IITB-ICG: An Impedance Cardiography (ICG) Database with Doppler Echocardiography as the Reference

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2. Dataset Title: IITB-ICG: An Impedance Cardiography (ICG) Database

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4. IEEE Keywords: Cardiology (15750); Bioimpedance measurement; Ultrasound echo (2529)

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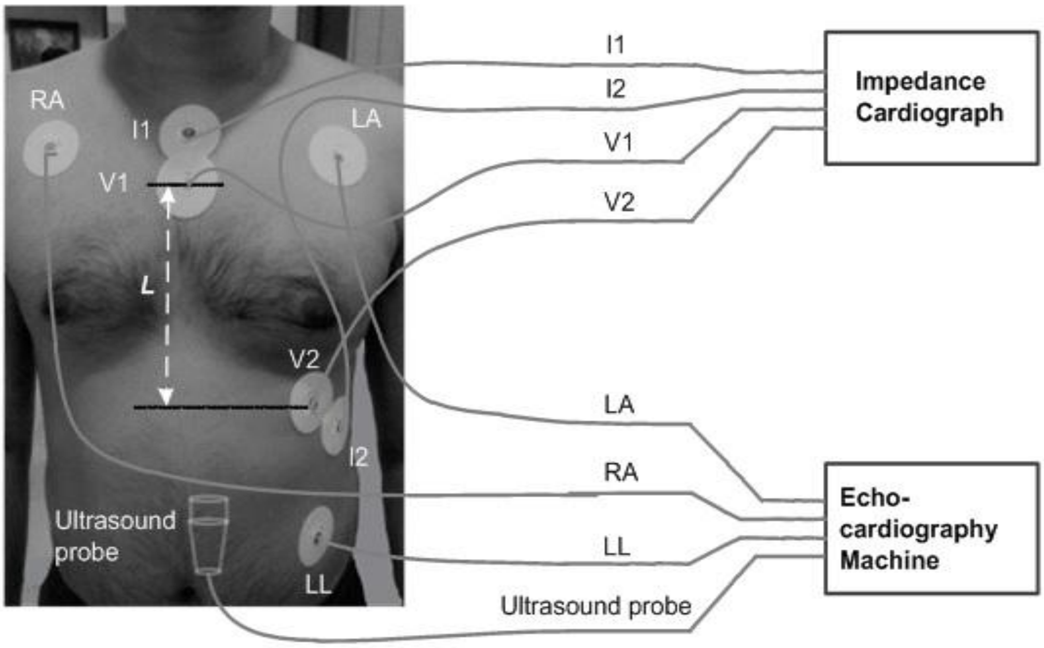
8. Recording Setup



9. Abstract

Impedance cardiography (ICG) is a noninvasive technique for sensing the thoracic impedance variation due to blood volume variation during the cardiac cycle, and using the sensed impedance to estimate stroke volume (SV) and other cardiovascular indices. The IITB-ICG database was prepared as part of a research project at IIT Bombay (Mumbai, India) to develop techniques for detecting ICG characteristic points and beat-to-beat estimation of stroke volume using Doppler echocardiography as the reference technique. The database comprises simultaneous recordings of ICG signals and Doppler echocardiograms from 18 subjects with normal health and 22 with cardiovascular disorders. Signals for subjects with normal health (SNH) were recorded under two conditions: at rest and after an exercise to induce significant beat-to-beat variability. Signals for subjects with cardiovascular disorders (SCD) were recorded only at rest. Each SNH recording has data for 630 and 625 cardiac cycles for the under-rest and post-exercise conditions, respectively, and each SCD recording has data for 842 cardiac cycles for the under-rest condition. The data files provide physical measurement data, ICG signals at 500 Hz, echocardiography images, and beat-to-beat SV measurement carried out manually from the Doppler echocardiograms.

10. Documentation & Instructions

A. Signal Recording Method

The signals (ICG, Doppler echocardiogram, ECG) were recorded from subjects with normal health and subjects with cardiovascular disorders, in a clinical setting, at Hardas Heart Care (Pune, Maharashtra, India) after the hospital's Ethics Committee approved the study protocol. The subjects for participation in the study were recruited, without considering gender and age balance, from among persons visiting the hospital for health check-ups, diagnosis, or post-operative treatment. They were informed about the study objectives and the signal recording procedure, and those willing to participate read and signed the consent form for participation. There was no monetary cost or benefit for participation. The subjects with normal health had no history of cardiovascular disorders, and they were selected based on ECG report and physical examination. The subjects with cardiovascular disorders were the patients undergoing post-operative treatment or having a history of cardiovascular disorders. The concerned cardiologist screened them to determine their suitability for participation in the study. The signals were recorded from 18 subjects with normal health and 22 with cardiovascular disorders.

