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POLITECNICO DI MILANO





Assessment of cardio-respiratory interactions and their stability in anesthetized patients under different mechanical ventilatory modes

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DIPARTIMENTO DI ELETTRONICA, INFORMAZIONE E BIOINGEGNERIA

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Summary

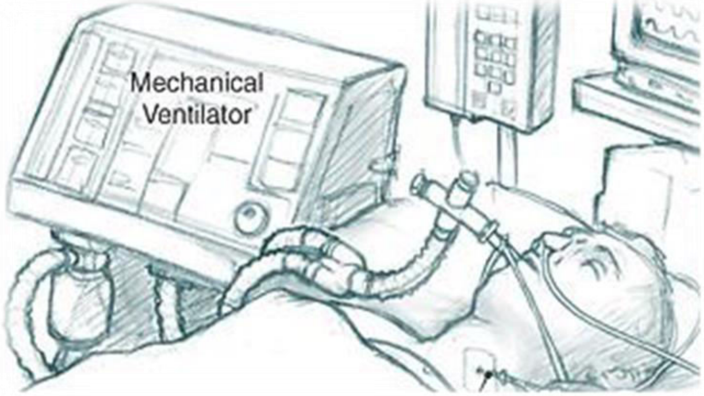
1. *Introduction*
2. *Aim*
3. *Experimental protocol*
4. *Methods*
5. *Results and discussion*
6. *Conclusion*

Introduction

Cardiac and respiratory systems are strictly connected

In anesthetized subjects mechanical ventilation (MV) could modify cardiorespiratory interactions

Many different MV modes are available in clinical practice



<u>How different MV modes act on cardiorespiratory interactions in critically ill patients?</u>

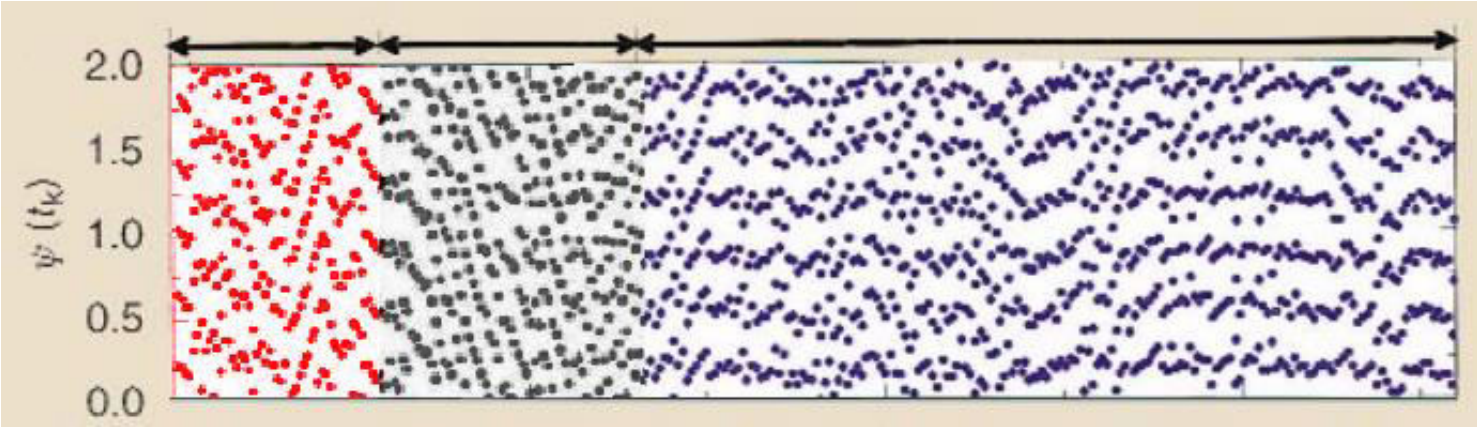
Cardioventilatory phase synchronization (CVPS) is «the repetitive occurring of m beats at the same respiratory phase values in n breathing cycles»

Phase Locking Ratio (PLR)

$$\frac{m \text{ beats}}{n \text{ respiratory cycles}}$$

Schafer C et al, 1998 Nature

SYNCHROGRAM



Red dots are synchronized 5:2

Black dots are not synchronized

Blue dots are synchronized 6:2

Schafer C et al, 1998 Nature

Aim

Starting from the method presented by Schafer:

- ***Quantification of CVPS strength***
- ***Classification of different PLR synchronization epochs to assess PLR variability***
- ***Investigation of different MV modes effects on CVPS in anesthetized critically ill patients***

3 randomized sessions of 30 minutes

(500 consecutive beats were extracted from every session)

one for each different MV mode:

- ***Pressure Controlled (PCV) – No patient trigger***
- ***Pressure Support (PSV) – Flow trigger***
- ***Neurally Adjusted Ventilatory Assist (NAVA) – Eadi trigger***

