HRV 2006

Ectopic Beats, Activity Effects and Heart Rate Turbulence

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Outline

- Overview of Cardiovascular Nonstationarity
- Activity/Sleep-Wake Effects
- Ectopy
  - HR Turbulence
  - QT Turbulence

Overview: Dealing with Discontinuities

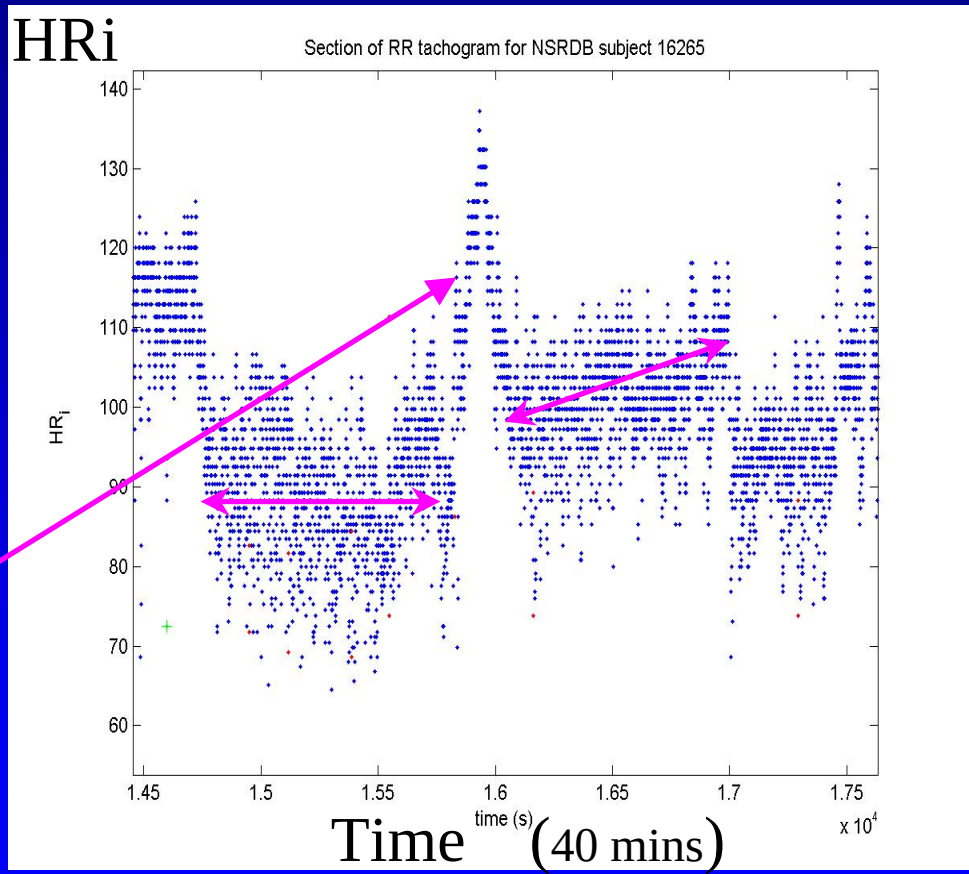
- RR tachogram unevenly sampled - Resampling introduces errors.
- Spectral methods assume linear, stationary processes
- RR tachogram is nonstationary; ***ectopy***, ***artefact*** or ***intrinsic cardiovascular changes***
- HRV is a function of both physical and mental activity
- Artefacts and ectopy can be removed, but this is also information
- Artefact is an indicator of state change
- Ectopy affects the RR tachogram **– Heart Rate Turbulence**

Cardiovascular Nonstationarity

Tachogram has many ***states*** with similar means or variances

Length of state varies ≈ minutes
(weakly stationary)

