

# Clinical Monitoring of the Tilt-Test: Task Force Monitor (TFM) and Heart Rate Variability (HRV)

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## Abstract

*The study of the Heart Rate Variability, using autoregressive analysis (AR) during Tilt Test, represents the leading approach to evaluate the sympathetic and vagal balance of the autonomic nervous system [1]. In clinical practice, AR is performed with traditional instrumentations (like GRPSD software) or with apparatuses of new generation like the Task Force Monitor (TFM). GRPSD allows a very accurate step-by-step spectral analysis but the procedure is quite complex; TFM, instead, analyses the ECG signals and presents autoregressive analysis in real time, but it is a “closed system” and it is not possible to verify the procedures performed by the system. To compare the two systems, 9 subjects were submitted to tilt test. AR analysis was performed on 39 different time intervals with both TFM and GRPSD. LF/HF ratios were compared. Concordance was present in the 82% of the cases but a mismatch was found in the remaining 18% probably due to the limitations in the analysis performed by TFM.*

## 1. Introduction

Neuromediate syncope is a transitory blackout caused by an abnormal response of the neurovegetative system to different stimuli [2]. The main test for the diagnosis of syncope is the Tilt Test, which is used to investigate the function of the cardiovascular system and to clarify the causes of syncope through analysis of Heart Rate Variability (HRV) and the blood pressure variability (BPV) [3]. The HRV analysis it's an important non-invasive method to analyse the vegetative nervous system by evaluating the balance between sympathetic and parasympathetic (or vagal) systems. The first one works to increase the heart rate and the second to reduce it. Both the systems work continuously together but their activity happens at different rates: at low frequencies the sympathetic component and at high frequencies the vagal one. To perform HRV, the R-R interval series (tachogram) is obtained from ECG signal and then it's fitted with a polynomial function [3].

To determine the power of the frequency components

of the tachogram spectrum, autoregressive analysis (AR) is performed. To apply the AR methods it's necessary to consider the tachogram as periodic and steady signal and had to be sampled at a rate equal to the mean of R-R intervals.

For the HRV analysis the important frequencies are:

- **The Low Frequency LF** (frequency range: from 0.04 to 0.15 Hz) component is determined basically of the sympathetic nervous system;
- **The High Frequency HF** (frequency range: from 0.15 to 0.4 Hz) component is synchronous with the breath and is related to the vagal nervous system and its variations [1].

In a healthy person, at rest, LF and HF components have a similar power. During the standing position the sympathetic tone increases and determines an augment of the LF component and a reduction of HF one. An abnormal balance between the sympathetic and the vagal components may lead to syncope [2]. In clinical practice, Tilt Test is performed with traditional instrumentations (Grass Polygraph, Light® Workstation, GRPSD software, Spark S.r.l Bologna [4]) or with apparatuses of new generation like the Task Force Monitor (TFM, CNSystems Medizintechnik GmbH [5]). Traditional systems allow a very accurate and complete step-by-step spectral analysis of the signals, from the signal steadiness and noise rejection to the choice of the order of autoregressive model [6,7], but procedures are quite complex and can be made only during post-processing phase by a skilled operator. These systems give a good interpretation of the Tilt Test, but they are operator-dependant and this may cause problem in the diagnosis. To solve this problem, the new generation devices like TFM can handle full Tilt Test, providing both the acquisition of Blood Pressure (BP) and ECG and presenting autoregressive analysis in real time. Nevertheless, TFM is a “closed system” and it's not possible to set the mathematical parameters (i.e. model order), verify the signal steadiness or remove respiratory artefact from HR. The aim of the study is to compare the consistency between the AR analysis performed with a validated system (GRPSD software) and the Task Force Monitor.

## 2. Materials and Methods

Nine patients (5 normal volunteers - Control Group – CG and 4 patients positive to the test - Vasovagal Group - VG). have been submitted to Tilt Test using TFM with the following protocols:

- 5 min in laying down position before the Tilt;
- 10 (CG) or 25 (VG) minutes in standing position;
- 5 min in laying down position after the Tilt.

AR analysis was performed in the following intervals:

- Control Group:
  - 1) 5 minutes in laying down position
  - 2) 4 min in standing position
  - 3) 1 min before the end of the Tilt Test
  - 4) 5 min in laying down position after the test
- Vasovagal Group:
  - 1) 5 min in laying down position
  - 2) 5 min before the syncope
  - 3) 1 or 2 min during the syncope
  - 4) 5 min in laying position after the Tilt

Tachogram, HF and LF powers (normalized on the whole area) and their ratio (LF/HF<sub>TFM</sub>) were automatically evaluated by the TFM during Test.