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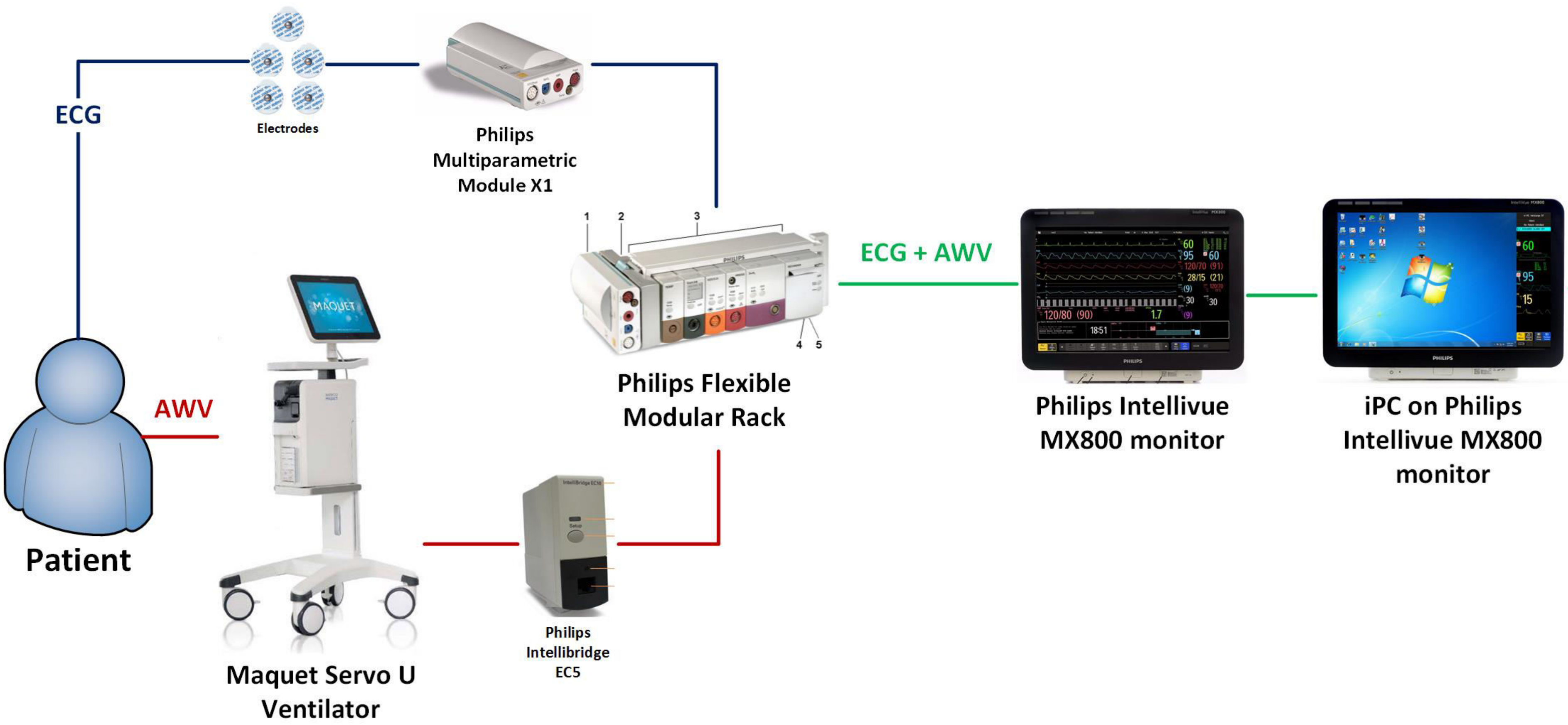
15 critically ill patients from ICU of L. Sacco Hospital – Milan *(Italy)*

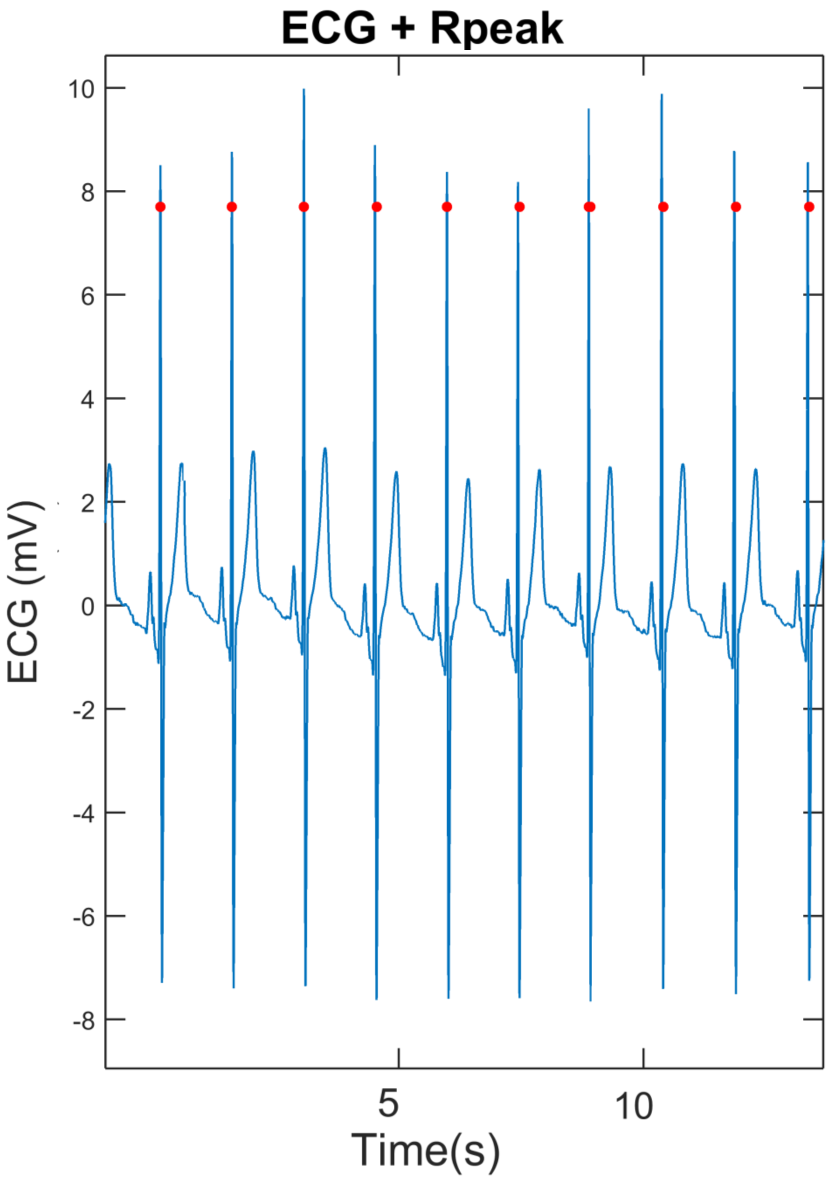
Sex (M/F)	9/6
Age(years)	46 ± 12,2
Height(cm)	165 ± 14
Weight(kg)	74 ± 7
Desease	post-surgery (5) pulmonary deseases (10)
ICU days before recording	9 ± 6

