Poincaré Plots: A Mini-Review

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Henri Poincaré (1854-1912)

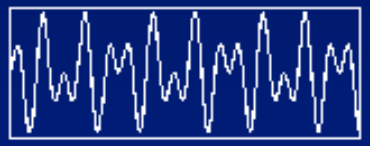
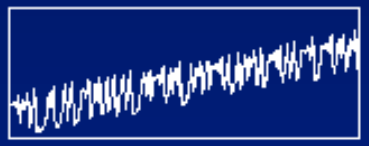
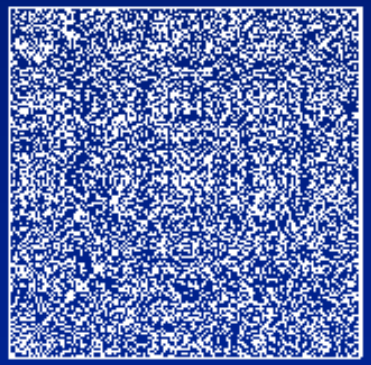
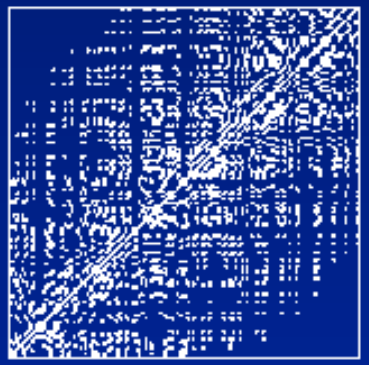
Poincaré plot

- Poincaré HRV plot is a graph in which each RR interval is plotted against next RR interval (a type of delay map)

- Synonyms
  - Scatter plot; scattergram
  - Return map; phase delay map
  - Lorenz plot

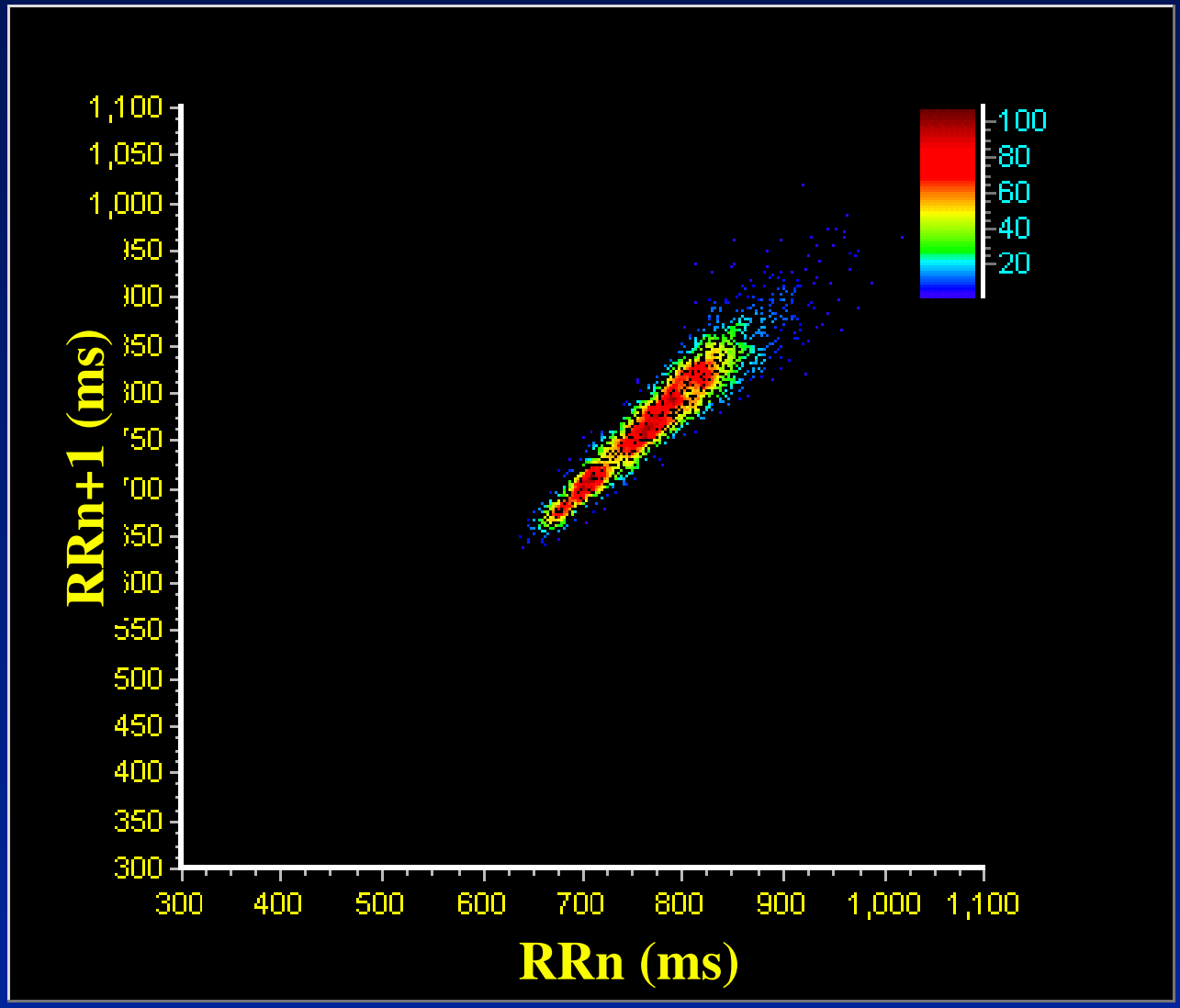
Poincaré & related plots as nonlinear tools