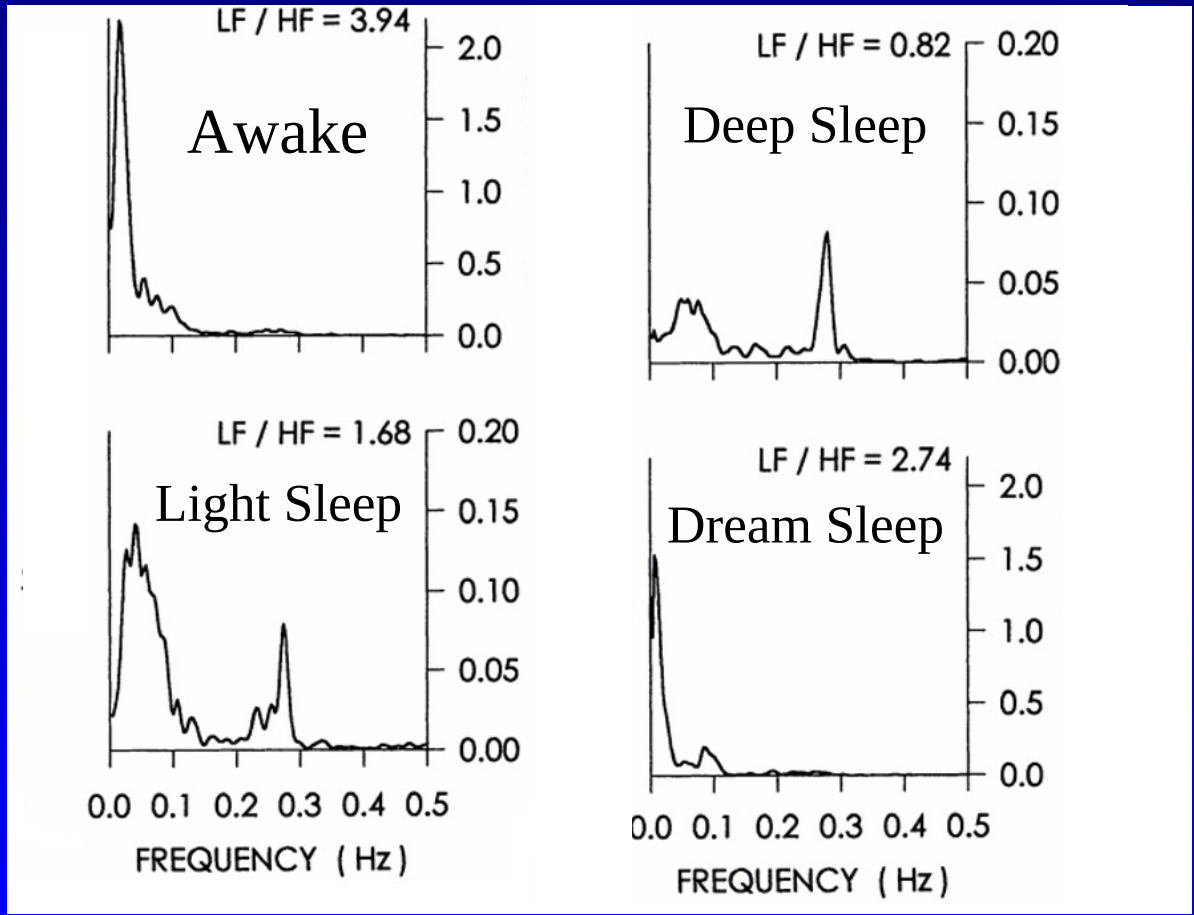
Movements between states have brief accelerations in RR interval → new mean and/or variance.



- Don’t apply HRV methods blindly - Must control for state!

