Quantitative Complexity Theory (QCT) in integrative analysis of hemodynamic response to posture change

Paweł Krzesiński[1], Jacek Marczyk[2], Bartosz Wolszczak[2], Grzegorz Gielerak[1] , Francesco Accardi[3]
[1]Departament of Cardiology and Internal Diseases, Military Institute of Medicine, Warsaw (Poland), [2]Ontonix s.r.l. Como (Italy),[3] Boston Scientific S.p.A. (Italy)

INTRODUCTION

The explanation of physiological mechanisms involved in adaptation of the cardiovascular system to intrinsic and environmental demands is crucial for both basic science and clinical research. Computational algorithms integrating multivariable data that comprehensively depict complex mechanisms of cardiovascular reactivity are currently being intensively researched.
Quantitative Complexity Theory (QCT) provides quantitative and holistic information on the state a multi-functional dynamic systems.
The research was aimed to present the first application of QCT in integrative analysis of cardiovascular hemodynamic response to posture change.

METHODS

Three cases of **healthy males** are presented: S1 (aged 44 years), S2 (31 years) and S3 (36 years). The subjects underwent **Head-Up Tilt Testing (HUTT)**, accoring to Italian Protocol. After stabilization phase (5 min in the supine position) the subject was tilted to the position of 60-70 degrees. The passive phase of tilting was followed by the provocation phase of further 15 min after 400 micrograms NTG sublingual spray. Test interruption (supine restored) was made when the protocol was completed in the absence of symptoms, or there was the occurrence of syncope/presyncope.
Beat-to-beat hemodynamic cardiovascular response to tilting was evaluated by **impedance cardiography (ICG)** with use of the Niccomo™ device (Medis, Ilmenau, Germany) integrated with Tensoscreen™ module (Medis, Ilmenau, Germany).
The collected data was analysed with use of QCT. Four moving-windows were tested: 50, 75, **100**, 125 samples. The data sampling frequency was corresponding with heart rate frequency (beat-by-beat sampling).

RESULTS

sensitive marker of cardiovascular hemodynamic response

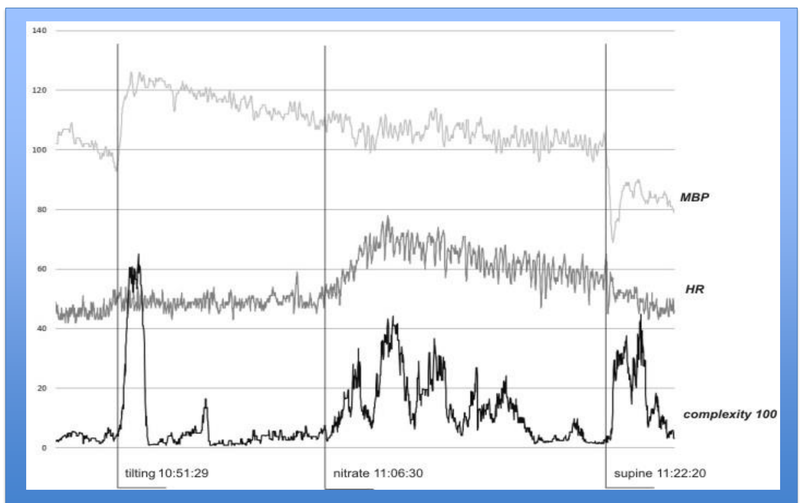

Fig. 1 Subject 1 - Trends of MBP (mmHg), HR (bpm) and complexity (beats/100

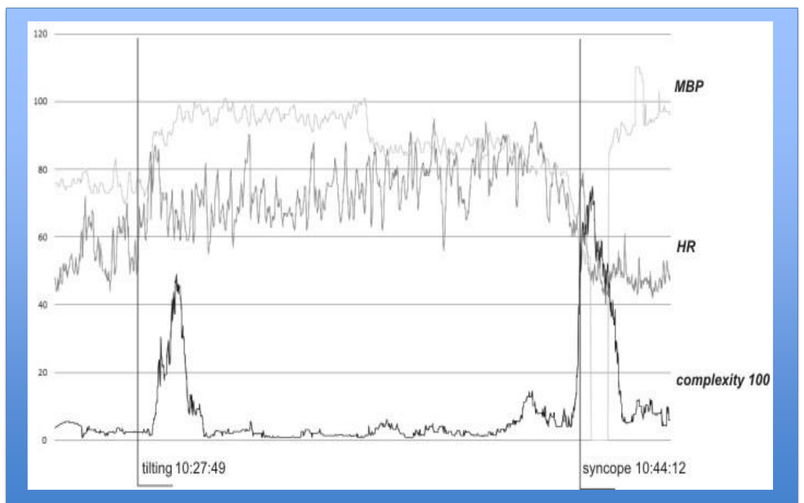

Fig. 2 Subject 2 -Trends of MBP (mmHg), HR (bpm) and complexity (beats/100)