Visualization of higher-dimensional phase spaces in two or three-dimensional sub-spaces

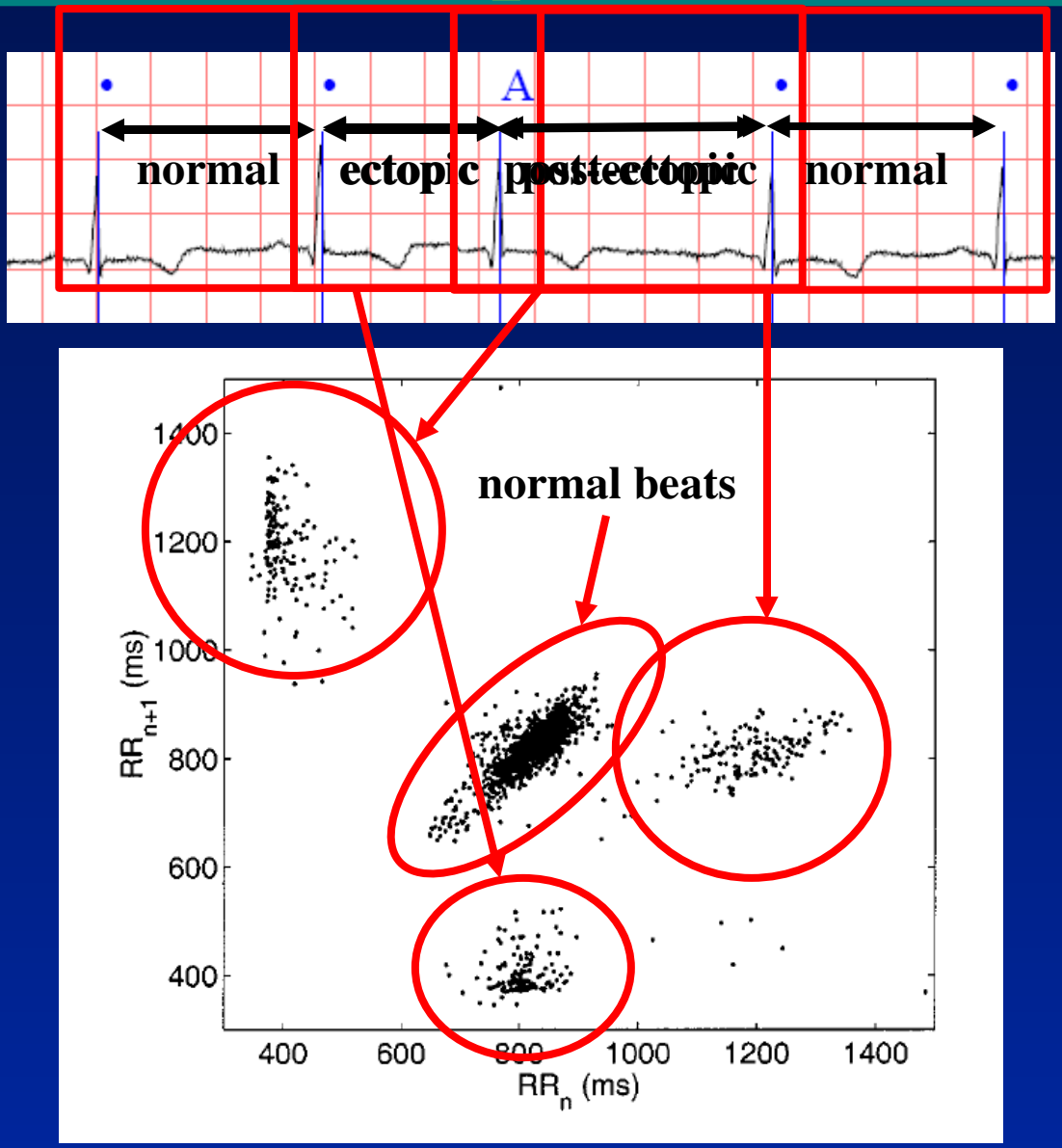
uncorrelated noise	harmonic oscillation	chaotic time series with linear trend	time series generated from an AR model
			
