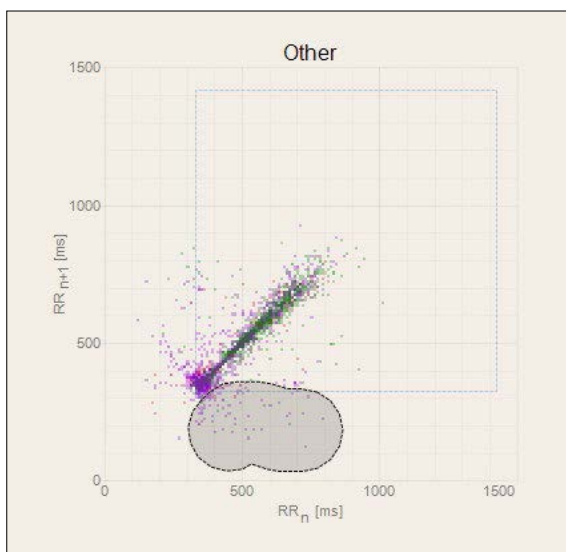
All the marked red points in the Poincaré graph represent couples of RR intervals around the ventricular premature beats (N-V-N). Since there is only one red cluster in this example, all the ventricular premature beats can be determined as monotopic (originating from the same point). Polytopic premature beats typically manifest themselves as more than one red cluster in the Poincaré graph.

**PAUSES**



It is extremely easy to detect pauses using the Poincaré graph. All the pauses manifest themselves as dots above the 2000 ms lines. The picture shows that pauses are frequent at this patient and that they are shorter than 2400 ms. The smallest cluster (in the upper right corner) represents two adjacent pauses.

**NOISE**



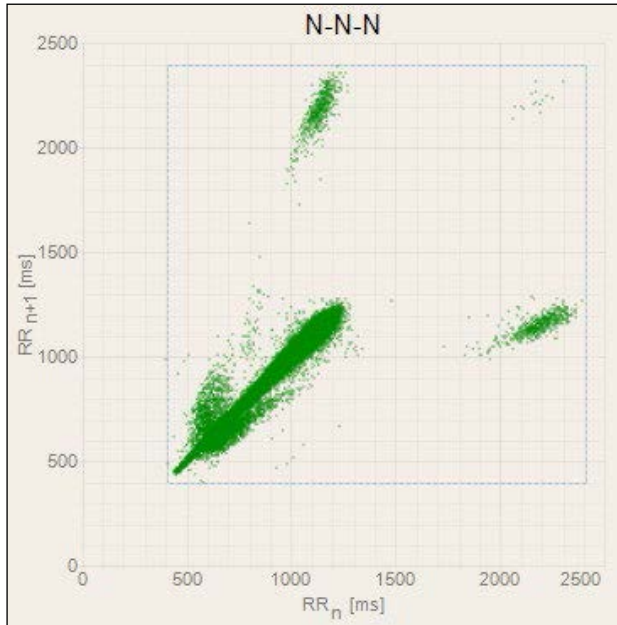
This picture can be used to demonstrate revealing noisy areas in the signal (misinterpreted RR intervals). Marking the area of suspicious points and then browsing in the ECG strip shows whether there are ectopies in the signal or a noise due to leadoff. Noisy areas can be easily deleted.



