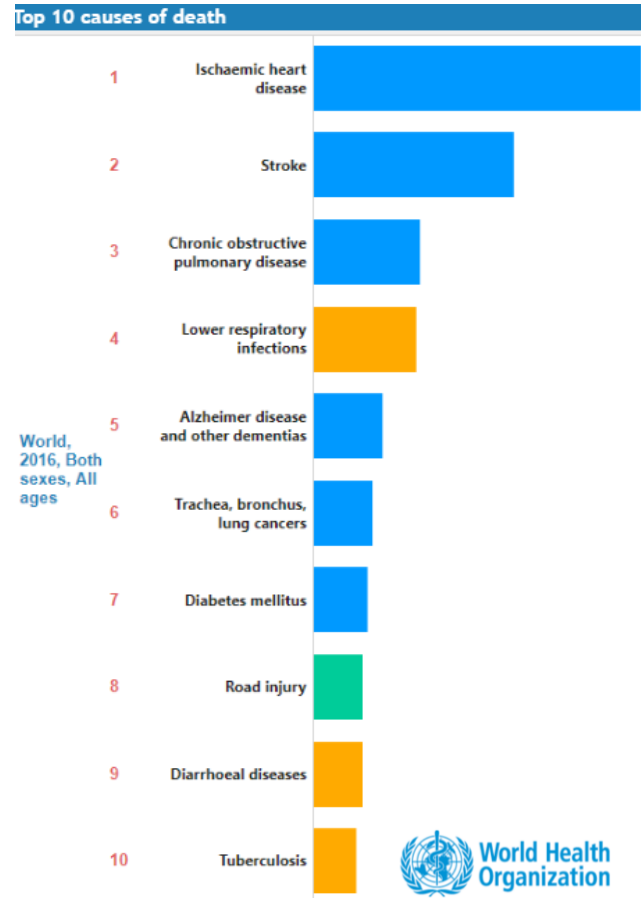


Heart Rate Variability analysis in critically illness and critical care

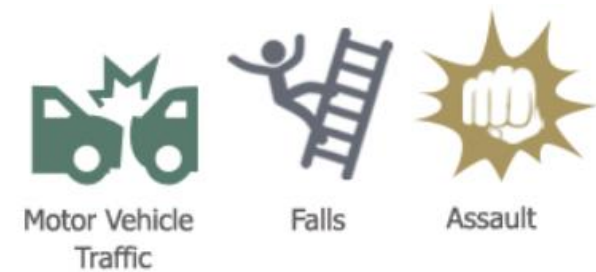
Ana Paula Rocha

Centro de Matemática da Universidade do Porto

Stroke and Traumatic Brain Injury are leading causes of death and disability around the world.



TBI causes:



Motivation

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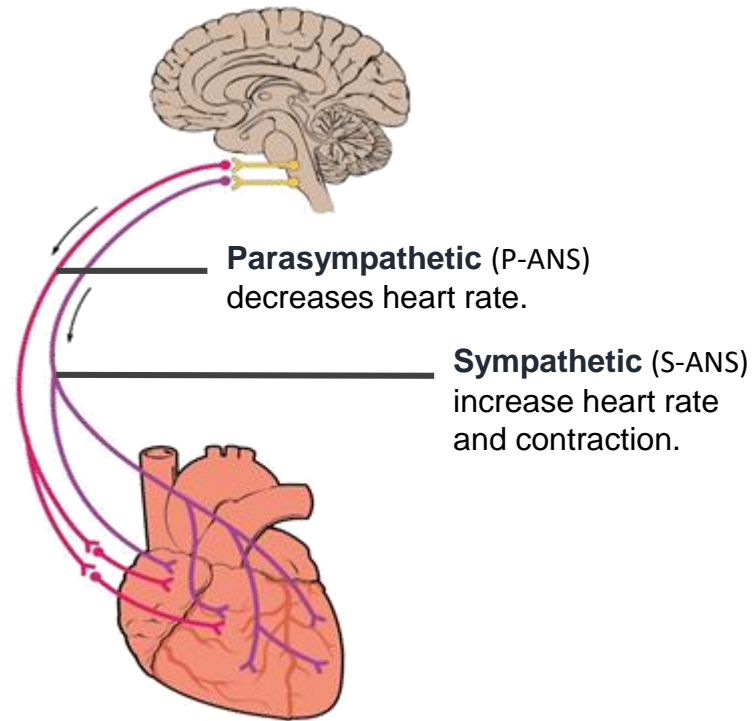
Aim

Methodology

Results

Going on ...

Patients with ABI may have ANS dysfunction which may aggravate critical illness



Acute Brain Injury (ABI)

ANS dysfunction

Systemic injury

Autonomic Nervous System (ANS) is the neurologic interface between the central nervous system and the rest of the body.

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Heart Rate Variability (HRV)

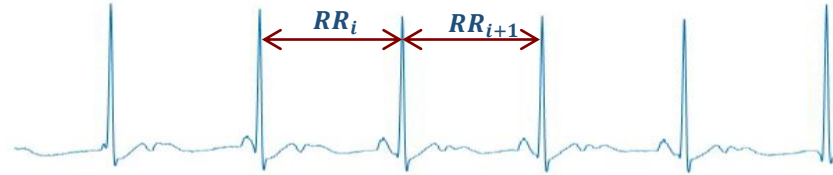
System



Signal - ECG



Time Series - $\{RR\}_i$
(tachogram)



Sympathetic:



increases HR

- Lower Frequency Modulation
- Slow response (over 5 sec)

Parasympathetic:



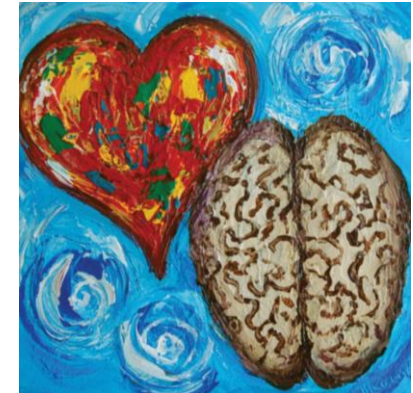
decreases HR

- Higher Frequency Modulation
- Fast response (1-2 heart beats)

General Aim: HRV as a tool to evaluate the ANS dysfunction in acute brain injury.