HRV depends on activity

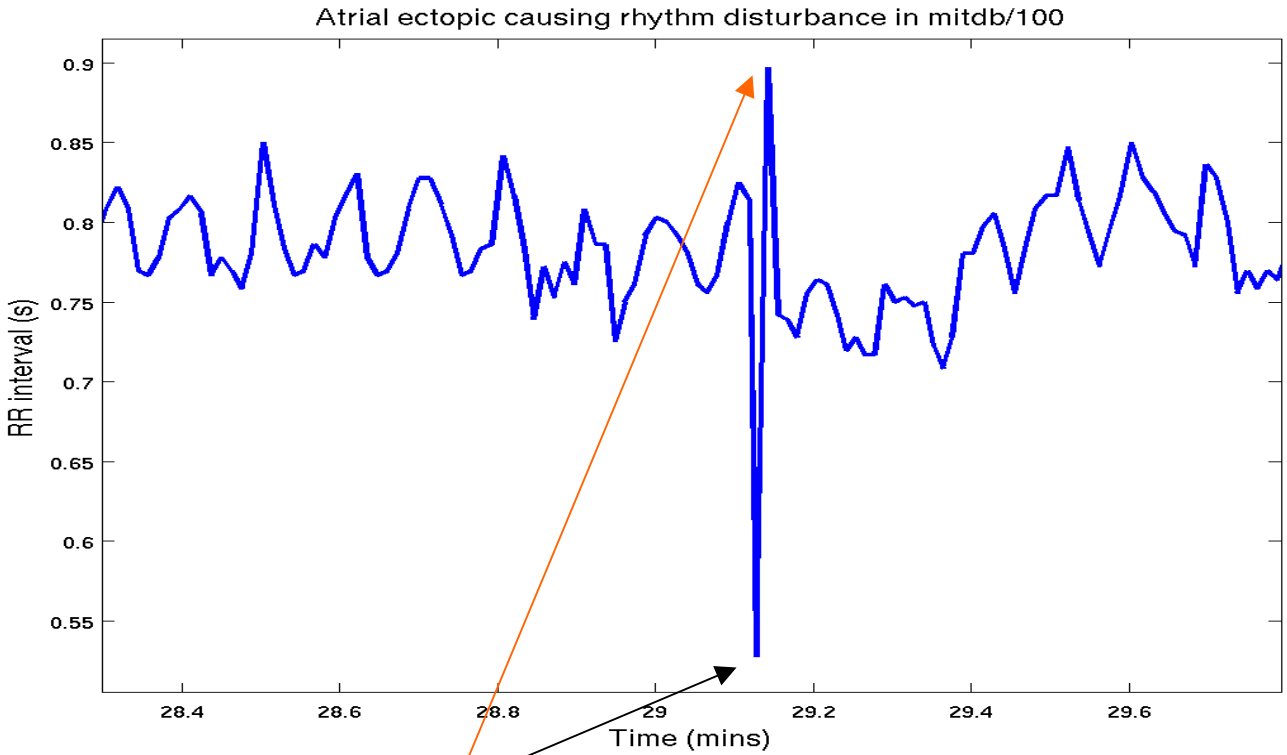
HRV changes significantly in different sleep states ⟶

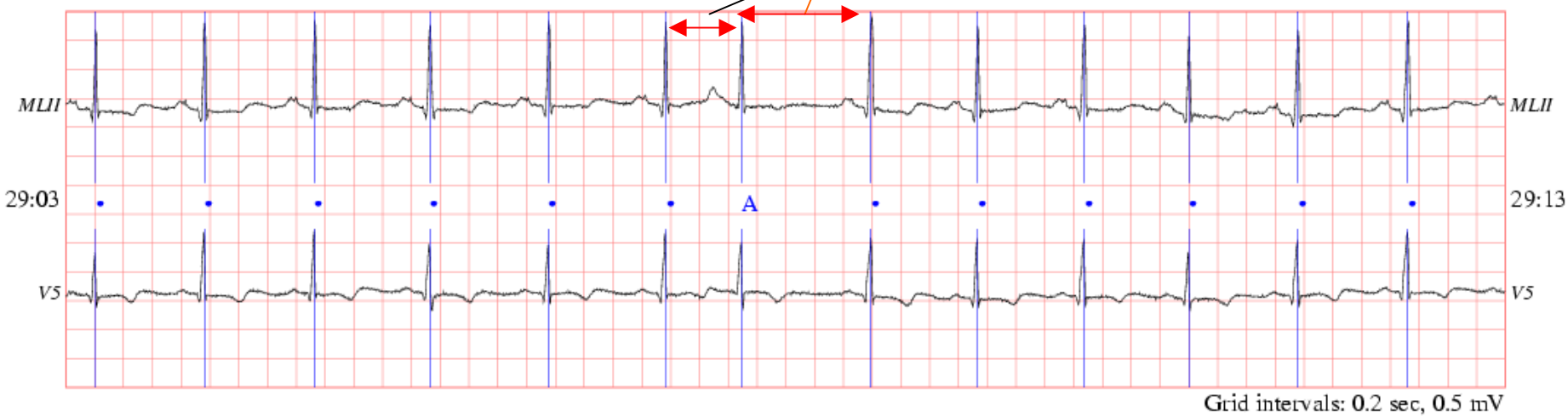


- **Control for state when applying HRV methods!**

Adapted from: Otzenberger *et al.* **Dynamic heart rate variability: a tool for exploring sympathovagal balance … in sleep** *Am J Physiol Heart Circ Physiol* 275: H946-H950, 1998.

