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NCT NUMBER : NOT AVAILABLE

DATE : 25/01/2019

DO ABNORMAL HEMODYNAMIC FEATURES GENERATE RELEVANT REACTIONS AND VIBRATIONS AT THE SKIN LEVEL WHEN RECORDED BY MICRO ACCELEROMETERS?

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Abstract

Heart contraction produces accelerations and displacements of the blood and cardiac mass at each cardiac cycle. Those displacements are known as “the recoil forces”. The kinocardiography (KCG) is an innovative hybrid method recording the heart induced - acceleration signals transmitted to the skin level and based on the principles of the seismocardiography (SCG) and ballistocardiography (BCG). Several biomechanical parameters can be derived from the KCG tracing, mainly the kinetic energy of blood and cardiac mass. However, the physiological genesis of the KCG signal is still unclear. The aim of this pivotal observational study is to investigate the possibly relationship between the heart-induced acceleration signals and the intracardiac pressures measured during cardiac catheterization among 100 consecutive patients suffering from heart failure and undergoing a planned catheterization as required by their medical condition.

Scientific proposal

Background

Heart contraction produces accelerations and displacements of the blood and cardiac mass at each cardiac cycle. Those displacements are known as “the recoil forces” and are transmitted to the body’s surface as low-frequency vibrations. Those low-frequency vibrations have been the subject of analysis for many years (since the early 1900s) by the mean of different techniques known as “seismocardiography”, “ballistocardiography”, “mecanocardiography”. However, the cumbersome and complex equipments, the lack of understanding the physiological origin of the signal and the secondary ambiguity in its interpretation resulted in a discontinuation of those techniques.

Recently, the tremendous improvement of technology and the development of micro-accelerometers and gyroscopes has led to the modelling of unobtrusive and easy-to-use devices, allowing a comprehensive and automatic analysis of the acceleration signals with 6 degree-of-freedom in the three cardinal axis (food-to-head, dorso-ventral, right-to-left) and two dimensions (longitudinal and rotational). Whenever the recording takes place close to the heart, the recording technique is called seismocardiogrpahy (SCG), while whenever it is recorded near the subject’s center of mass, the technique is called ballistocardiogrpahy (BCG). The kino-cardiography (KCG) is an hybrid technique recording simultaneously and continuously the SCG and BCG signals, coupling with the traditional ECG (figure 1).

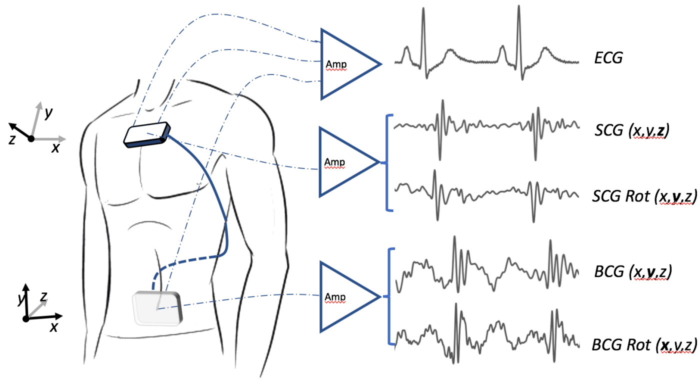

Figure 1. Kinocardiography device measuring 2-lead ECG, 6-DOF Seismocardiography (SCG) and 6-DOF Ballistocardiography (BCG). There are two housings, one placed over the sternum and the other one over the lumbar column. The standard axis system is used for BCG and SCG: BCG x, y, and z are respectively left-to-right, foot-to-head, and ventro-dorsal axis; SGC x,y, and z are respectively right-to-left, foot-to-head, and dorso-ventral axis.