It is intended:

- to associate cerebral multimodal neuromonitoring with HRV
- to contribute to the improvement of the knowledge of ANS dysfunction of intensive care patients with brain injury.



The Brain and the Heart
© Mark Kazav 2015

Heart rate variability in Brain Death

Motivation

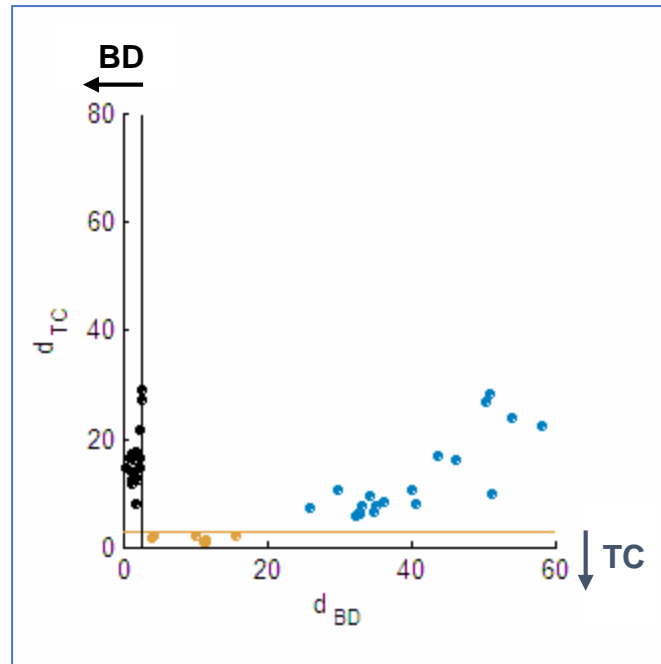
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Decision diagram: Multivariate confidence regions (97,5%)

Follow-up and prognosis in Pediatric Critical Care Bedside

Motivation

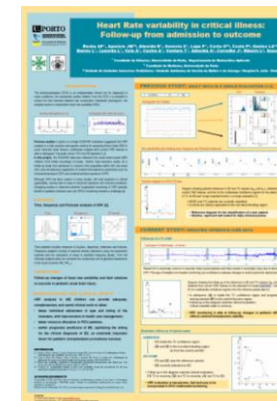
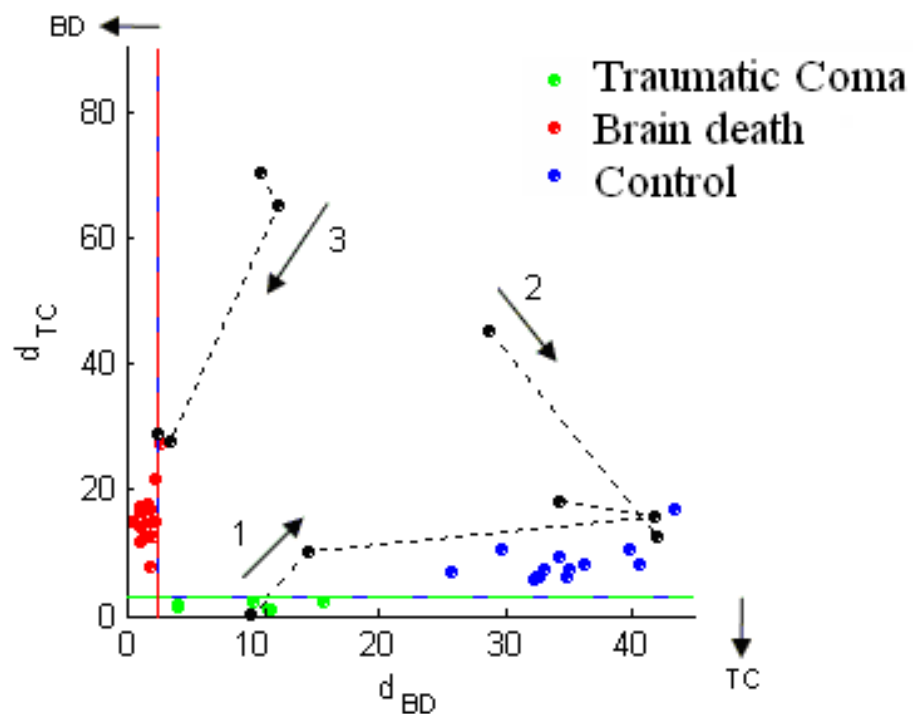
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Going on ...



Methods of HRV study In 1996, a consensus panel issued a set of guidelines regarding the measurement and interpretation of HRV.