Changes due to *ectopy*

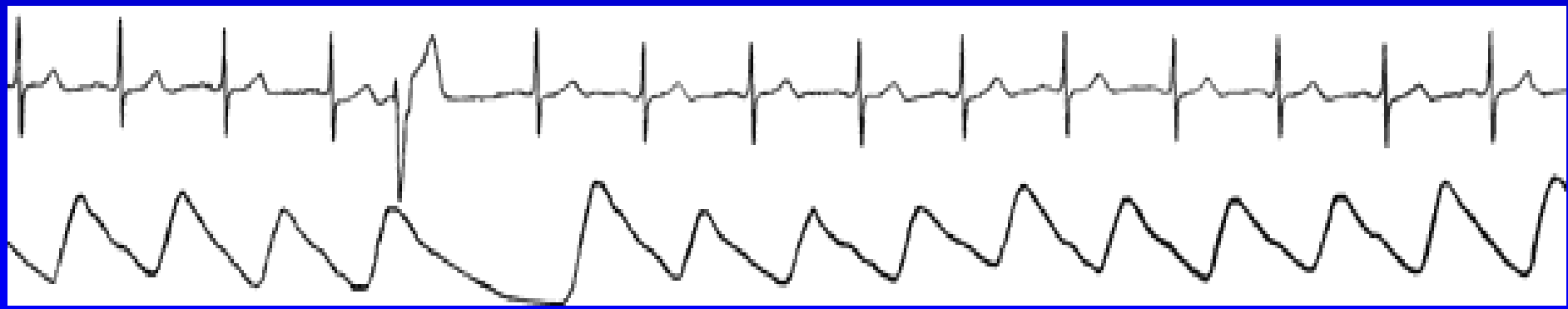




Data courtesy of PhysioNet; http://www.physionet.org

Heart Rate Turbulence

- SA node response to ectopic beat; short HR acceleration then deceleration.
- Maintain BP; rapid parasympathetic withdrawal?
- Then parasympathetic innervation → baseline



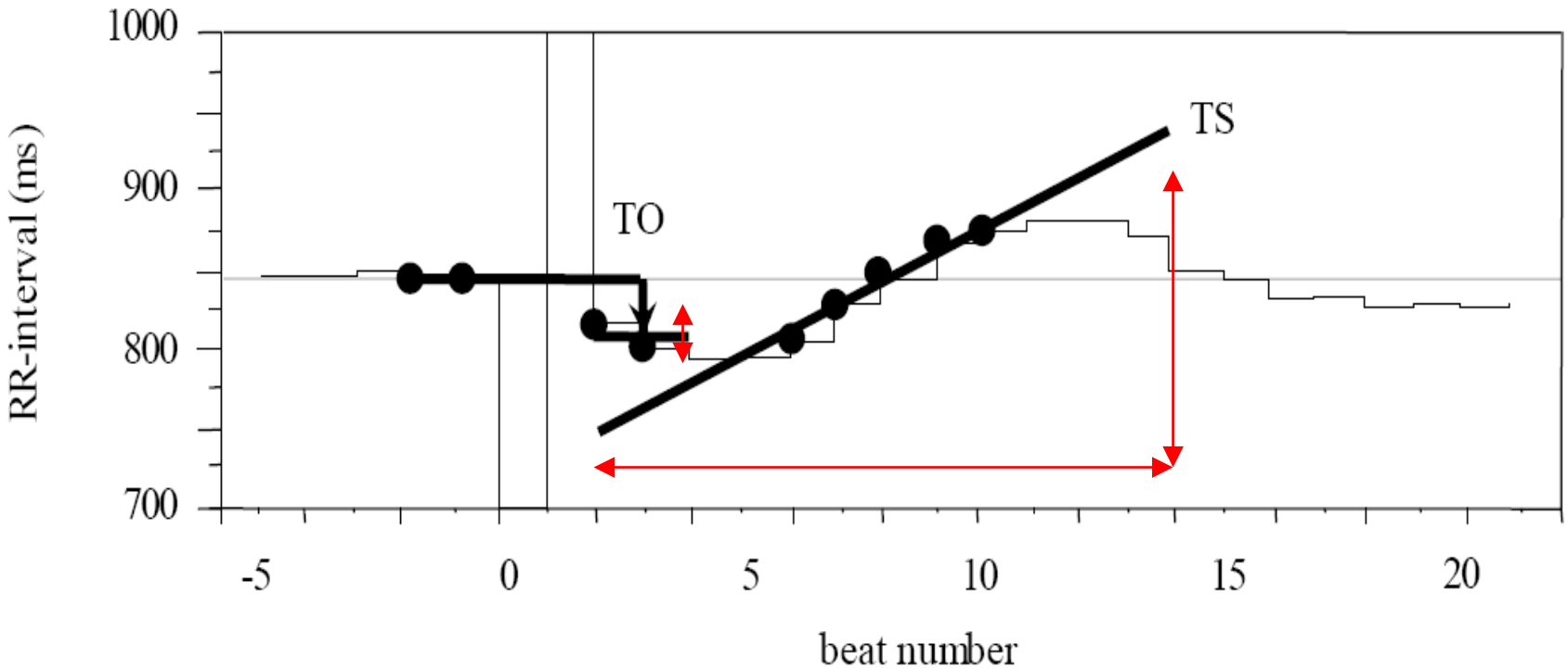
http://www.h-r-t.org/hrt/en/hrtdemo_js.html