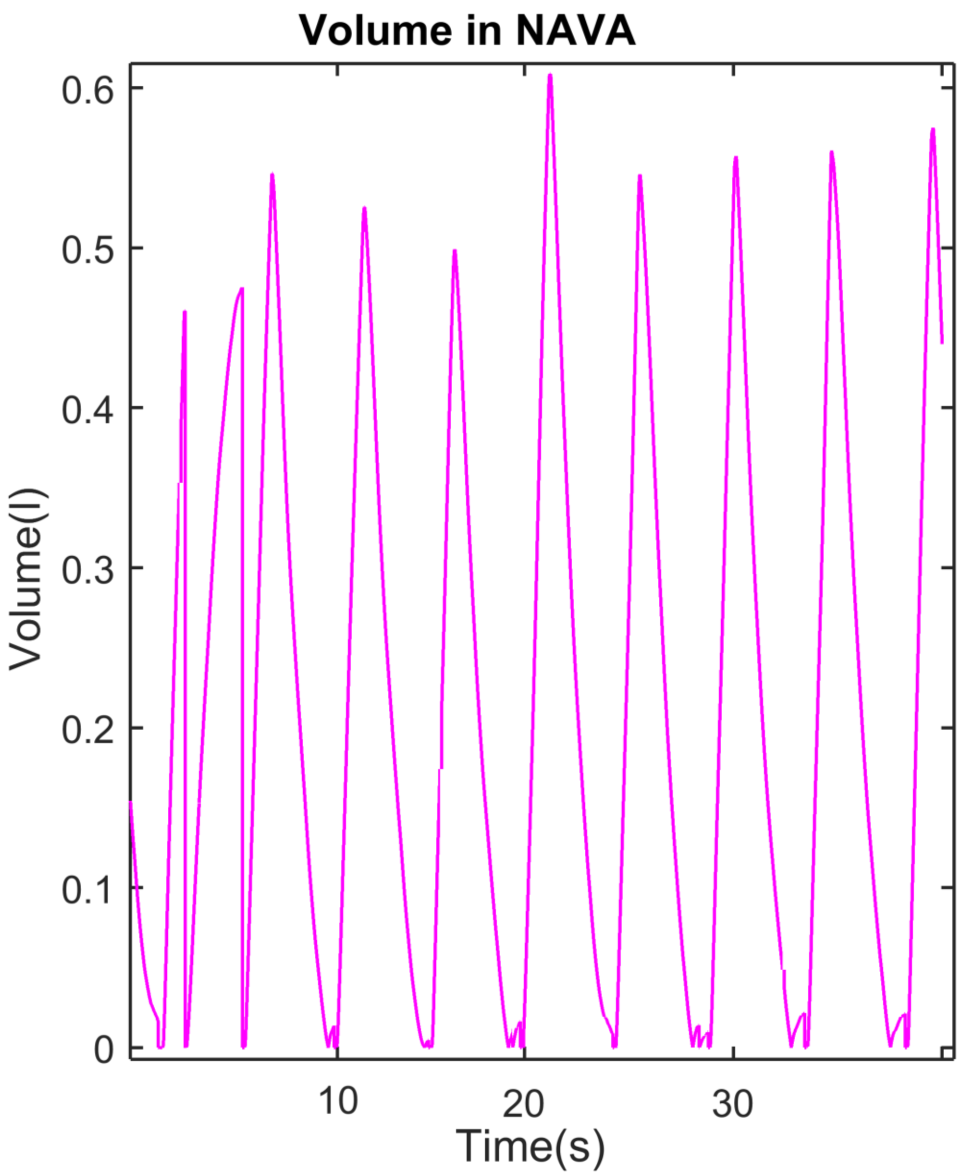
Clinical parameters (i.e. sedation level) were kept constant during the different experimental conditions.