This technique has been developed at the Université Libre de Bruxelles by the engineer team together with the cardiovascular department. It is a wearable device with two detectors, one of which is placed over the lumbar region close to the subject's center of mass (BCG) and the other one close to the heart over the subclavicular sternum (SCG). Each detector contains a MEMS accelerometer and gyroscope sensor (LSM6DSL, STMicroelectronics) and is attached to the body with standard sticky gel electrodes (the lumbar detector is further secured in place with an elastic band). The KCG device is remotely controlled with a smartphone or a tablet connected via Bluetooth and collects a two-lead ECG at 200 Hz (ADS1292R, AD Instruments) together with 3-Degree of Freedom (DOF) linear (LIN) accelerations and 3-DOF rotational (ROT) angular velocities from the sternum and the lumbar region. While the BCG measures overall body accelerations, the SCG sensor mainly records local chest wall motion. In brief, a total of 12-DOF linear accelerations and angular velocity signals are recorded at 50 Hz. Standard nomenclature is used: for BCG signals, x is the lateral (left-to-right) axis, y is the longitudinal body (caudo-cranial) axis, and z is the anteroposterior (ventro-dorsal) axis; for SCG signals, the z-axis points in the opposite direction (dorso-ventral) and the x-axis right-to-left. Linear and rotational kinetic energy can be automatically derived from the acceleration signals for each cardinal axis, thus providing global information about the mechanical performance of the heart (figure 2).

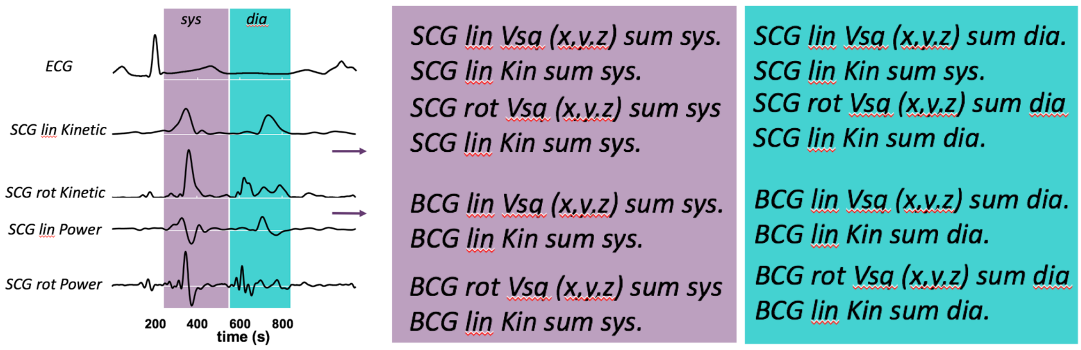

Figure 2. Mesures of velocities, kinetic energy and power recorded with the KCG during both the systolic and diastolic phase of the cardiac cycle.

However, the physiological origin of the KCG signals is incompletely understood and cannot be compared to worldwide recognised clinical parameters, such as the left ventricle ejection fraction or the cardiac output. Therefore, is mandatory to compare the KCG signals with intracardiac hemodynamic parameters, such as intracavitary pressure and cardiac output, in order to highlight the origin of this innovative biomechanical signal.

Aim

The aim of this pivotal study is to highlight the origin of the KCG signals and thus to widen the knowledge of the mechanical performance of the heart. Clinical and hemodynamic parameters obtained during invasive catheterization will be compared to the accelerations and acceleration-derived signals obtained unobtrusively with the KCG device.

Methods

Patients suffering from heart failure and undergoing a planned cardiac catheterization as required by their medical condition will be asked to participate to the study. In case of consent, the KCG will be placed onto the skin surface of the patient, the first house on the sternum and the second house on the lumbar column. As described above, the KCG records a continuous signal, synchronized with intracavitary pressure profiles and transferred to a tablet via Bluetooth. At a second stage, specific algorithms will compute kinetic energy, cardiac power and work form the signals.

The cardiac catheterization will be performed by a trained invasive cardiologist and classical parameters will be obtained according to the clinical status of the patient (intracavitary pressures, pulmonary resistance, cardiac output).

Inclusion criteria are very large: patients aging 18 to 80 years old and suffering from heart failure, regardless of its etiology, can participate to the study. Exclusion criteria include patients with left ventricle assistance device and those who denied consent. Authors plan to rule-in 100 subjects.

Authors do not foresee adverse effect or complication, since the KCG is totally unobtrusive.

The protocol has been approved by the Ethical committee of the Erasme Hospital.

Perspective

This study aims to better understand the physiological origin of the KCG signals through the simultaneous recording of intracardiac parameters and to identify which of the KCG signals better cope with classical haemodynamic features and thus could be of potential clinical relevance.

At a later stage, this KCG signal could couple with the classical cardiovascular exams in the clinical practice and empower the diagnostic and therapeutic strategies.