Spectral Analysis

Motivation

Introduction

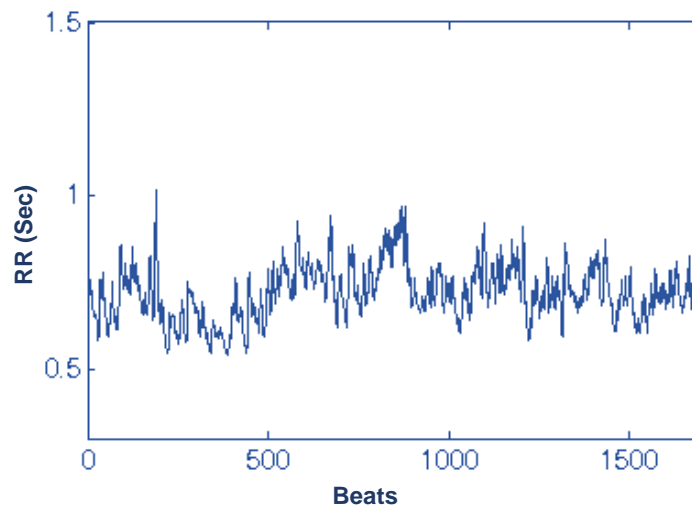
Aim

Methodology

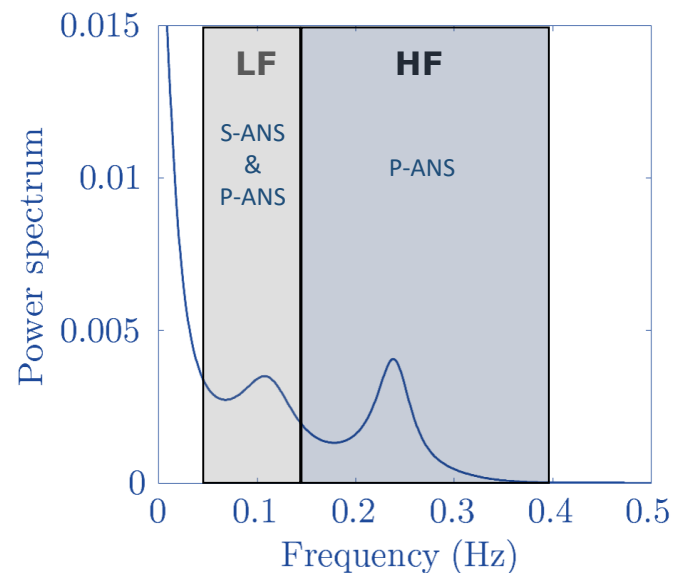
Results

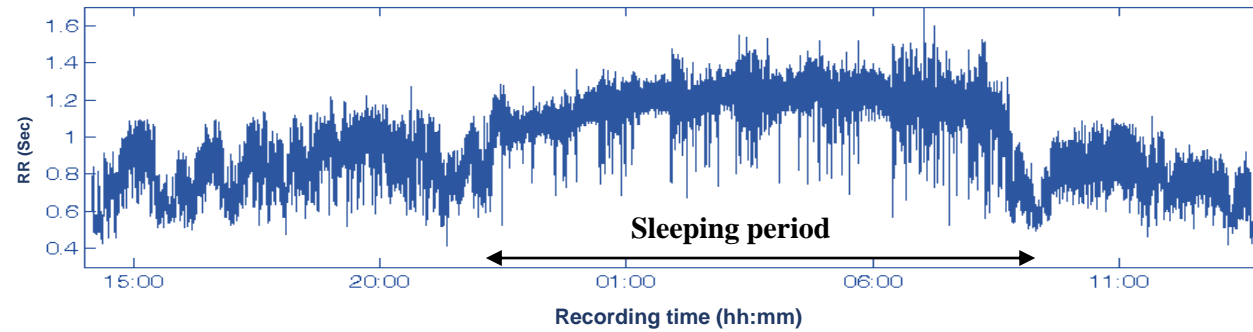
Going on ...

Tachogram of a normal subject

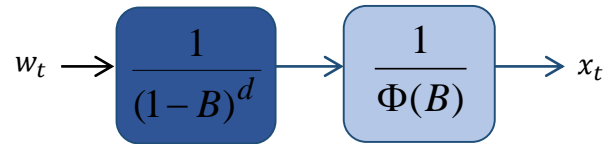


Spectrum using AR modeling





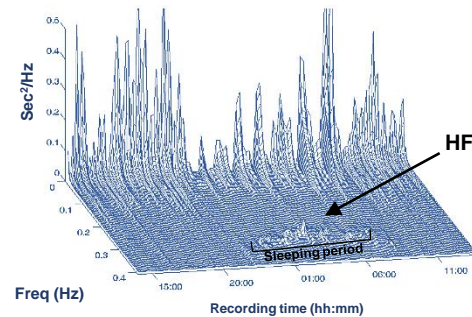
ARFIMA(p,d,0)