Methods – Signal acquisition

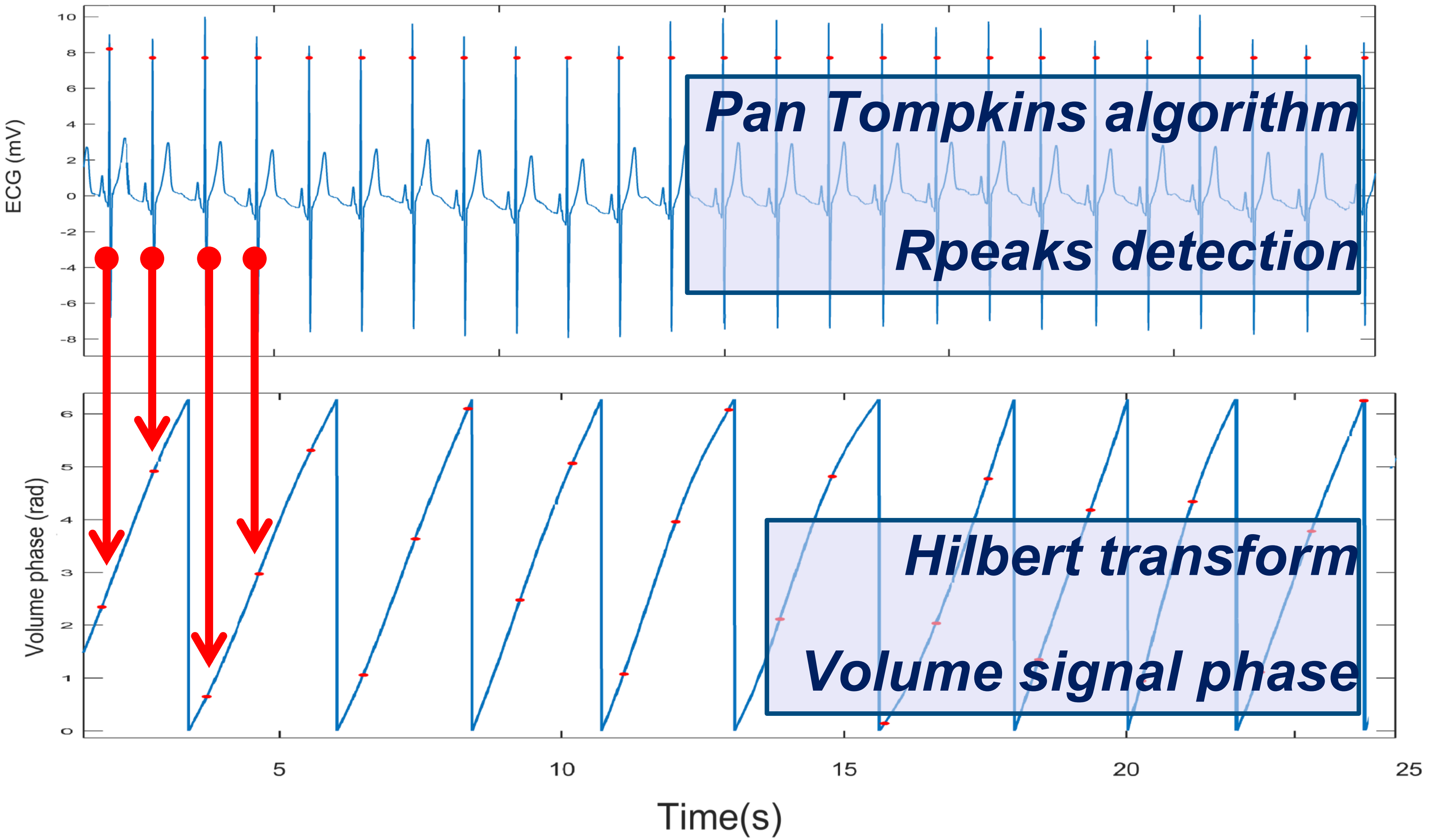


Methods – Signal recording

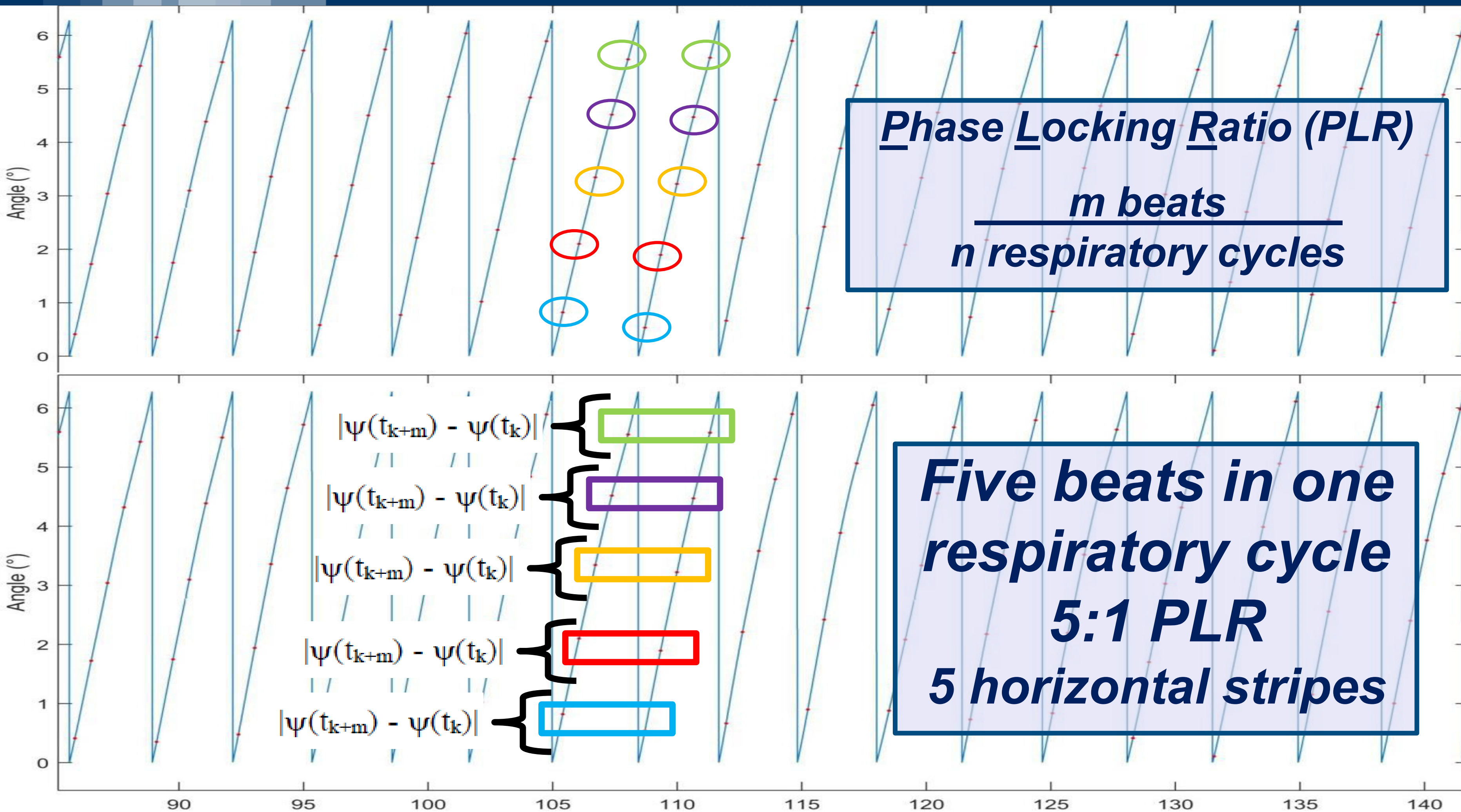




Methods – Signal processing