Credit: R. Schneider: http://www.librasch.org/

Heart Rate Turbulence

- Ectopic beats disturb RR tachogram stationarity
- Disturbance lasts ≈ 10 - 20 beats
- HRT quantifies this disturbance using 2 metrics:
  - TO: Turbulence Onset
  - TS: Turbulence Slope

TS/TO: Turbulence Onset/Slope



Credit: Bauer A, Barthel P, Schneider R, Schmidt G. Dynamics of Heart Rate Turbulence. Circulation 2001b; Vol. 104; No. 17; Supplement; II-339, 1622.

Turbulence Onset

$$TO = \frac{(RR^{+2} + RR^{+3}) - (RR^{-2} + RR^{-1})}{RR^{-2} + RR^{-1}} \times 100$$

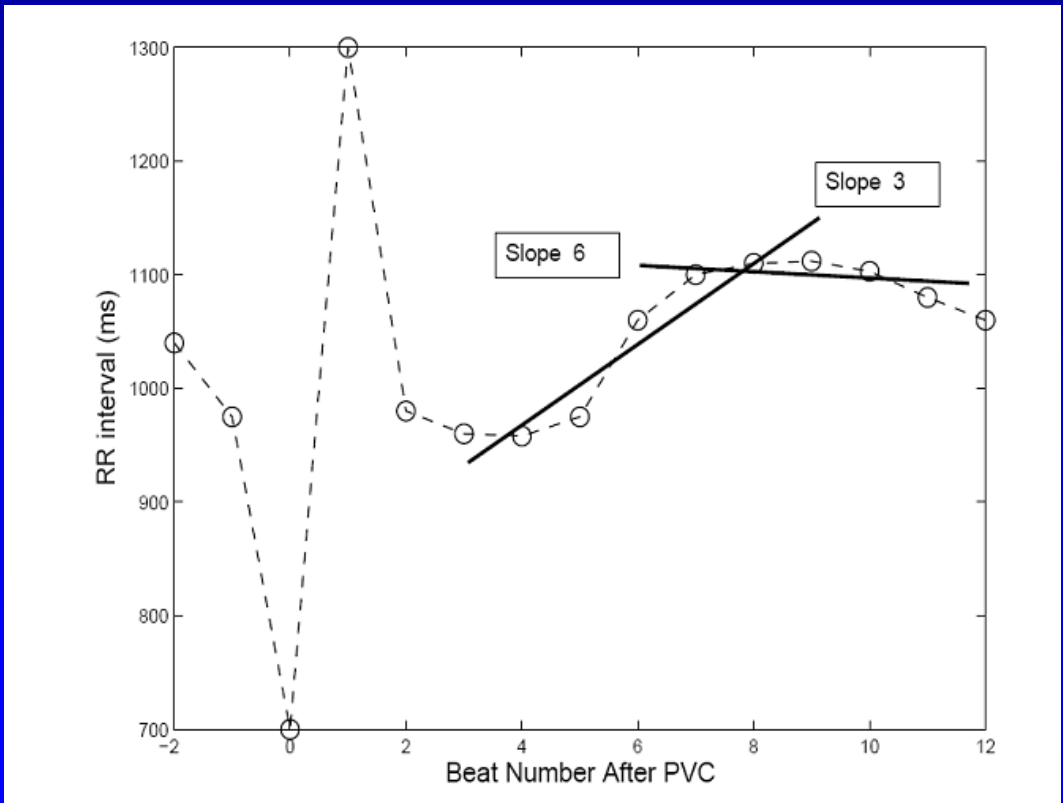
(+ index $\Rightarrow$ intervals after ectopic, - index $\Rightarrow$ before)

Percentage difference between mean of each pair of NN intervals on either side of ectopic pair

Must average the TO over >> 10 ectopics

TS: Turbulence Slope

Find steepest slope for each possible sequence of 5 consecutive normal intervals from $RR^{+2} \longrightarrow RR^{+16}$



Usually average 10-20 time series first then calculate *one* TS on the average time series!