			

Source: http://en.wikipedia.org/wiki/Recurrence_plot

Poincaré HRV plot: normal



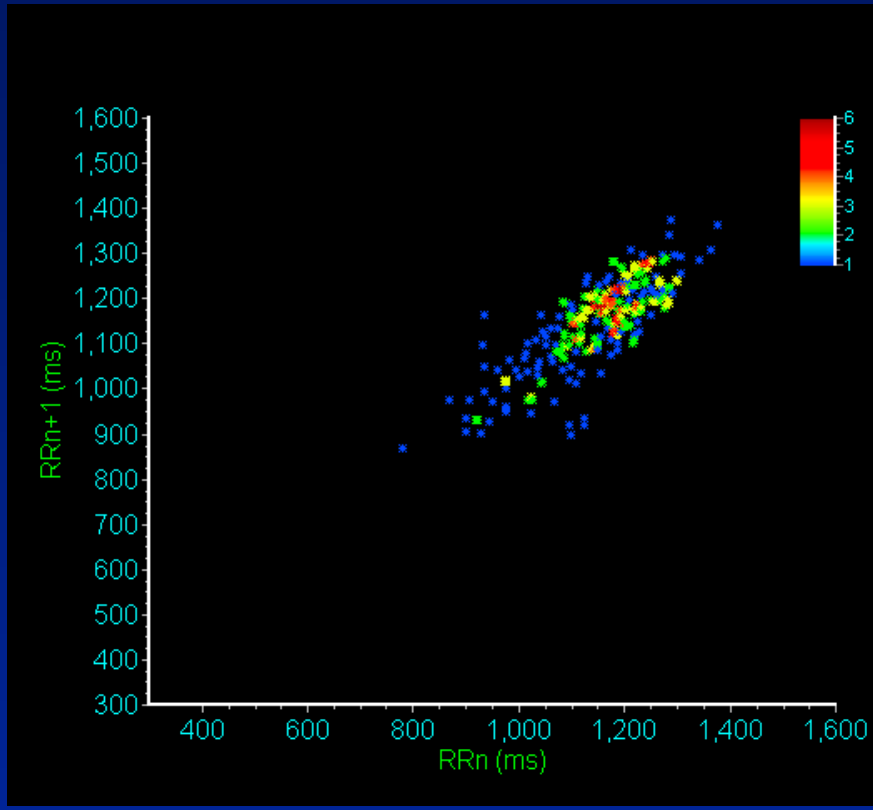
Visualization of ectopic beats



Poincaré HRV plot: healthy vs. disease