Methods – Automatic synchronization assessment

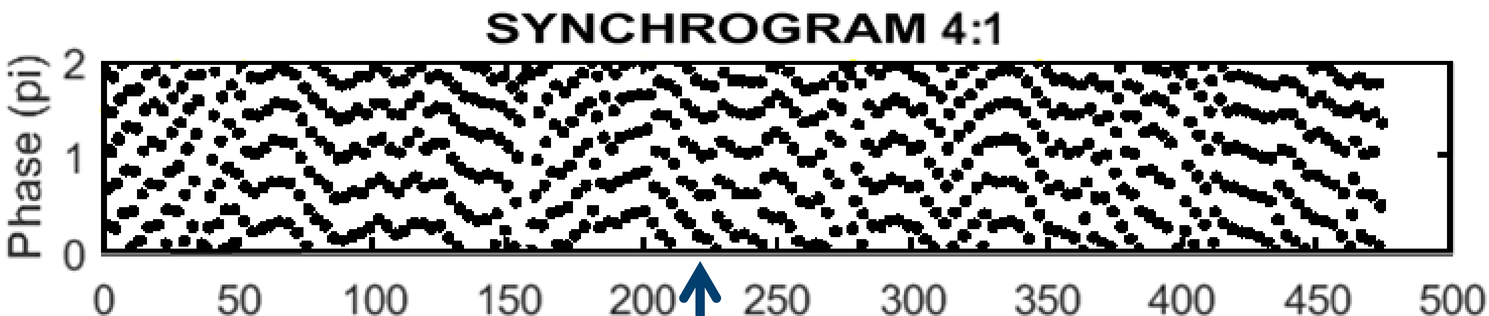


$$max\left|\Psi\left(t_{k+m}\right)-\Psi\left(t_{k}\right)\right|<TH \rightarrow TH=\frac{2n\pi}{m\delta} \rightarrow$$