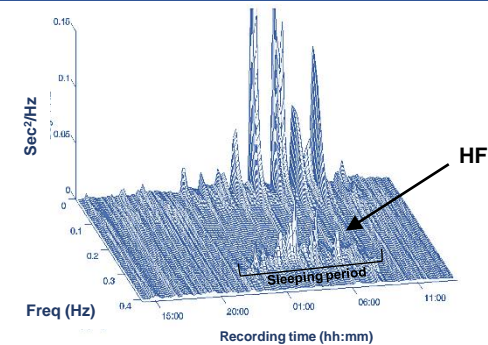
$$\Phi(B)(1-B)^d x_t = w_t$$

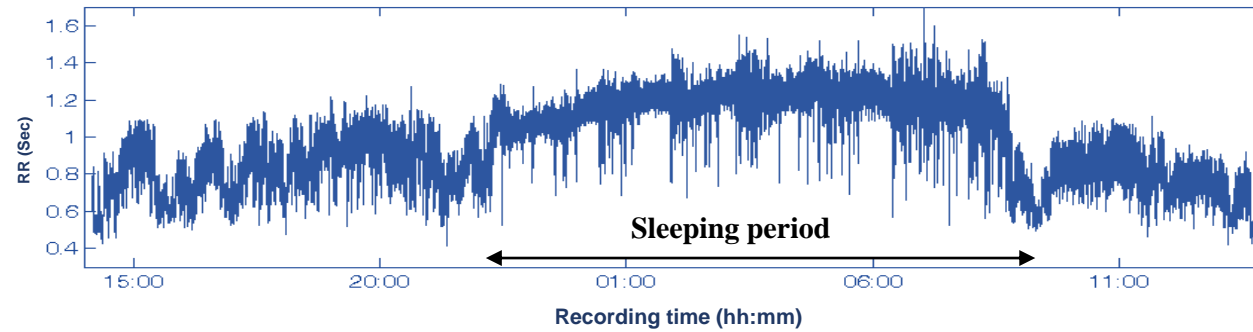
d long memory in mean

time-variant spectrum



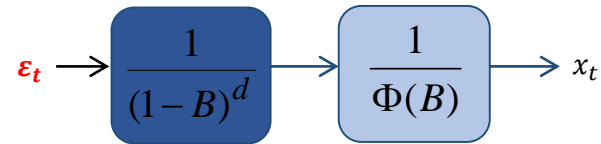
ARFIMA-GARCH time-variant spectrum
(Long-memory component removed)





ARFIMA(p,d,0) – GARCH(1,1)

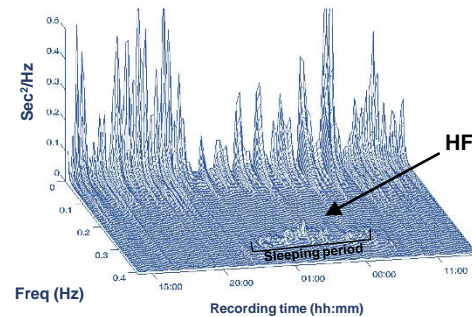
$$\sigma_t^2 = u_o + v\sigma_{t-1}^2 + u\varepsilon_{t-1}^2 \quad \text{volatility}$$



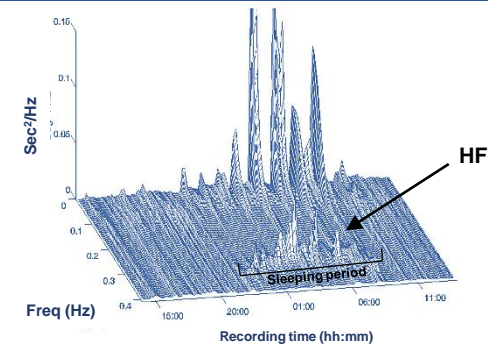
d long memory in mean

$$\varepsilon_t = \sigma_t z_t$$

time-variant spectrum



ARFIMA-GARCH time-variant spectrum
(Long-memory component removed)



Clinical Application in Acute Brain Injury

HRV + multimodal monitoring – NeuroCritical Care Unit (NCCU)

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- Severe TBI patients

- Variables collected

Brain Variables

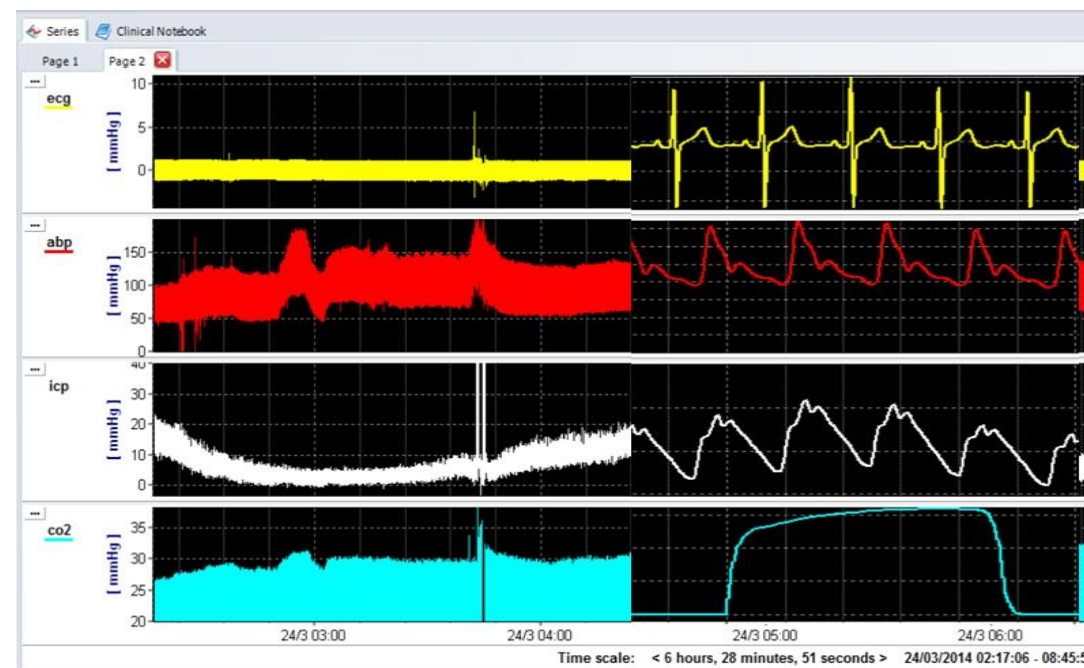
↳ ICP, PRx, RAP

Systemic Variables

↳ ECG, ABP, CICr

HRV Variables

↳ LF, HF, TP



Case 1 – HRV + Plateau Waves (PW)