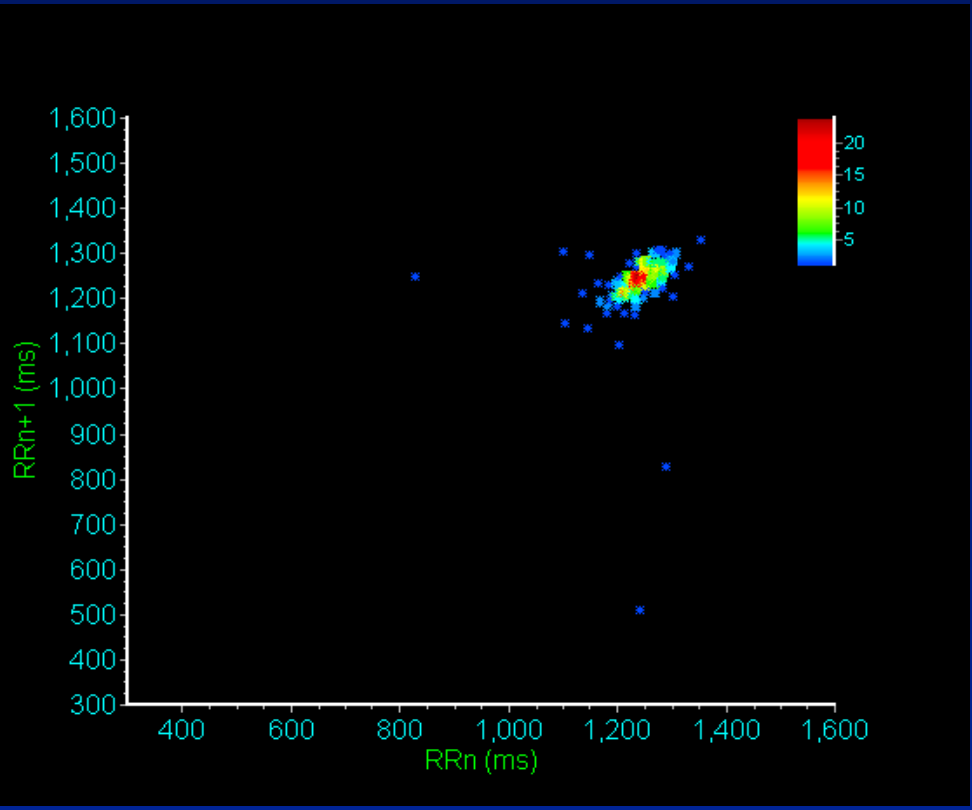
Healthy Control

mean heart rate : 52 bpm



Critically ill Patient

mean heart rate : 51 bpm



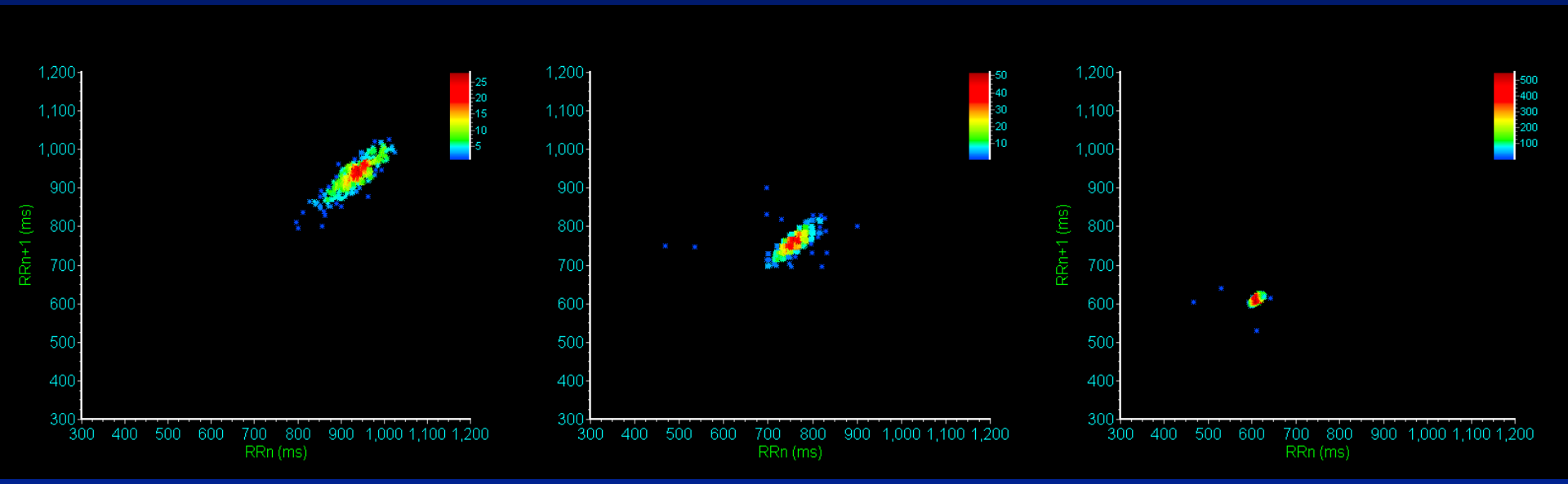
Data Source: Taipei Veterans General Hospital, Taiwan