Then, data were exported in ASCII format and analyzed with the GRPSD Software. After removing non-stationary intervals, the better AR order model (0-20) was chosen using all the implemented methods (AIC: Akaike Information Criteria, FPE: Final Prediction Error, MDL: Minimum Description Length and CAT: Criterion Autoregressive Transfer), and selecting the biggest one [6,7]. Then the spectral analysis was performed on , considering the normalized power of the LF and the HF components and calculating their ratio(LF/HF<sub>GRPSD</sub>).

Since we cannot know the exact analysis algorithm of the TFM, the selection of the signal part for the GRPSD software could not be exactly the same of the TFM, so it's possible that the power of the LF and HF may result different, in absolute value, but the ratios ( prevalence of sympathetic or vagal system) have to be equal both for TFM and GRPSD Software.

To verify the concordance between the LF/HF<sub>TFM</sub> and LF/HF<sub>GRPSD</sub> a McNemar Test was performed.

## 3. Results

The results of the study are shown in the tables and in the figures below.

For each analysed phase, the number of beats (HB), the LF and HF components' amplitudes obtained with GRPSD and TFM, the ratio between LF and HF and the model orders (used with GRPSD) are reported in the tables.

Figures and tables 1 and 2 refer to CG patients and

figure and table 3 presents the result of a VG subject.

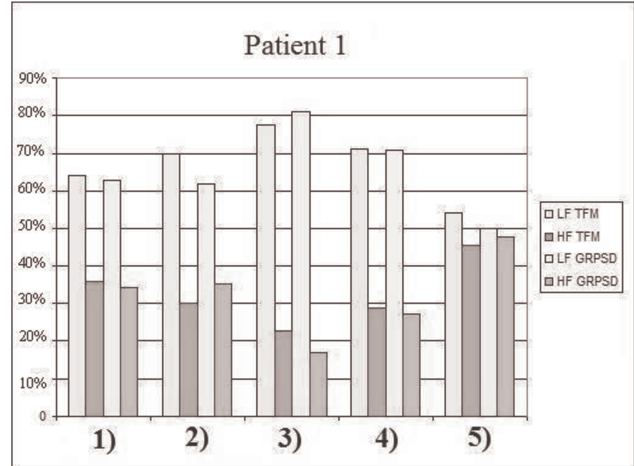


Figure 1: Example of LF and HF components' amplitudes for the different phases of the first patient. The plot shows a good agreement between GRPSD and TFM.

	HB	LF (%)		HF (%)		LF/HF		MO
		TFM	GRPSD	TFM	GRPSD	TFM	GRPSD	
1)	306	64,19	63	35,82	34	2,28	1,85	10
2)	321	69,9	62	30,1	35	2,5	1,79	9
3)	267	77,4	81	22,6	17	3,7	4,7	10
4)	67	71,3	71	28,7	27	2,5	2,63	8
5)	324	54,3	50	45,7	48	1,3	1,05	8

Table 1: analysis results for patient 1.

In each phase of the test, the ratios between LF and HF agree (they are all >1).

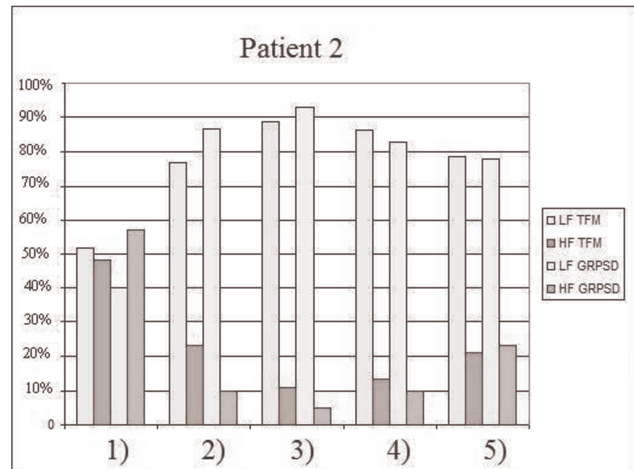


Figure 2: Example of LF and HF components' amplitudes for the different phases of the first patient. The plot shows a mismatch between GRPSD and TFM for phase 1.