Motivation

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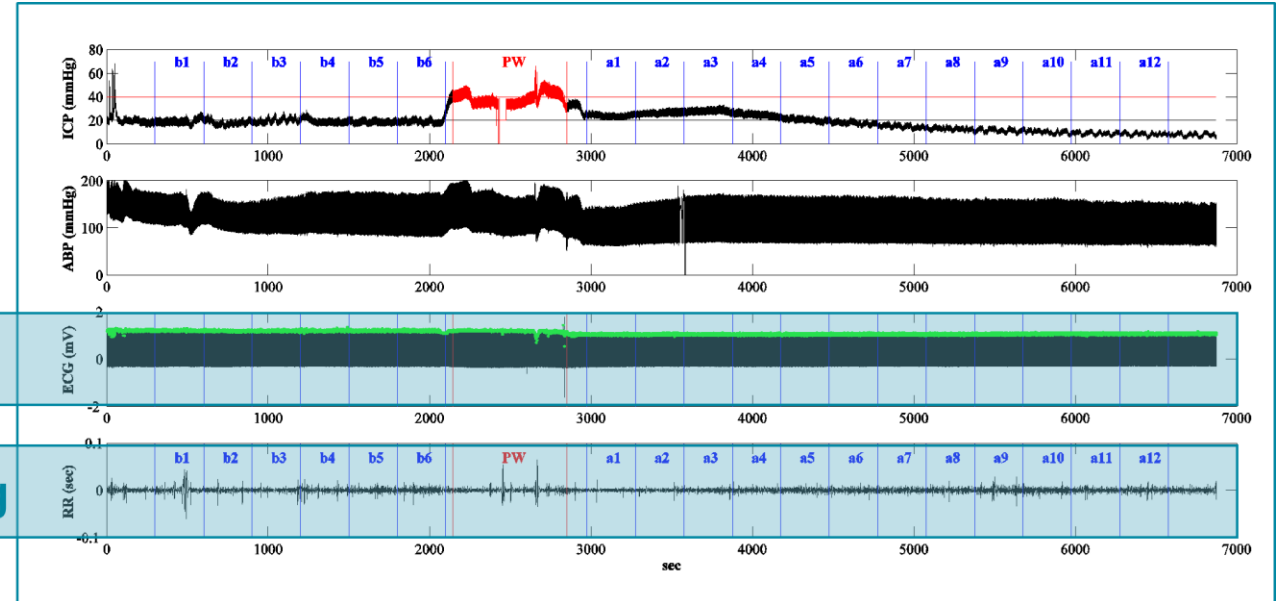
Methodology

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Going on ...

ECG delineation

RR series extraction preprocessing



PW

- Related with cerebrovascular reactivity
- Related to autonomic dysfunction?

Case 1 – HRV + Plateau Waves (PW)

Motivation

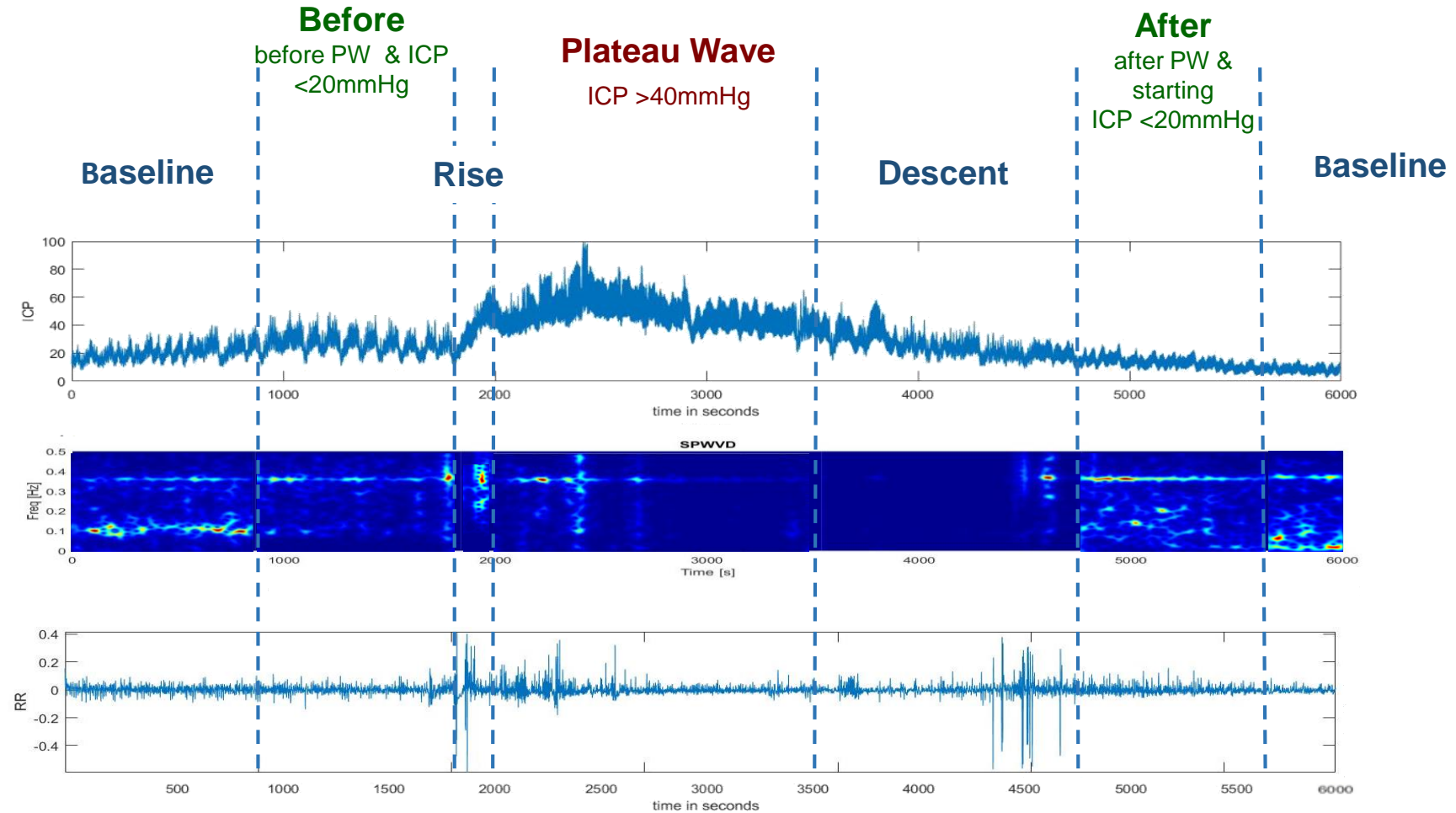
Introduction

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Case 2 – HRV + decompressive craniectomy (DC)