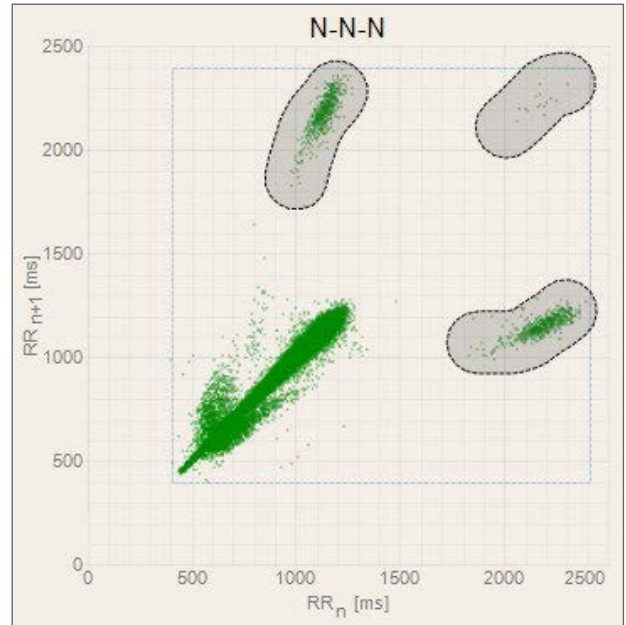
## BTL's contribution

Although the Poincaré graph has been implemented in many commercial Holter systems, only the BTL CardioPoint makes it interactive. Any section in the graph can be marked and all events (represented by individual dots) inside the selection can be reviewed and verified. This makes the Poincaré graph not only a tool for analyzing patients' HRV, but also a tool for detecting rhythm disorders and potential noisy areas.

### WORK PROCEDURE EXAMPLE 1:



From the very first look, the Poincaré graph looks suspicious as there are more clusters. Furthermore, these clusters are positioned behind the 2000 ms range. This may indicate pauses, but also noise (falsely diagnosed pauses). Hence it is recommended to review the ECG strips corresponding to the dots inside these clusters.

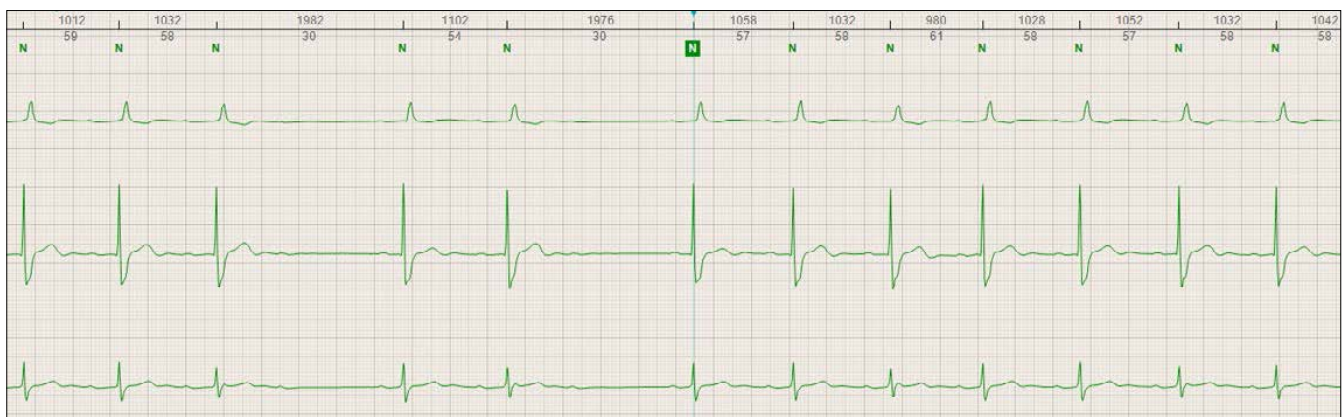


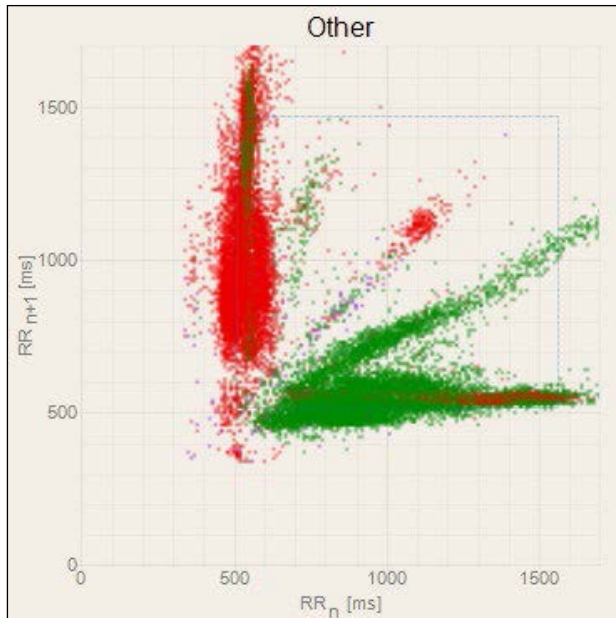
Marking the clusters and using the navigation buttons (Next Beat, Previous Beat, First Beat, ...) now allows to reveal and browse through all the events in the ECG strip window. Any falsely detected pause can be easily removed from the diagnostics using the Delete button.