	HB	LF (%)		HF (%)		LF/HF		MO
		TFM	GRPSD	TFM	GRPSD	TFM	GRPSD	
1)	280	51,8	40	48,2	57	1,1	0,7	10
2)	334	76,9	87	23,1	10	5,1	8,7	10
3)	283	88,9	93	11,1	5	11,5	18,6	10
4)	73	86,7	83	13,3	10	7,2	8,3	10
5)	266	78,7	78	21,3	23	4,1	3,4	10

Table 2: analysis results for patient 2.

In the first phase the HF component evaluated by TFM is overestimated and the LF/HF ratios don't agree ( $LF/HF_{TFM} > 1$  but  $LF/HF_{GRPSD} < 1$ ).

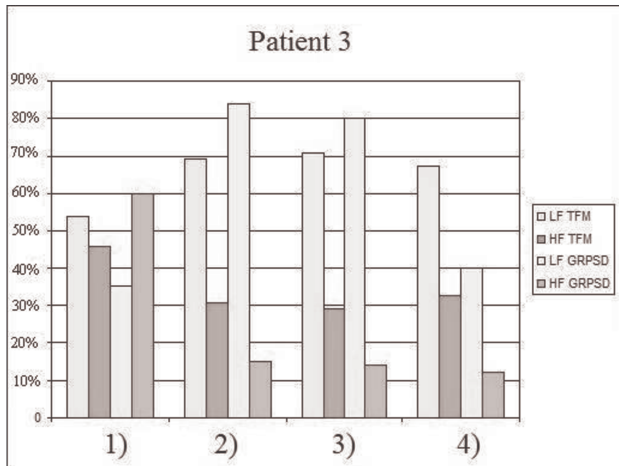


Figure 3: Example of LF and HF components' amplitudes for the different phases of the first patient. The plot shows a mismatch between GRPSD and TFM for phases 1.

	HB	LF (%)		HF (%)		LF/HF (%)		MO
		TFM	GRPSD	TFM	GRPSD	TFM	GRPSD	
1)	713	53,9	35	46,1	60	1,8	0,58	10
2)	459	69,25	84	30,74	15	2,94	5,6	8
3)	77	70,96	80	29,03	14	4,26	5,71	10
4)	591	67,5	40	32,5	12	2,4	3,33	10

Table 3: analysis results for patient 3.

For the third patients, there is a mismatch between the results obtained with GRPSD and TFM in the first phase ( $LF/HF_{TFM} > 1$ ;  $LF/HF_{GRPSD} < 1$ ).

In the other parts (2 to 4), the ratios are concordant. Summarizing the results for all the phases of all the patients (both CG and VG), 32 agreements and 7 mismatches between TFM and GRPSD were obtained (see table 4).

	N	N	Ntot
	( $LF/HF_{TFM} < 1$ )	( $LF/HF_{TFM} > 1$ )	
N ( $LF/HF_{GRPSD} < 1$ )	4	6	10
N ( $LF/HF_{GRPSD} > 1$ )	1	28	29
Ntot	5	34	39
P	0.131		

Table 4: agreements and disagreements between GRPSD and TFM

#### 4. Discussion and conclusions

Although an agreement between TFM and GRPSD is present in the 82% of the analysed phases, in 7 cases (18%) the results between the two instruments are different. In 6 cases  $LF/HF_{TFM} < 1$ ;  $LF/HF_{GRPSD} > 1$  and in the remaining one  $LF/HF_{TFM} > 1$ ;  $LF/HF_{GRPSD} < 1$ .

Differences regard both LF and HF components and probably are due to the automation of the TFM analysis:

- The band limits of the spectrum components are fixed and non-editable.
- No verification of the correlation between the breathing activity and the HF component of the spectrum.
- The frequency peaks of the spectrum components are unknown
- The order of the model is fixed and immutable by the user.
- It's impossible to eliminate any artefacts due to noise or arrhythmic beats.
- The steadiness of the considered signal is not verified.
- It is impossible to verify which RR intervals are used for the HRV.
- Mistakes are not resolvable by using BPV analysis instead of HRV because the discrepancy with GRPSD are both in LF and HF components.

In conclusion, despite TFM is very "user friendly" system which performs sophisticated analyses, sometimes it gets to wrong results because of the incorrect application of the AR analysis algorithm. The system is "closed" and it is impossible for the operator to verify the correctness of the procedure steps and the result is a "reject or accept" choice, based on pure confidence!

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