Outlier Rejection Important:

(See Notes)

Clifford, G.D., "ECG Statistics, Noise, Artefacts and Missing Data", Chapter 3 in *Advanced methods and tools for ECG data Analysis*, Clifford,*et al* (Eds), Artech House,2006.

Examples

Run: http://www.librasch.org/hrt/en/hrtdemo_java.html

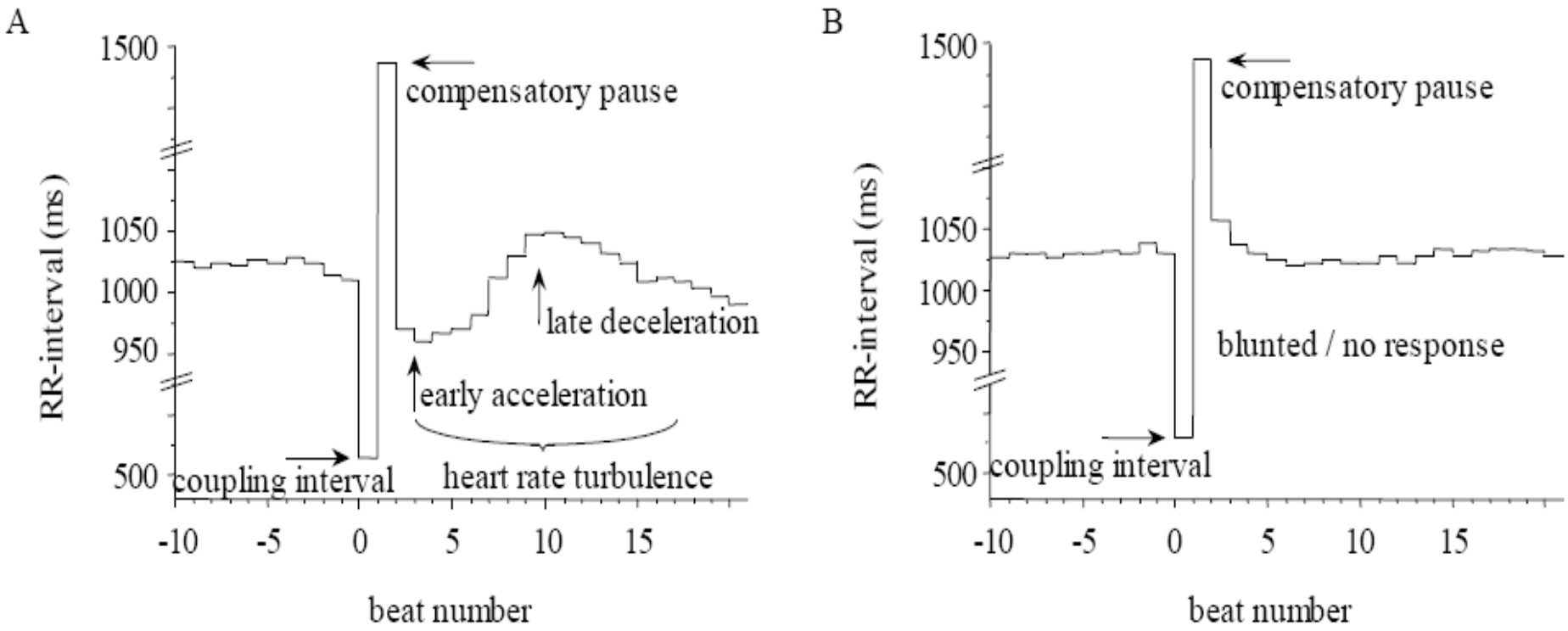


Figure 1: Examples of heart rate turbulence patterns in two postinfarction patients. (A) Typical acceleration-deceleration sequence of RR intervals after coupling interval and compensatory pause of a VPC recorded in a 64-year-old woman with anterior myocardial infarction who survived during follow-up. (B) Almost random pattern recorded in a 77-year-old man with inferior myocardial infarction who died 7 month after the index infarction.