HRV in different stages of cancer

Early-detected cancer patient

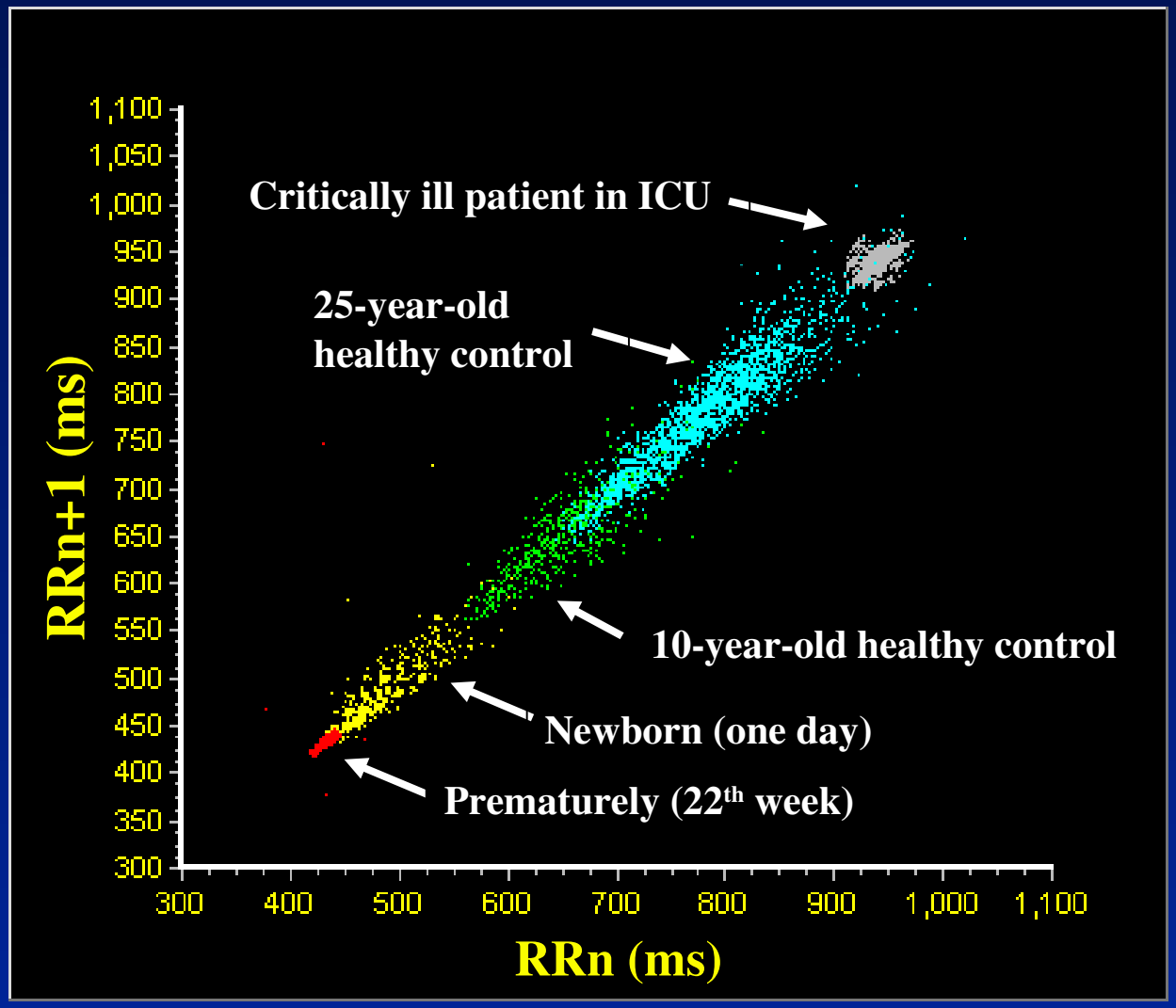
Chemotherapy cancer patient

Hospice cancer patient



Data Source: Taipei Veterans General Hospital, Taiwan

