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Letter to the Editor

Wearable wireless remote monitoring system: An alternative for prolonged electrocardiographic monitoring

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Reflex syncope, also named neurally mediated syncope is, by far, the most common cause of syncope [1]. The study of patients with syncope is often challenging, once high-risk causes of syncope (such as aortic stenosis or malignant arrhythmias) have been ruled out.

Holter systems can be applied only 24–48 h ordinarily, and sometimes this time is not enough to establish a definite diagnosis. In case longer monitoring were needed, implantable monitors, such as Reveal® device, might be used, but physicians have to take into account that it is an invasive procedure, which may entail discomfort and other complications.

A new generation patented wireless remote monitoring platform, Nuubo's dynamic ECG (nECG Platform), which consists of a non-invasive and single-lead dynamic ECG system that incorporates biomedical e-textile technology may help to establish the diagnosis in patients with syncope by enabling a long non-invasive comfortable monitoring, reducing the procedure to the simple act of wearing an nECG shirt.

Our aim was to assess the accuracy of the Nuubo system in the diagnosis of patients with reflex syncope. In order to evaluate this point, we compared the results obtained with the Nuubo system with those obtained by means of a conventional monitoring system during a tilt table test.

Thirty-one consecutive patients with clinical suspicion of reflex syncope who underwent a tilt table test were enrolled in the study. They were monitored by the conventional tilt table test protocol, with continuous electrocardiogram monitoring, and, at the same time, with the new Nuubo system. Informed consent was obtained for every patient. For every patient, a standardized protocol form with 2 epidemiological, 1 clinical and 20 electrocardiographic variables was completed and included in our database. This protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the local ethical committee.

Nuubo's technology consists of three elements: 1) nECG SHIRT: a biomedical shirt that captures the electrocardiographic signal via the textile electrodes technology (BlendFix®) integrated into the garment which enables non-invasive reception of a medical quality ECG signal by obtaining a great adherence of textile electrodes to the skin; 2) nECG MINDER: a electronic device that is attached to the garment and transmit the ECG signal via Bluetooth® (among other signals such as accelerometer and GPS) to a computer, and also stores the information in a microSD card; and 3) nECG SUITE: a software package that manages sessions, patients, activities and users, and allows the visualization and analysis of data (such as ECG, activity index, heart rate) captured by the nECG device. The platform is a medical device already certified in the European Union.

Statistical analysis was performed with PASW Statistics V 18.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were reported as mean value and standard deviation (SD), and were compared by a 2-tailed Student's *t*-test. Categorical variables were expressed as frequency and percentage, and were compared with the χ^2 test and Fisher's exact test when appropriate. Inter-methods agreement was evaluated by the performance of Intra-class Correlation Coefficient (ICC) and Kappa index. All tests were two-sided and differences were considered statistically significant at P-values < 0.05.

The mean age of our patient population ($n = 31$) was 46 years (SD 21), 14 (45.2%) were male, and 19 (61.3%) experienced syncope during the test. Main electrocardiographic findings are summarized in Table 1.

Inter-methods agreement analysis is depicted in Table 2. These results showed excellent correlation between the two techniques for the evaluation of the most frequently assessed electrocardiographic parameters in patients with reflex syncope.

In the last years, several studies have been published, showing the high exactitude of wearable electronic devices, and its usefulness in the diagnosis and management of patients with cardiac pathologies [2–4].

In the field of cardiac remote monitoring, Nuubo's technology moves a step forward. The device enables a remote, continuous, non-invasive

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Table 1
Electrocardiographic findings.

	Mean	Standard deviation
Baseline heart rate TTT	72.1	12.8
Baseline heart rate Nuubo	73.8	14.0
Peak heart rate TTT	107.9	22.2
Peak heart rate Nuubo	114.3	25.1
Minimum heart rate TTT	50.1	26.0
Minimum heart rate Nuubo	48.8	25.6
Time to minimum heart rate TTT (seconds)	14.5	10.3
Time to minimum heart rate Nuubo (seconds)	16.0	10.8
Episodes of asystolia TTT[a]	5	16.1%
Episodes of asystolia Nuubo[a]	4	14.3%
Time in asystolia TTT (seconds)	19.8	12.0
Time in asystolia Nuubo (seconds)	20.8	13.9
Maximum PR interval TTT (milliseconds)	160.0	26.3
Maximum PR interval Nuubo (milliseconds)	145.7	25.6

TTT: tilt table test conventional monitoring.
[a] Data expressed in number and percentage.

Table 2
Inter-methods agreement.

Quantitative variables		
	ICC (IC 95%)	*P*
Baseline heart rate	0.975 (0.947–0.989)	<0.001
Peak heart rate	0.887 (0.756–0.948)	<0.001
Minimum heart rate	0.991 (0.980–0.996)	<0.001
Time to minimum heart rate	0.925 (0.838–0.965)	<0.001
Time in asystolia (seconds)	0.994 (0.907–1.000)	0.001
Maximum PR interval	0.883 (0.739–0.947)	<0.001
Qualitative variables		
	Kappa index	*P*
Presence of asystolia	0.868	<0.001
Presence of AV-block	1.000	<0.001
Presence of nodal rhythm	0.868	<0.001

ICC: Intra-class correlation coefficient; 95% CI: 95% confidence interval; AV-block: atrioventricular block.

and long-lasting monitoring, at the time that is comfortable for the patient and has a minimum impact on his quality of life. The elastic textile adapts to the patients' movements, permitting them to carry out daily physical activities without the limitation of wires. Also, the device has a built-in 3-axis accelerometer that measures the position and inclination of the patient in every moment, which is another useful tool when syncope is analyzed. This fact allows to evaluate patients in real-life setting, where most reflex syncopes usually happen.

These advantages together with the good correlation showed in our findings should encourage a widespread use of this technology for the diagnosis of reflex syncope, as it would record any electrocardiographic event in a more physiological real-life setting than the traditional tilt-test table.

In conclusion, Nuubo's technology enables to obtain similar results in the analysis of electrocardiographic parameters to those acquired in a conventional tilt-test, in a more comfortable way, and permitting a remote monitoring of the patient.

The authors of this manuscript certify that they comply with the Principles of Ethical Publishing in the International Journal of Cardiology.

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