Ectopic Beats, Activity Effects and Heart Rate Turbulence

Gari Clifford
gari@mit.edu
www.mit.edu/~gari/

Harvard-MIT
Division of Health Sciences & Technology
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

- Awake
- Light Sleep
- Deep Sleep
- Dream Sleep

Control for state when applying HRV methods!

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 $\rightarrow$ baseline

http://www.h-r-t.org/hrt/en/hrdemo_js.html
Credit: R. Schneider: http://www.librasch.org/
Heart Rate Turbulence

• Ectopic beats disturb RR tachogram stationarity
• Disturbance lasts \( \approx 10 - 20 \) beats
• HRT quantifies this disturbance using 2 metrics:
  – TO: Turbulence Onset
  – TS: Turbulence Slope
TS/TO: Turbulence Onset/Slope

Turbulence Onset

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

(+ index ⇒ intervals after ectopic, - index ⇒ 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 $RR^{+2} \rightarrow RR^{+16}$

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

Outlier Rejection Important:
(See Notes)

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 months 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)

• 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

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

\[ QTc = \frac{QT}{RR^n} \]

\[ n = \frac{1}{2}, \frac{1}{3} \]
Nonstationarity Example: QT Hysteresis

- **Prolonged QT**
- **QTc = QT \cdot RR^{-\frac{1}{3}}**
- **Resting**
- **Bradycardia**
- **Tachycardia**

Graph showing the relationship between QT interval and RR interval, with different states indicated.
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.

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.