Motivation

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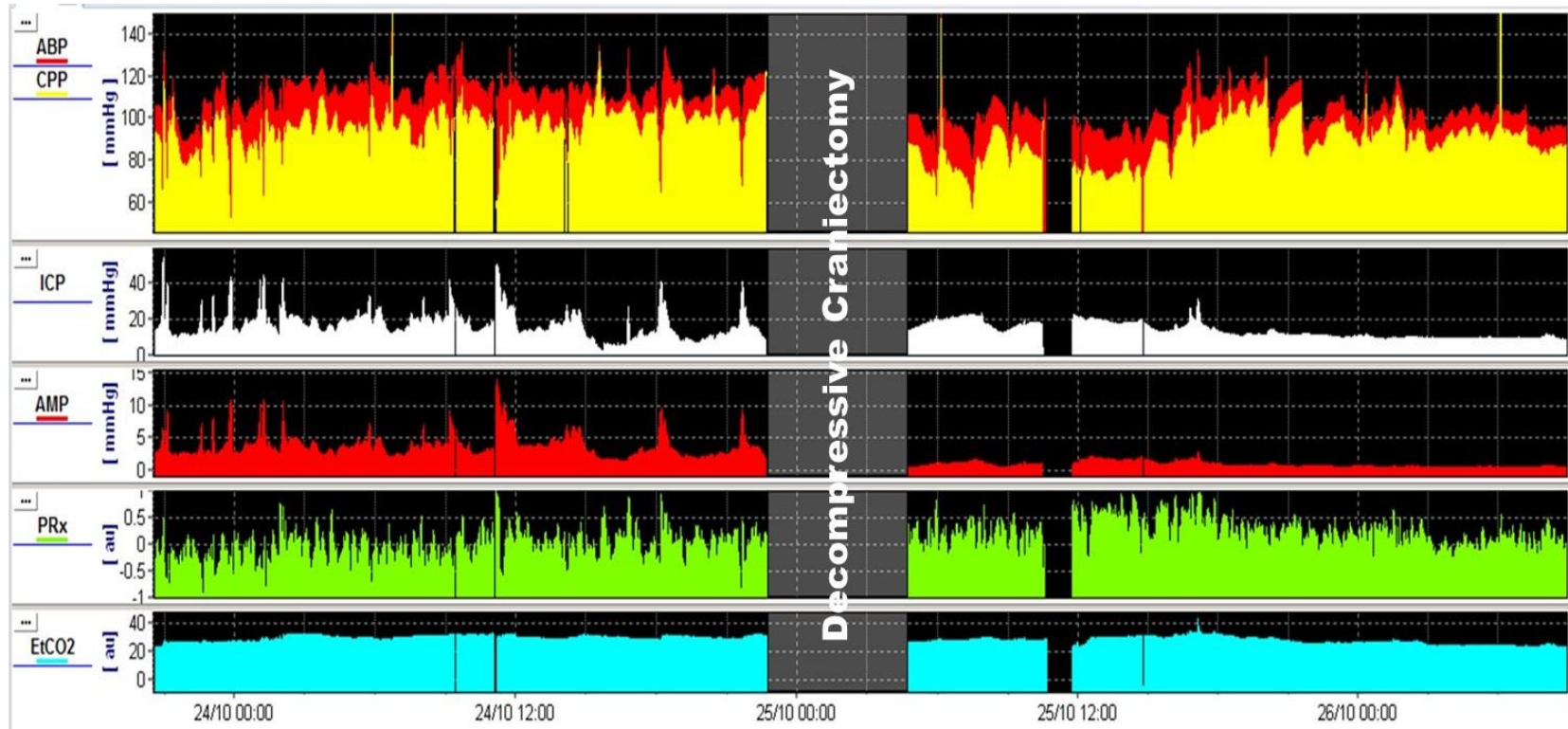
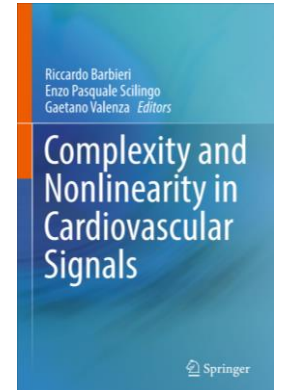


Fig. 17.5 Multimodal brain monitoring changes before and after decompressive craniectomy represented by mean arterial blood pressure (ABP), cerebral perfusion pressure (CPP), intracranial pressure (ICP), amplitude of ICP (AMP), cerebrovascular pressure reactivity (PRx) and endtidal carbon dioxide (ETCO2)

Case 2 – HRV + decompressive craniectomy (DC)



Motivation

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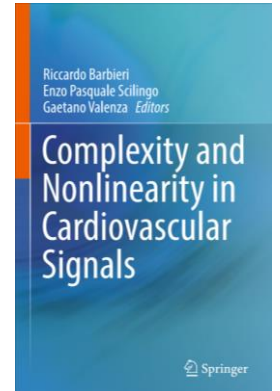
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Fig. 17.6 Multimodal brain monitoring documentation of the evolution to irreversible zero flow and brain death. While intracranial pressure (ICP) increases and cerebral perfusion pressure (CPP) compromises, cerebral blood flow (CBF) and brain tissue oxygen pressure (pbtO₂) decline to ischemic thresholds. Arterial blood pressure (ABP) remains almost constant. Cerebrovascular reactivity pressure (PRx) in the lower panel becomes a *solid line* clearly meaning severe impairment of cerebral autoregulation (CAR)

