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Preliminary Validation of a 64-lead Body Surface Potential Mapping on Healthy Volunteers

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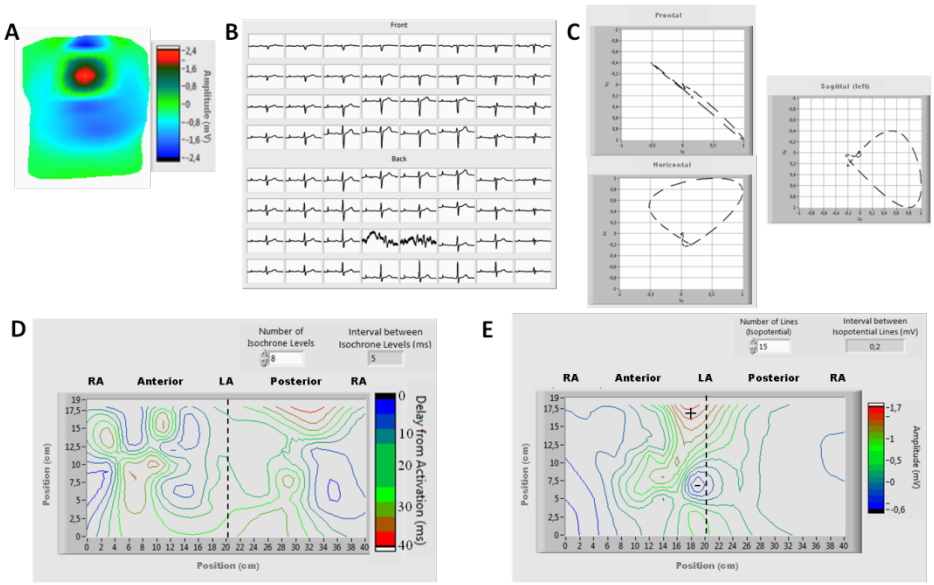
Background, Motivation and Objective. Cardiovascular diseases are the leading causes of mortality worldwide, affecting 4% of the population in Brazil and representing a public health problem, with total cost of 0.6% of the national Gross Domestic Product. Intrinsic characteristics from these diseases can affect the anatomy and physiology of the heart, modifying its excitation-coupling characteristics and the propagation of electrical activity, with potential consequences on its mechanical pumping ability. Invasive and non-invasive commercial systems have been used in clinical practice to help diagnose and treat these patients. Recently, body surface potential mapping (BSPM) systems have been used with great expectation, increasing the success rate of treatment of patients with complex heart disorders. BSPM systems allow real time acquisition of up to 300 electrodes with the body surface potentials (BSPs) projected with a colour-coded basis on a 3D torso shell, allowing non-invasive investigation of the spatial-temporal behaviour of cardiac electrical activity. Imported BSPM systems have a high cost, making it difficult to use in public health centres and clinical research in Brazil. This study aims to present the preliminary validation in healthy volunteers of a recently developed national 64-channel BSPM equipment.

Methods. 64 BSP signals (42 on the chest and 22 on the back, 1 minute) from 4 control volunteers were collected (ethics committee research protocol n° CAAE:-00591712.0.1001.0068). Hardware consists of 4 modules of 16 channels each, with a buffer, 1st stage amplification (30 dB), band-pass filter (0.5-150 Hz) and configurable 2nd stage amplification (10-30 dB, 30 dB by default). Each of the 16 channels modules contains a sample and hold circuit, multiplexer and high-voltage isolation amplifier. An embedded control board sends pulses at 16 kHz for synchronization with the multichannel acquisition module (NI USB DAQ 6363) allowing BSPs digitalization at 16-bit precision (the right-leg electrode is the reference). Demultiplexing is done via LabVIEW™ (version 14.0.1f3, 32-bit) and the resulting sampling frequency is of 1 kHz/channel. BSPs are then pre-processed digitally by a second order low-pass Savitzky-Golay filter with cut-off at 150 Hz. 60 Hz Notch filtering with band of 6 Hz was implemented to remove powerline interference. Baseline is removed by subtracting the output of a second order Lynn's lowpass filter from the delayed output, eliminating frequencies below 0.26 Hz. The Pan-Tompkins algorithm is applied on a selected lead (DII default) in order to allow heart rate monitoring and vectocardiogram (VCG) plots. A graphical user interface (GUI) was developed in LabVIEW: the user can customize the BSPs pre-processing setup, simultaneously analyse long-segment recordings up to 4 BSPs or short episodes of all 64 BSPs (panoramic view), access to the 12 lead ECG and to the VCG signals, either as orthogonal 1D signals (Vx, Vy,Vz), by the projection of the vectors on 2D planes or in 3D VCGs are obtained from predetermined torso's electrodes position (modified Frank leads) or by weighting the 12 lead ECG with transfer coefficients obtained by three different methods (Inverse Dower, Uijen and Willems). The platform also allows users to investigate cardiac potential propagation on the torso with sequential isopotential maps and with isochronous maps, where activations are obtained by the higher dV/dt module.

Results. A pseudo real time BSPM system with 64 channels has been developed for non-invasive clinical investigation of the heart's electrical activity and pre-validated on healthy volunteers. The system allows visualization of BSPs waveforms, isopotential and isochronous maps and VCGs (an illustrative movie is available at https://youtu.be/E0e7qIBLi1k). An example of a 3D colour-coded torso potential map obtained during a ventricular beat is presented in Fig A. A panoramic view of all 64 BSPs is presented on Fig B (two electrodes with bad contact). Fig C presents the VCG of a typical QRS complex projected on the anatomical planes (frontal plane: counter-clockwise loop with 45° inclination; horizontal plane: counter-clockwise loop with -45° inclination; and left sagittal plane: counter-clockwise loop with 45° inclination). Fig D shows an isochronous map obtained from 40 ms during a ventricular beat; the early activations occur on the regions marked in blue, on the left-superior and right inferior portions of the anterior torso, and on the right inferior of the posterior torso. The activation wavefronts propagate to the centre in both torso sides, with colours increasingly closer from red. Fig E displays an isopotential map with the highest and lowest voltage peaks respectively on the left superior and left inferior portions of the torso.

Discussion and Conclusions. A non-invasive investigation tool using high density electrodes allows tracking both 3D spatial-temporal cardiac propagation patterns and BSPs' morphological and temporal changes. The system presented provides also visualization of well-established clinical diagnostic tools (12-ECG lead and VCG), facilitating the use of this equipment on the clinical practice and contributing to the interpretation of BSPM maps by cardiologists.

Figure: A. Illustration of a typical 3D potential torso map. **B.** 64 BSPs panoramic view. **C.** Frank lead VCG -2D projections (Frontal, Horizontal [left] and Sagittal [left]). **D.** A 2D Isochronous map of the QRS complex. **E.** 2D Isopotential map obtained close to the R peak, with the highest and lowest voltage peaks marked respectively with + and – symbols. RA: right arm; LA: left arm.



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