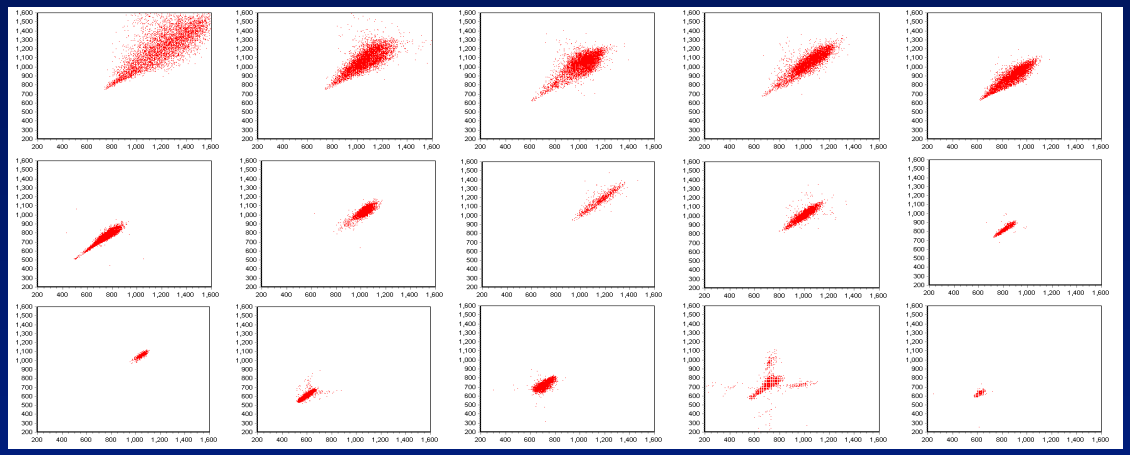
How aging and illness may affect the geometry of Poincaré HRV plot



Data Source: Taipei Veterans General Hospital, Taiwan

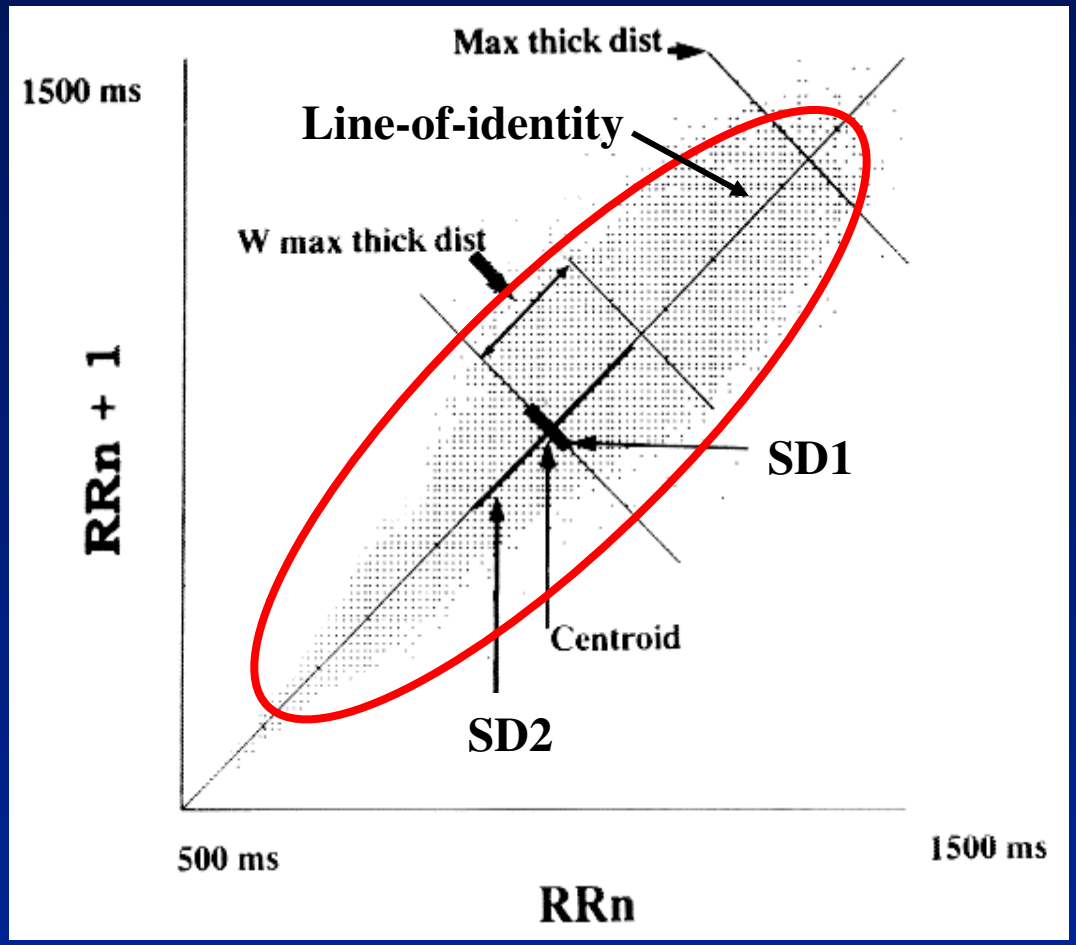
Quantitative analysis of Poincaré HRV plots