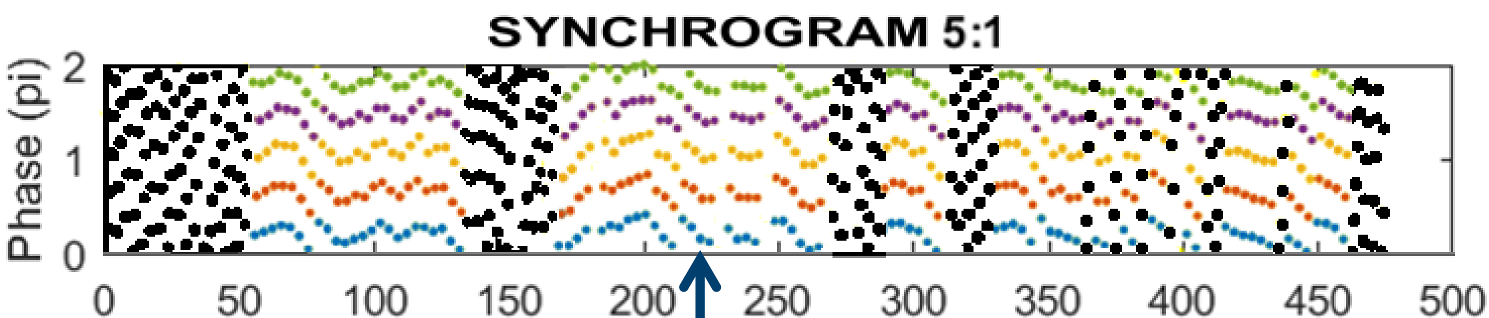
m n

5:1

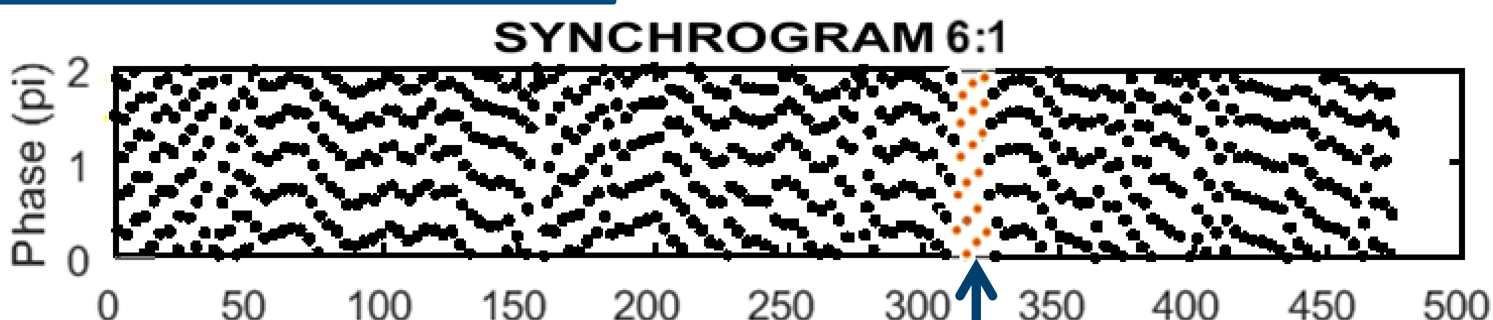
Methods – Synchrogram example



Black dots are not synchronized



Coloured dots are synchronized



Red dots highline quasi-periodic 6:1 ***behaviour of phase volume values***

Methods – PLR estimation

$$PLR_{estimated} = f_h / f_r$$

f_h is the heart frequency
f_r is the respiratory frequency

For example if $PLR_{estimated} = 3.14$

DEVIL'S STAIRCASE

Respiratory cycle															
3	/	/	3:3	4:3	5:3	6:3	7:3	8:3	9:3	10:3	11:3	12:3	13:3	14:3	15:3
2	/	2:2	3:2	4:2	5:2	6:2	7:2	8:2	9:2	10:2	11:2	12:2	13:2	14:2	15:2
1	1:1	2:1	3:1	4:1	5:1	6:1	7:1	/	/	/	/	/	/	/	/
QRS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Methods – Synchronization indexes

Index	Aim	Definition
Sync (%)	*Assess the CVPS strength.*	*Percentage of time in which the most frequent PLR is observed.*
PLRV	*Quantify the PLR variability (PLRV) and CVPS stability.*	*Number of changes in the PLR series (every PLR value is referred to a 30-beats running window).*

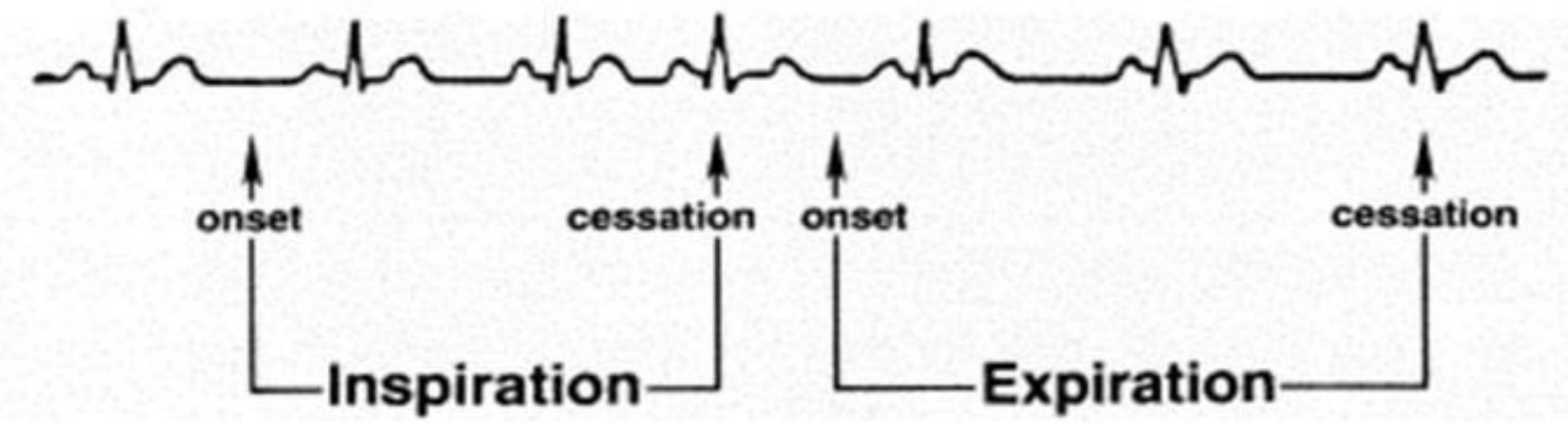
PLRV: During five 30-beats window sliding in the same series:

3:1 → 3:1 → 4:1 → NO SYNC → 5:2

Number of changes of detected PLR in every series (3)