Figure Credit: Mäkikallio *et al.*, Eur. Heart J., April 2005; 26:

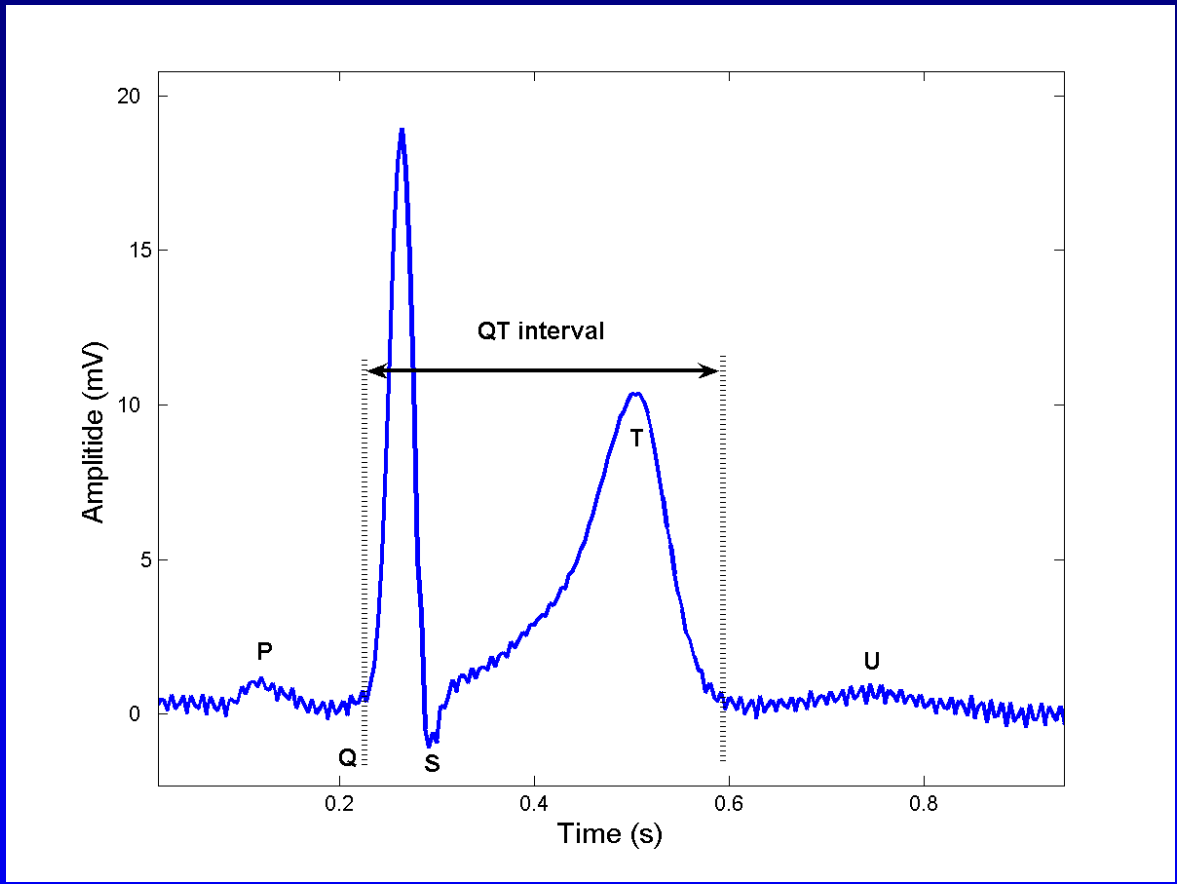
Normal Response

TO > 0 and **TS > 2.5** are normal

(a healthy response to PVCs is a strong sinus acceleration followed by a rapid deceleration)

- **An independent predictor of late mortality after acute MI** [Schmidt 1999, Ghuran 2002, Wichterle 2004, Watanabe 2005, Baur 2006]
- **Abnormal HRT Predicts Initiation of Ventricular Arrhythmias** [Iwasa 2005]
- **HRT indices appear to correlate better with EF than SDNN in Chagas disease** [Tundo2005]
- **HRT Predicts Cardiac Death in Patients Undergoing CABG** [Cygankiewicz 2003]
- **Prognostic Marker in Patients with Chronic Heart Failure** [Kayama 2002]
- **Risk Predictors in Patients With Diabetes Mellitus** [Barthel 2002]
- **Decreased HRT in patients with diabetes mellitus** [Barthel 2000]