Case 2 – HRV + decompressive craniectomy (DC)



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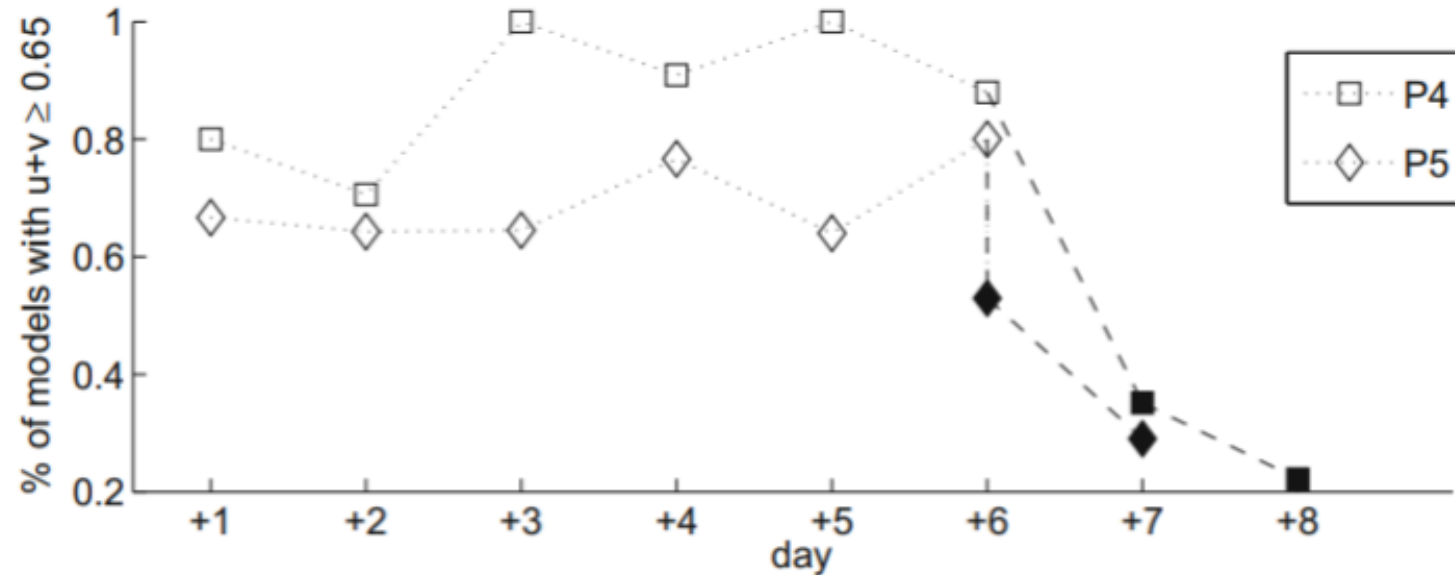
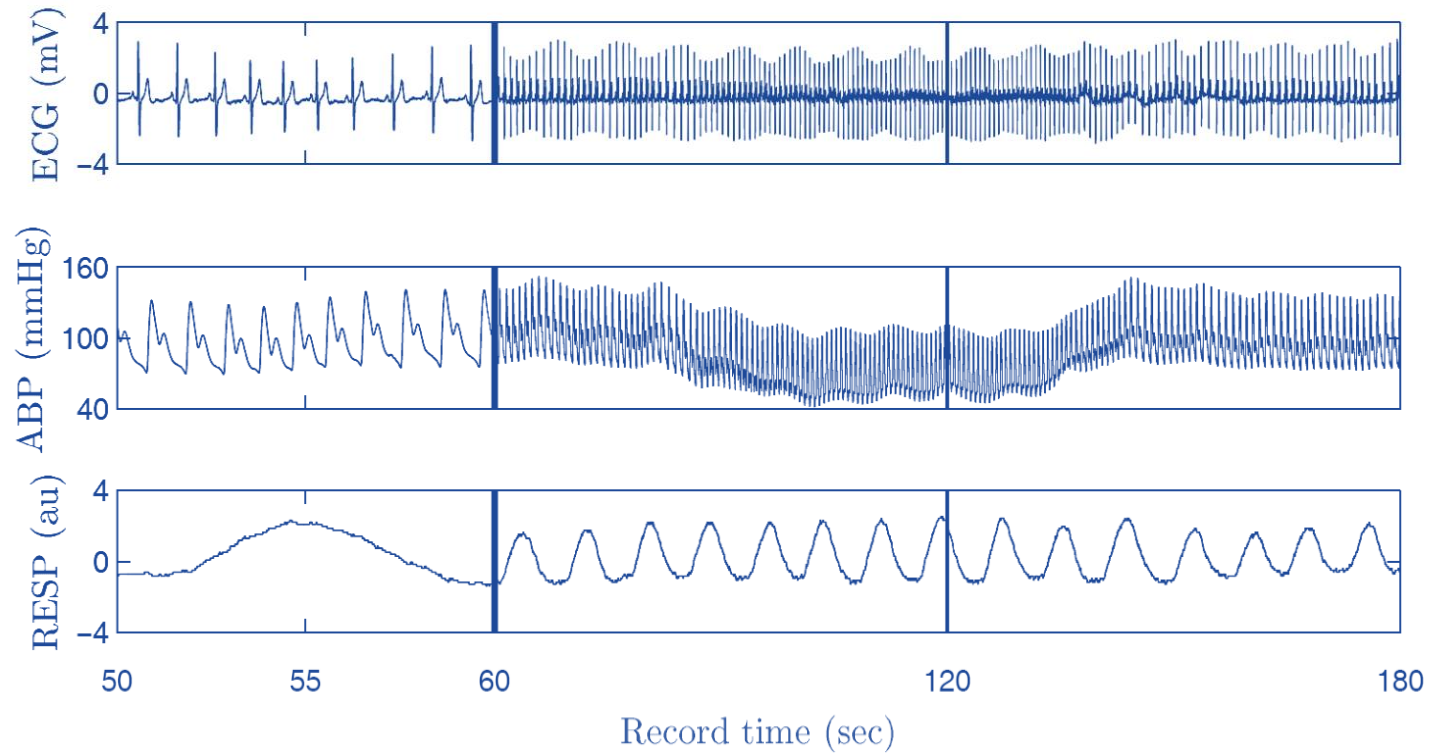
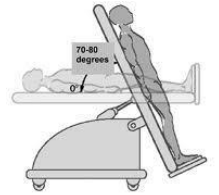