The gender, age, height, and weight of the subjects were noted. As part of the ICG recording, basal impedance, impedance signal, impedance derivative (ICG), and ECG were recorded using "HIC-2000 Bio-electric Impedance Cardiograph" from Bio-Impedance Technology (Chapel Hill, NC, USA). The impedance sensing used a four-electrode configuration with Ag-AgCl disposable ECG spot electrodes. The excitation current was injected using the outer two electrodes, and the resulting voltage was picked up across the inner two electrodes. The upper current injecting electrode was placed on the front of the neck above the suprasternal notch, with the lower current injecting electrode placed on the left lateral side of the thorax below the xiphisternal junction. The upper voltage sensing electrode was placed at the base of the neck below the upper current electrode, with the lower voltage sensing electrode placed on the left lateral side of the thorax at the level of the xiphisternal junction. The voltage-sensing electrodes were also used for ECG recording. The instrument used a 1-mA excitation current at 100 kHz. It provided analog outputs with sensitivities of 40 mV/Ω for impedance, 400 mV/Ω-s^{-1} for ICG, and 0.25 mV/V for ECG. The analog output signals from the ICG instrument were acquired at a sampling frequency of 500 Hz using an eight-channel 12-bit signal acquisition module ("KUSB-3102" from Keithley Instruments (Cleveland, Ohio, USA)) connected through USB to a battery-powered notebook PC.

The echocardiograms for the aortic blood flow velocity profile were recorded using "iE33 Echocardiography System" from Philips Ultrasound (Bothell, Wash., USA), with a 2.5-MHz phased-array probe placed on the chest in a five-chamber apical long-axis view of the ascending aorta, with an ultrasound gel applied for good contact with the skin. The machine also had a facility to record an ECG using three electrodes. The first electrode was placed below the right clavicle near the right shoulder, the second electrode below the left clavicle near the left shoulder, and the third electrode below the pectoral muscles on the lower edge of the left rib cage. These electrode positions are shown in the figure along with the ICG electrodes. The ECG recorded using the three-electrode ECG recorder of the echocardiography machine was displayed along with the Doppler echocardiogram. The aortic diameter was measured using parasternal long-axis view at the level of the aortic annulus during mid-systole. The velocity-time integral (VTI) for each cardiac cycle was manually estimated as the area between the envelope of the Doppler spectrum and its baseline with the help of the built-in software of the echocardiography machine and its track ball by tracing the spectral envelope. The beat-to-beat SV values were calculated as the product of the VTI and the cross-section area of aortic annulus during mid-systole.

The instruments for acquiring the ICG signals and Doppler echocardiograms employed independent time bases. The Doppler echocardiogram recording was a sequence of images for 3.2-s intervals with 0.2-s overlap. The cardiac cycles in the Doppler echocardiogram images were synchronized with the cardiac cycles in the ICG recordings by visually aligning the R-R intervals in the corresponding ECG recordings, and the beat-to-beat SV values were noted with the cardiac cycle number.

Two recordings were carried out for subjects with normal health. The first recording was carried out with the subject relaxed, rested, and lying in the left-lateral position with a slight right leg fold. For the second recording, the subject underwent an exercise to increase the heart rate. The exercise was carried out, following the first four stages of the Bruce exercise protocol, for about 10 min on the "GE T-2100" treadmill (GE Healthcare, Wauwatosa, WI, USA) attached with a "Smart Biphasic" defibrillator (Philips Healthcare, Andover, MA, USA). The signals were recorded soon after the cessation of the exercise, and the subject was lying in the same way as for the first recording. The first and second recordings are called "under-rest" and "post-exercise" recordings, respectively. The post-exercise recordings have significant beat-to-beat variability in the R-R intervals and SV values. Only the under-rest recording was carried out for a subject with a cardiovascular disorder. For all recordings, the subjects were advised to avoid movements to minimize motion artifacts, but no restrictions were placed on breathing.

The under-rest (UR) and post-exercise (PE) recordings from the 18 subjects with normal health (SNH) have 630 and 625 cardiac cycles, respectively, and these are referred to as the SNH-UR and SNH-PE recordings. The UR recordings from the 22 subjects with cardiovascular disorders (SCD) have 842 cardiac cycles, and these are referred to as the SCD-UR recordings.

The recordings for the database were carried out over 13 months, starting in July 2014. The database was published in July 2025.

B. Database Organization

The database is named "IITB-ICG", with the organization as given in Table 1. It comprises a ".pdf" file providing the database description and seven ".zip" files with zipped data folders. It can also be downloaded as a combined zipped file.

The Doppler echocardiogram, ICG signal recording, signed consent forms, and medical report for each subject are saved in a folder named with the respective 2-letter subject code, with the organization as given in Table 2.

Information of the 'SNH' and 'SCD' subjects are tabulated in the files named as "XX_SNH_ info_meas.xlsx" and "XX_SCD_info_meas.xlsx ", respectively, with the format as given in Table 3. The files have columns for the subject code, name, gender, age, address, consent, clinical report, gender, height, weight, medical history, and the distance between the two voltage sensing electrodes.

Format for the Doppler echocardiogram frame number, the manually measured beat-to-beat values of RR intervals, VTI, and SV values in ".xlsx" files are given in Table 4.