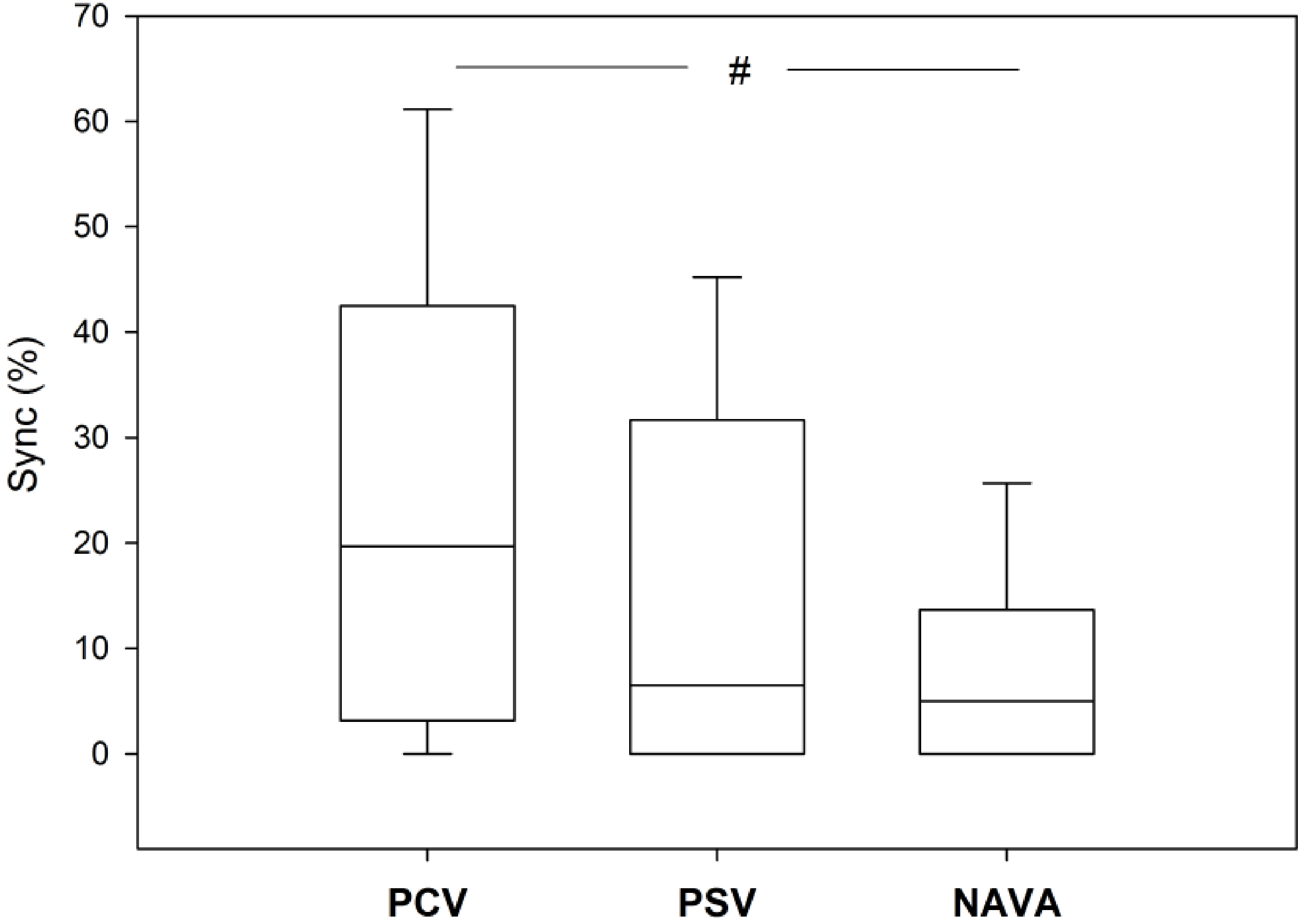
Methods – Other indexes

Index	Aim	Definition
RSA amplitude	***Quantify the Respiratory Sinus Arrhythmia (RSA).***	***Mean of the differences between max and min RR intervals within every respiratory cycle.***