Fig. 17.8 Percentage of models with $u + v \geq 0.65$ for BD patients, P4 and P5. *Dark marks* correspond to time after zero flow (ZF)

- HRV provides new measures to describe the individual patient HRV dynamics, which may be particularly relevant to clinicians who manage critically ill patients with complex medical conditions that change rapidly and sometimes unpredictably.
- Further studies are warranted to fully appraise HRV modeling in acute brain injury, in particular by including other variables

Current aim:

- cerebral multimodal neuromonitoring ↔ **HRV** and **Baroreflex**
- ANS dysfunction study in **postural change** of ABI intensive care patients



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Physiological Network modern approaches

Motivation

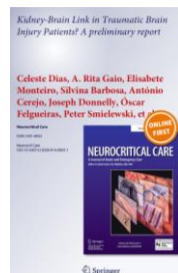
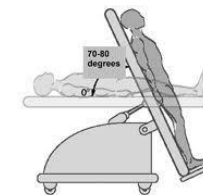
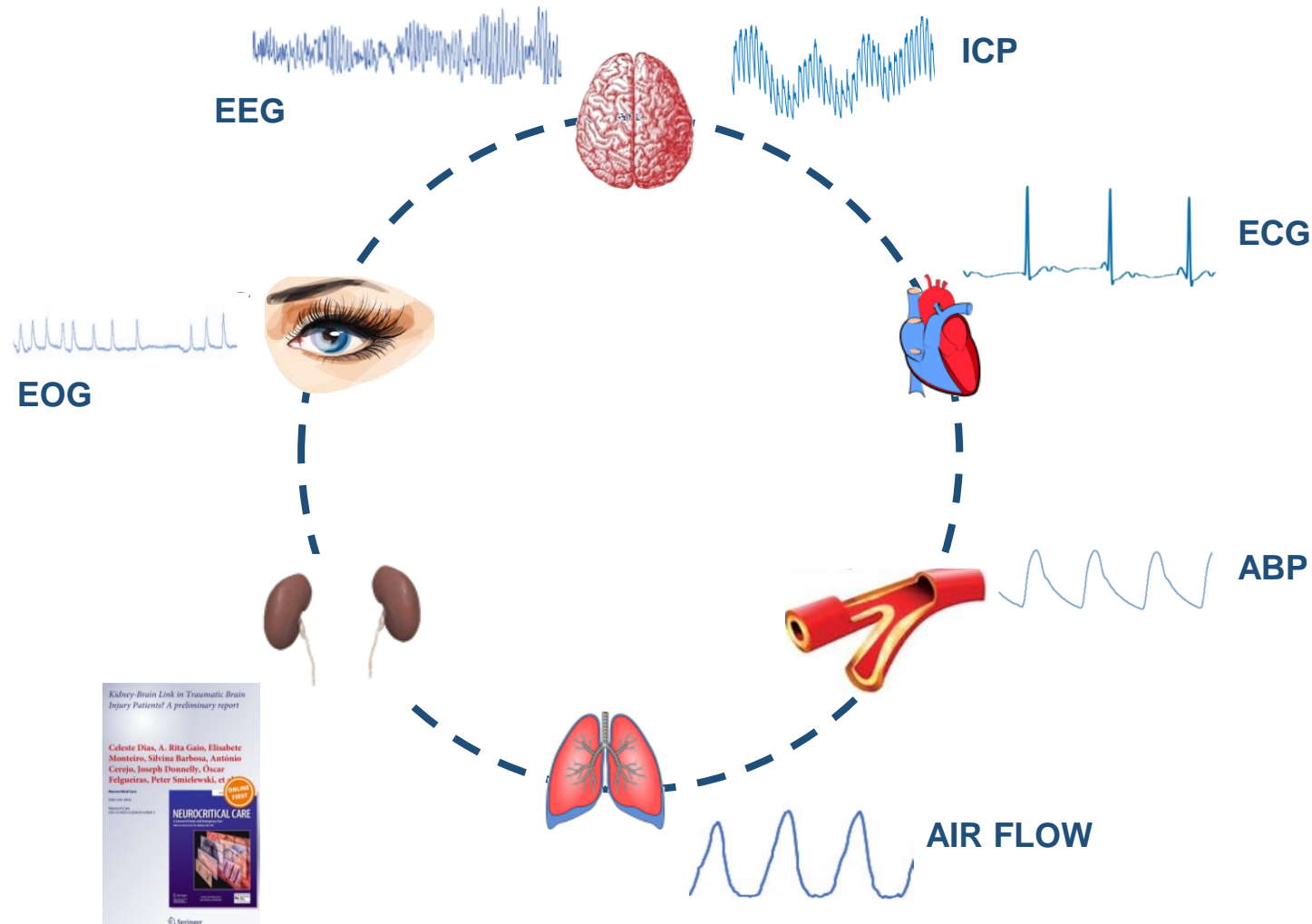
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- UNIV MILAN & PALERMO
- UCNC - CHSJ
- UCIP - CHSJ
- CEFA & CMDP