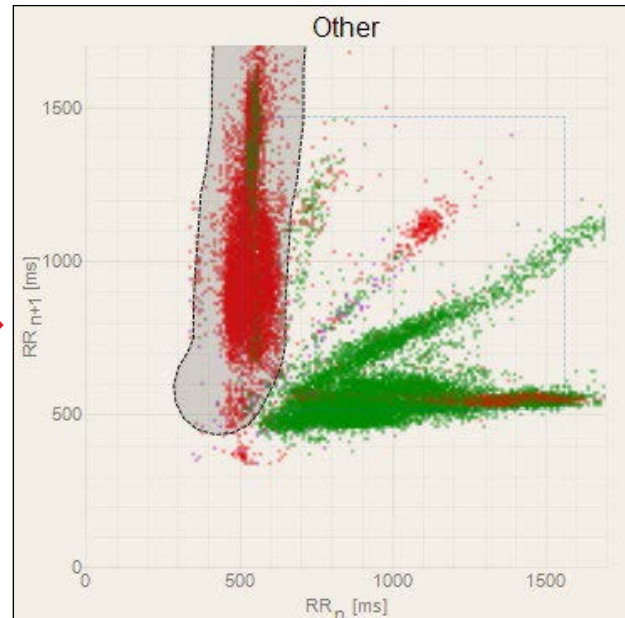
The navigation menu contains the following elements:

- Left arrow button
- Right arrow button labeled "Next Beat"
- Left arrow button labeled "First Beat" and right arrow button
- Red "X" icon labeled "Delete" and two circular arrows (refresh/reset)
- Down arrow button labeled "Next Row"
- Radio button selected for "Sort by Time"
- Radio button for "Sort by Value"

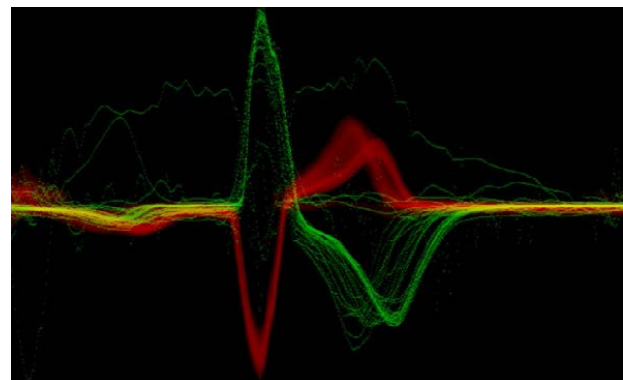


**WORK PROCEDURE EXAMPLE 2:**

In a healthy person, the graph *Other* should stay empty since any dot in this graph may correspond to an ectopy. In this example, the graph is full of dots that furthermore form a pattern typical for premature beats. Moreover, the red color indicates ventricular beats. It is hence recommended to explore the corresponding ECG signal



Marking an area of interest is again the first step. Now instead of browsing the ECG strip, pressing the “/” button on keyboard will open a Graphical Split tool.



The Graphical split tool displays all the heart beats based on the selection made in the Poincaré graph one behind each other. Hence, an instant and clear look at all the selected beats is provided and all morphologies can now be easily compared. In this example, it is possible to see that polytopic (having different shapes) premature ventricular beats are present in the signal.



## About BTL CardioPoint

The BTL CardioPoint is a versatile software solution integrating ECG, Stress test, Holter, ABPM and Spirometry into one unified platform with one patient database and the same logic of controls for each module. The software has a fully customizable interface, and its layout and work steps can be easily adapted. The operator is allowed to arbitrarily add or move tables, ECG strips and other windows. Fast and intuitive work is ensured by an ergonomically optimized user interface with shortened mouse tracks and hotkeys. Colour schemes are designed for both dark and light ambience. The BTL CardioPoint can be used as a stand-alone cardiology system, or it can be seamlessly integrated into an existing ambulatory or hospital system. The BTL CardioPoint is software that adapts to the user, instead of the user having to adapt to the software.