Nonstationarity Example: QT Hysteresis

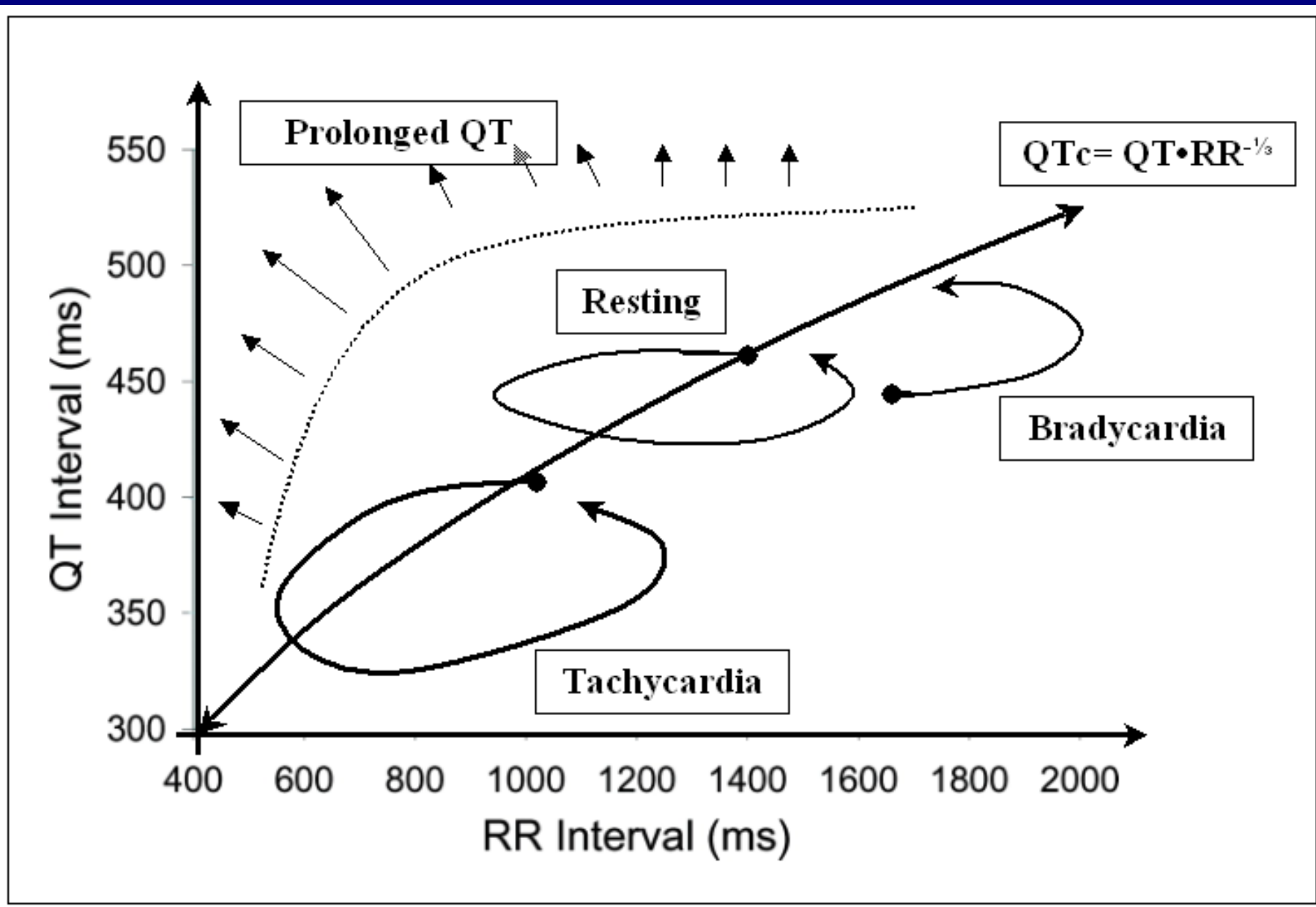


$$QTc = QT/RR^{n}$$

$$n = ½, ⅓$$

- QT is HR-dependent
- QT interval = depolarization + repolarization
- QTc: marker of arrhythmias & potential predictor of mortality

Nonstationarity Example: QT Hysteresis



QT turbulence

- QT-interval turbulence occurs in association with HRT following induced ventricular or atrial ectopy
- Replace NN intervals by QT intervals
- QT TO *but not TS* reported to be useful (so far)
- Other metrics exist; It's a nascent field

Patients with ischemic VT and LV dysfunction exhibited significantly lower QT TO values than those with nonischemic VT and normal LV function.

Savelieva,I., Wichterle,D., and Camm, J.A., QT-Interval Turbulence Induced by Atrial and Ventricular Extrastimuli in Patients with Ventricular Tachycardia, PACE, 28, s1, S187-S192, 2005,

Recap / Conclusions

- Nonstationarities important both as confounders and information conveyors

- Don’t just ignore/remove them

- HRT is interesting approach to extracting information from very short nonstationary segments of data

Acknowledgements: Many, many thanks to Raphael Schneider!

See www.h-r-t.org for more information and software.