Variable geometries of Poincaré HRV plots



- Ellipse fitting technique
- Histogram technique
- Correlation coefficient

Ellipse fitting technique



SD1: dispersion (standard deviation) of points perpendicular to the axis of line-of-identity

SD2: dispersion (standard deviation) of points along the axis of line-of-identity

Huikuri, H. V. et al. Circulation 1996;93:1836-1844

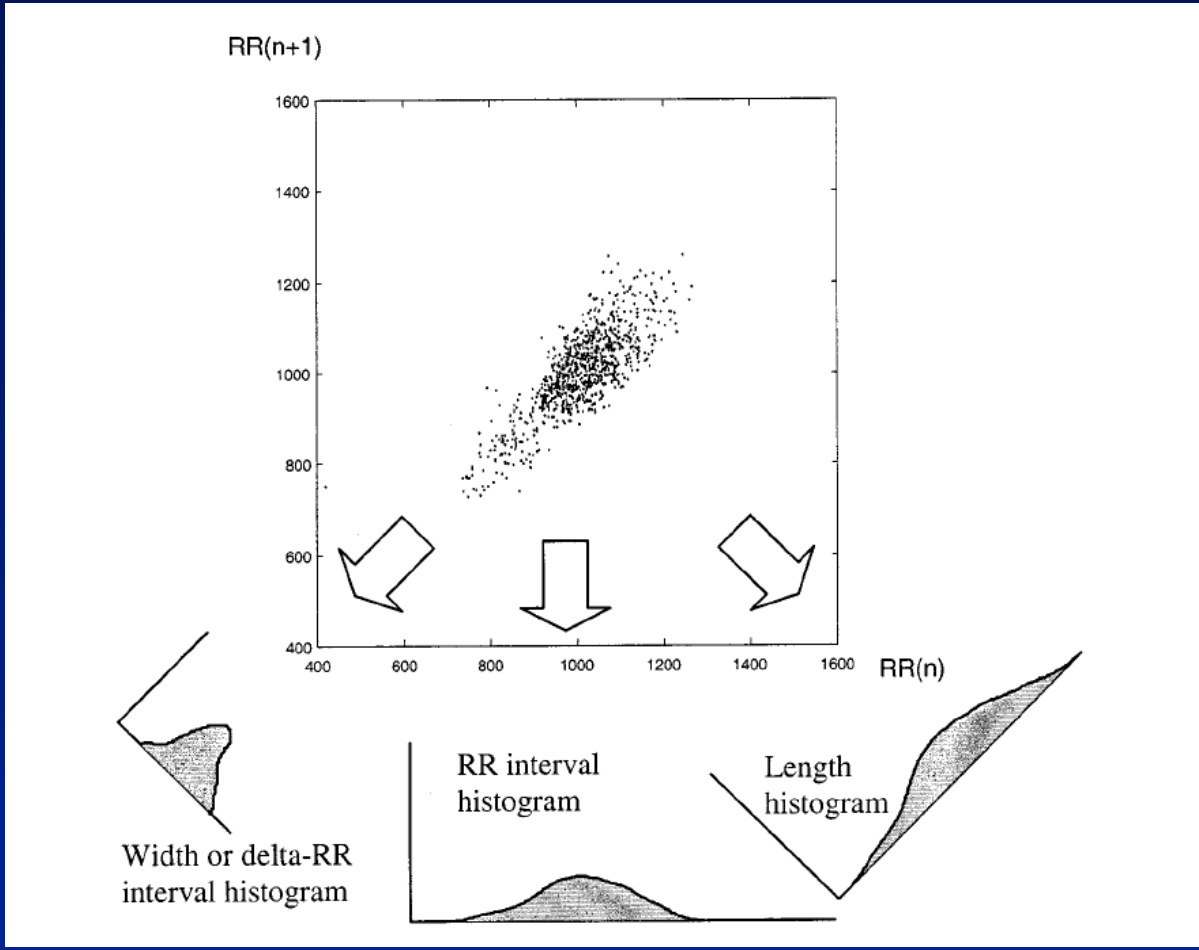
Ellipse fitting technique – Risk Stratification in Cardiovascular Disease