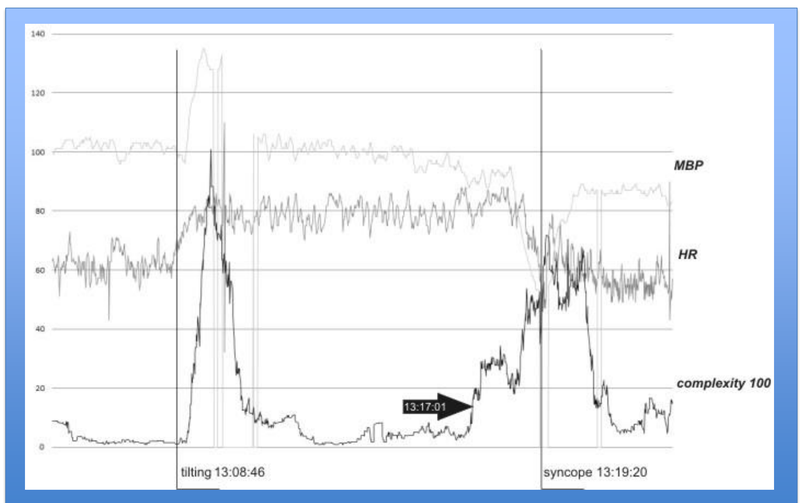

Fig. 3 Subject 3 - Trends of MBP (mmHg), HR (bpm) and complexity (beats/100)

Negative HUTT.
In the pre-tilting phase (5 minutes) complexity was stable (mean value 370 bits). After tilting (10:51:29) complexity suddenly rose to 6510 bits (10:53:01), then fell to baseline value (stabilization about 10.58.00). After nitrate administration (11:06:30) it increased to 4430 bits (11:10:20) and fell to baseline after about 7.30 minutes. After supine restoration (11:22:20) complexity rose again to 4480 bits (11:24:49).

Positive HUTT - syncope type 1 (mixed) according to VASIS classification.
In the pre-tilting phase (5 minutes) complexity was stable (mean value 320 bits). After tilting (10:27:49) complexity suddenly rose till 4900 bits (10:29:24), then fell to baseline value (stabilization about 10.30). At approximately 10.40 complexity started to rise again reaching 1290 bits at 10.42.12, then temporarily dropped to a minimum of 400 bits and eventually rose to 7500 bits during syncope (11:44:45). In the period 10.30 -10.40 complexity was in the range of 100-500 bits (mean 240 bits).

Positive HUTT - syncope type 1 (mixed) according to VASIS classification.
In the pre-tilting phase (5 minutes) complexity was stable (mean value 270 bits). After tilting (13:08:46) complexity suddenly rose up to 10090 bits (13:09:25), then fell to baseline value (stabilization about 13.12:00). At approximately 13.17:00 complexity started to rise again reaching 7170 bits during syncope (13:19:22).