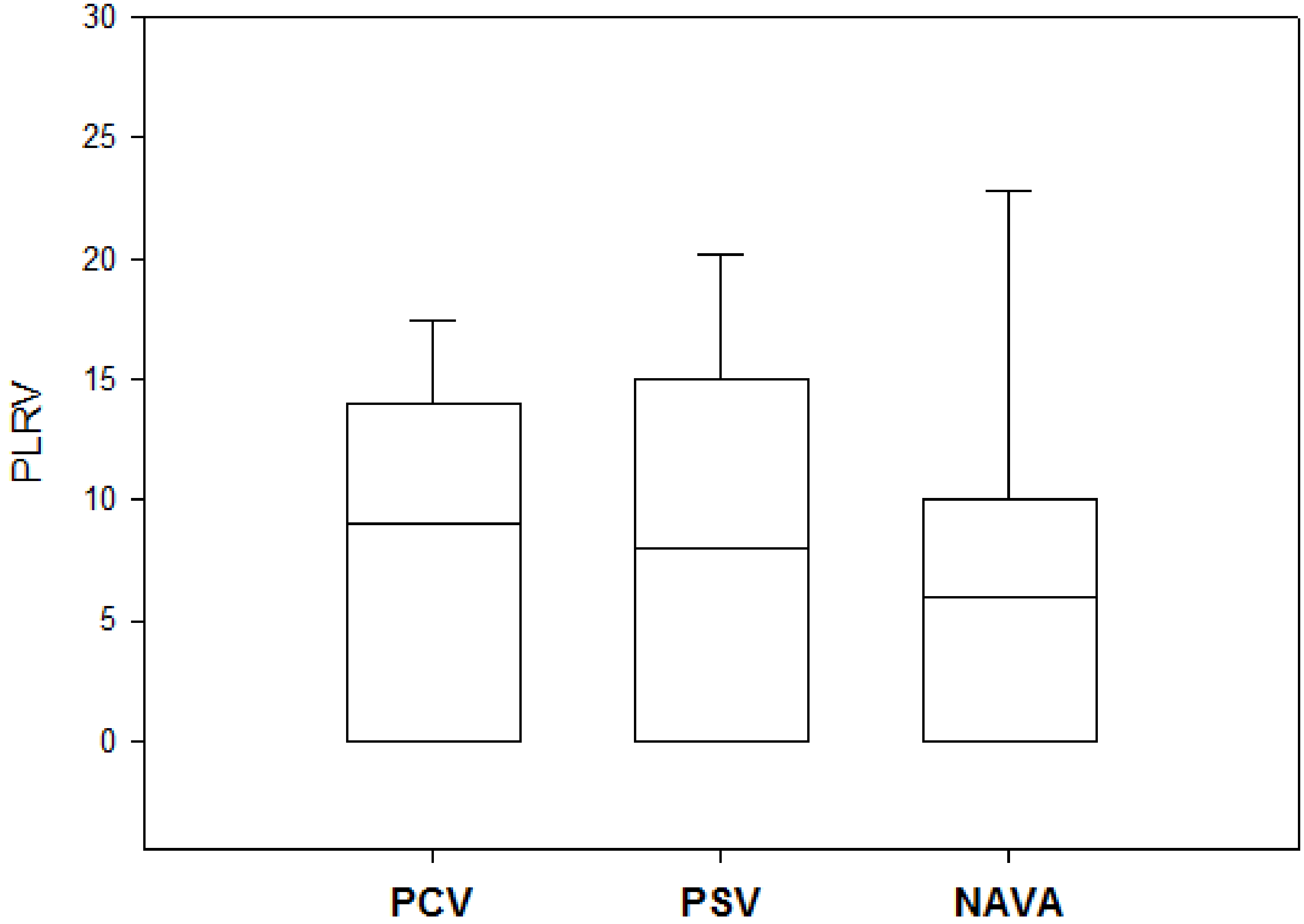
Results – Sync index

One-way ANOVA RM was performed



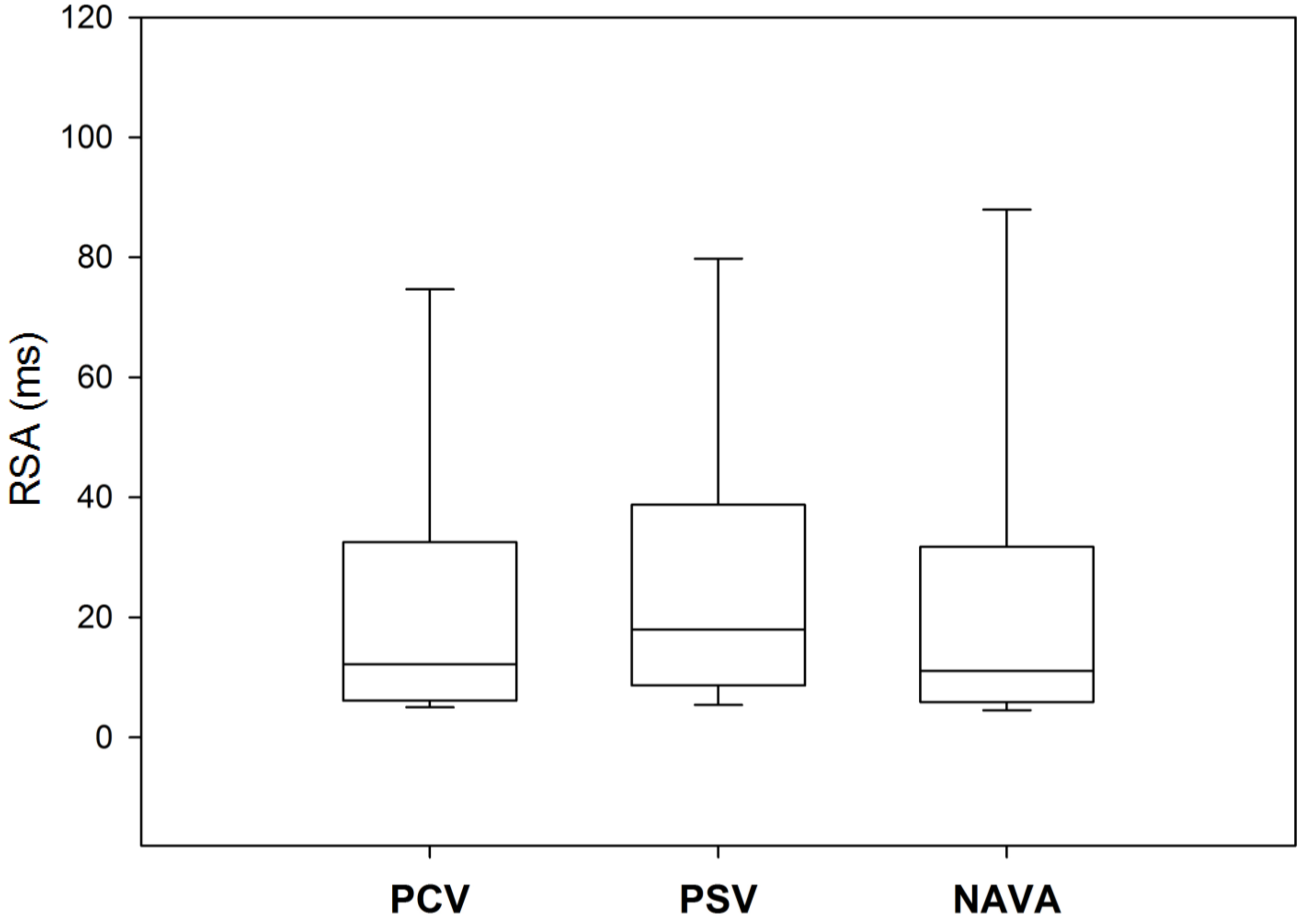
Box-and-whisker plot of SYNC as a function of the MV. # indicates p<0.05 vs PCV.

Results - PLRV



Box-and-whisker plots report the 10th, 25th, 50th, 75th and 90th percentiles of PLRV as a function of the MV modes.

Results – RSA amplitude



Box-and-whisker plots report the 10th, 25th, 50th, 75th and 90th percentiles of RSA as a function of the MV modes.

Discussion – Sync index

SYNC index was able to distinguish PCV from NAVA

Higher values of Sync were detected during PCV

We could speculate that it is more likely to find synchronization when an external oscillator, working at fixed frequency, is strong enough to align the behaviour of another oscillator.

Discussion – Other indexes

The reduction of RSA with MV and sedation might be responsible for the inability of RSA to separate the diverse MV strategies.

PLRV index did not provide significant differences, thus suggesting that the three MV modes led to similar PLR stability.

Conclusion

***PSV and NAVA maintain a more physiological variability in the interactions between respiratory function and heart** by preventing their strict locking and allowing a more flexible adaptation to the variable needs of the patient in ICU.*

Phase domain analysis and the proposed Sync index were found suitable to describe cardioventilatory interactions.

Future developments should:

- ***analyse other respiratory signals as airway flow and airway pressure;***
- ***investigate correlations between different indexes;***
- ***extend analysis duration to monitor long term effects of MV modes.***

Ending

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Thanks for your attention