Table 1. Studies of Non-Linear HRV in Cardiac Patients

Reference	Population	Results/Conclusions
Brouwer et al., 1996 [19]	95 pts with HF, HRV and Poincaré plots from 24 hr holter recordings (Ibopamine Multicenter Trial study group)	Shape of Poincaré plots independent prognostic value in pts with mild to moderate HF
Bigger et al., 1996 [2]	(1) 715 pts with recent MI (2) 274 healthy pts (3) 19 pts with heart transplant (Multicenter Post Infarction Program)	MI or denervation of the heart causes a steeper slope and decreased height of power law slope
Huikuri et al., 1999 [10]	446 with MI with decreased LV function (EF<35%) F/U 685±360 days	Alpha 1 is the most powerful predictor of all cause mortality
Huikuri et al., 1998 [7]	Random sample of 347 patients of >65 yrs F/U for 10 yrs	Power law slope is a more powerful predictor of death than the traditional risk markers in elderly subjects
Kamen et al, 1995 [21]	Poincaré plot pattern to display beat to beat HRV data from 23 pts with HF and compared with 20 healthy people	Poincaré plot is a semi-quantitative tool which can be applied to the analysis of R-R interval
Laitio et al., 2002 [22]	HRV and Poincaré plots of 40 pts with CABG	SD1/SD2 ratio is the most powerful independent predictor of postoperative ischaemia
Laitio et al., 2004 [13]	32 pts aged ≥60 yrs admitted to hospital for surgical repair of traumatic hip fracture	Alpha-1 predicts post operative myocardial infarction
Lombardi et al.1996 [8]	HRV in 2 groups of pts after MI (normal and reduced LVEF). Group1: 20 pts; Group 2: 15 pts	Steeper slope of the negative regression line between power and frequency among reduced LVEF
Mäkikallio et al., 1998 [23]	38 pts with stable angina without previous MI or cardiac medication and 38 age matched healthy pts	Alpha-1 helps differentiate CAD and healthy pts

Stein PK et al. Indian Pacing and Electrophysiology Journal 2005;5:210-220

Histogram technique



Brennan M. et al. IEEE Trans Biomed Eng 2001;48:1342-47

Do these indices actually measure nonlinear properties of heart rate dynamics

Table 3. *Correlation coefficients among average HR, time and frequency domain measures, and quantitative beat-to-beat analysis of HR variability at ventilatory threshold*

	HR	SDANN	SDsd	SDsd/SDANN	HF	LF	LF/HF	SD1/SD2	SD2	SD1	ApEn
HR	1.0	0.63‡	0.59‡	0.16	0.47†	0.58‡	0.51†	0.18	0.61‡	0.58‡	0.54†
SDANN		1.0	0.54†	−0.51†	0.29	0.73‡	0.78‡	0.46†	0.99‡	0.52†	−0.45*
SDsd			1.0	0.33	0.70†	0.63‡	0.48†	0.27	0.49†	0.99‡	−0.47†
SDsd/SDANN				1.0	0.20	−0.18	−0.42*	0.94‡	−0.56†	0.36*	0.23
HF					1.0	0.21	0.07	0.15	0.24	0.70‡	0.27
LF						1.0	0.90‡	−0.18	0.73‡	0.62‡	−0.54†
LF/HF							1.0	−0.21	0.79‡	0.49†	−0.33
SD1/SD2								1.0	−0.52†	0.31	0.27
SD2									1.0	0.47†	−0.45*
SD1										1.0	−0.48†
ApEn											1.0

Values are Pearson's correlation coefficients; $n = 31$. See Table 2 for definition of abbreviations. *$P < 0.05$; †$P < 0.01$; ‡$P < 0.001$.

Tulppo MP et al. Am J Physiol 1996;271:H244-H252

Do these indices actually measure nonlinear properties of heart rate dynamics

- Ellipse fitting technique

$$\mathrm{SD1}^2 = \mathrm{Var}(x_1) = \mathrm{Var}\left(\frac{1}{\sqrt{2}}\mathrm{RR}_n - \frac{1}{\sqrt{2}}\mathrm{RR}_{n+1}\right)$$
$$= \tfrac{1}{2}\mathrm{Var}(\mathrm{RR}_n - \mathrm{RR}_{n+1}) = \tfrac{1}{2}\mathrm{SDSD}^2.$$

$$\mathrm{SD2}^2 = 2SDRR^2 - \tfrac{1}{2}\mathrm{SDSD}^2.$$

SDRR : standard deviation of the RR intervals

SDSD: standard deviation of the successive differences of the RR intervals

Brennan M. et al. IEEE Trans Biomed Eng 2001;48:1342-47

Summary

- Advantages
  - Simple visualization tool
  - Outlier (ectopic beat or artifact) identifier
  - Possible insights into short-term and long-term variability
- Limitations
  - Derived statistics not independent of other time domain measures