„fitting“ to the application

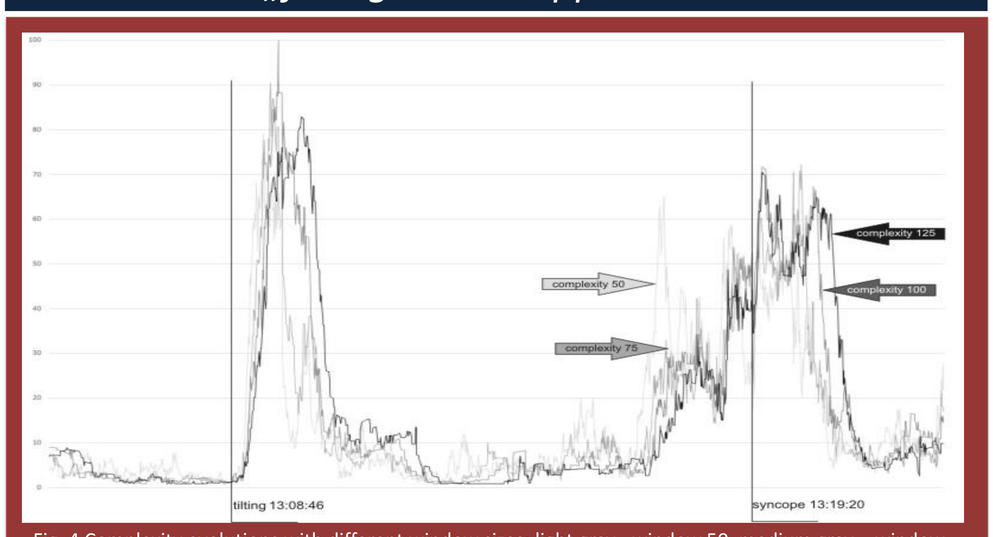

Fig. 4 Complexity evolutions with different window sizes: light gray - window 50, medium gray - window 75, dark gray - window 100, black - window 125 (units presented as bits/100)

In general, the **narrowest window** produces results with the highest variablity but also the lowest lag in relation to the actual hemodynamics, preferred when the early detection of hemodynamic disturbances is the priority.
The advantage of a **wide window** lies in higher resistence to „noise“ and higher specificity to clinically relevant hemodynamic changes.

mechanism identification

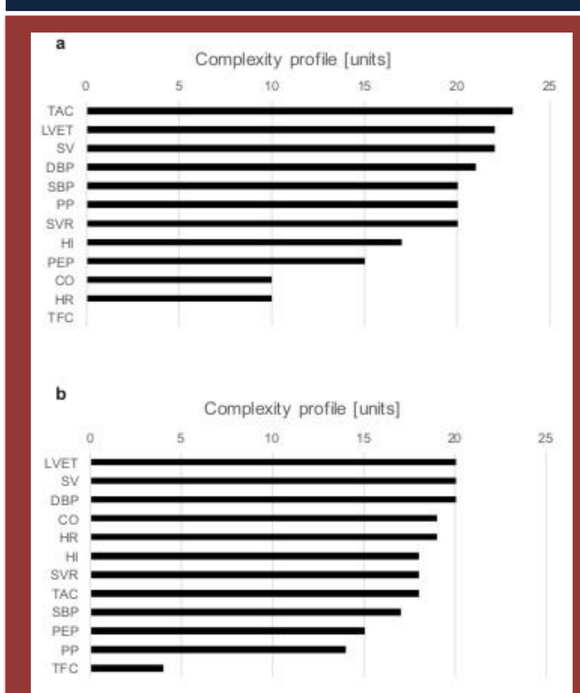

Fig. 5 Chart a - Complexity profiles at the moment of syncope event for S2; chart b - Complexity profiles at the moment of syncope event for S3

CO - Cardiac Output; DBP - Diastolic Blood ; HI - Heather Index HR - Heart Rate; LVET - Left Ventricular Ejection Time; MBP - Mean Blood Pressure; PEP - Pre-Ejection Period; PP - Pulse Pressure; SBP - Systolic Blood Pressure; SV - Stroke Volume; SVR - Systemic Vascular Resistance; TAC - Total Arterial Compliance; TFC - Thoracic Fluid Content

A **Complexity Profile** is a breakdown of total system complexity into its components in terms of percentage of contribution of each component.

The bar chart provides a **ranking of hemodynamic parameters** in terms of contribution to the vasovagal reaction. For both presented cases LVET and SV are the top complexity drivers. On the contrary, TFC had the lowest contribution for both presented cases.

Although both subjects were classified as mixed type of vasovagal syncope, there were some clear differences between them. For S2 TAC and blood pressure indices (SBP, DBP, PP) had greater contribution to vasovagal reaction than HR and CO while for S3 it was the opposite.

Such a detailed assessment of hemodynamic triggers may result in more effective treatment, tailored to individual pattern of vasovagal reaction.

CONCLUSIONS

Complexity has been shown to be a sensitive marker of cardiovascular hemodynamic response to ortostatic stress and vasodilator administration. Its increase preceded changes of standard cardiovascular parameters.
Complexity profiling provided a detailed assessment of individual hemodynamic pattern of syncope and different complexity settings (window size) produced results of different clinical usability.

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