Organization of the folders ' SNH_consent_reports' and ' SCD_consent_reports ' with consent forms and medical reports of 'SNH' and 'SCD' is shown in Table 5.

The subject identities are masked in the images and data files, and the files containing subject-specific information are not included in the database.

Table 1 Organization of the database "IITB-ICG" (SNH: subjects with normal health, SCD: subjects with cardiovascular disorders, XX: 2-letter subject code).

File	Description
IITB-ICG-Description.pdf	Database description as a ".pdf" file
IITB-ICG-data1.zip	Zipped folder "SNH_UR" with SNH-UR (subjects with normal health, under-rest) recording data, containing a folder for each subject (XX: 2-letter subject code) with the Doppler echocardiograms, ICG data files, and manually calculated beat-to-beat SV values. Format: Table 2.
IITB-ICG-data2.zip	Zipped folder "SNH-PE" with SNH-PE (subjects with normal health, post-exercise) recording data, containing a folder for each subject (XX: 2-letter subject code) with the Doppler echocardiograms, ICG data files, and manually calculated beat-to-beat SV values. Format: Table 2.
IITB-ICG-data3.zip	Zipped folder "SCD-UR" with SCD-UR (subjects with cardiovascular disorders, under-rest) recording data, containing a folder for each subject (XX: 2-letter subject code) with the Doppler echocardiograms, ICG data files, and manually calculated beat-to-beat SV values. Format: Table 2.
IITB-ICG-data4.zip	Zipped folder "SNH-consent_reports" with consents and medical reports for the subjects with normal health. XX: 2-letter subject code. Format: Table 5. This folder is not available in the database.
IITB-ICG-data5.zip	Zipped folder "SCD-consent_reports" with consents and medical reports for the subjects with cardiovascular disorders. XX: 2-letter subject code. Format: Table 5. This folder is not available in the database.
IITB-ICG-data6.zip	Zipped folder "SNH_info_meas" with physical measurements for the subjects with normal health. Format: Table 3.
IITB-ICG-data7.zip	Zipped folder "SCD_info_meas" with physical measurements for the subjects with cardiovascular disorders. Format: Table 3.
IITB-ICG-combined.zip	Zipped file combining "IITB-ICG-Description.pdf", IITB-ICG-data1.zip", ..., "IITB-ICG-data7.zip"

Table 2 Organization of the folders "XX_SNH_UR", with XX replaced by 2-letter subject code, The folders "XX_SNH_PE" and "XX_SCD_UR" are organized similarly.

Folder	File(s)	Description
XX_SNH_UR_DE	XX_SNH_UR_NNNN.jpg	Doppler echocardiogram frames recorded from the subject with code 'XX' in the under-rest condition, as ".jpg" image files. "NNNN": frame number.
XX_SNH_ UR _ICG	XX_SNH_UR_ICG.mat	ICG recorded from the subject with code "XX" in the under-rest condition, waveforms as ".mat" file.
	XX_SNH_UR_ICG.fig	ICG recorded from the subject with code "XX" in the under-rest condition, plots as ".fig" file.
XX_SNH_ UR _VTI	XX_SNH_UR_VTI.xlsx	Manual measurements of beat-to-beat R-R intervals, VTI, and SV values from echocardiogram, as '.xlsx' file, format as in Table 4.

Table 3 Format of the tables used for recording information from subjects with normal health (SNH) and subjects with cardiovascular disorders (SCD).

Sr. no.	Subject code	Name (not included), gender, age (years), address (not included), consent (not included), clinical report (not included)	Height (cm), weight (kg)	Medical history (not included)	L (cm), aortic diameter (cm)	Basal impedance $Z_0(\Omega)$
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Table 4 Format of the tables with the manually measured beat-to-beat values of RR intervals, VTI, and SV values are in ". xlsx" files.

Sr. no.	Subject code	Doppler echo frame	Cycle number	ECG-RR intervals	VTI (cm)	SV (mL)
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--	--	--	--	--	--	--
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Table 5 Organization of the folders "XX_SNH_consent_reports" with consent forms and medical reports of SNH subjects, with "XX" as the subject code and "XX_SCD_consent_reports" with consent forms and medical reports of SCD subjects.

Files	Description
XX_SNH_consent_ reports.pdf	Scans of signed consent forms and medical reports (not included).
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XX_SCD_consent_ report.pdf	Scans of signed consent forms and medical reports (not included)
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C. Instruction

The database may be downloaded as a ".pdf" file with the database description and seven ".zip" files with the zipped data folders. It may also be downloaded as a single ".zip" file combining the eight files. The files and folders are described in Tables 1-5.

The ICG data files may be input for processing using the following Matlab code:

```
%Matlab code for loading the icg data file
clc; close all; clear all;
load
XX_SCD_UR_ECG_ICG.mat %Change the subject file name as
required%

% loading data file
ch1 = data(:,1); % Zo
ch2 = data(:,2); % -z(t)
ch3 = data(:,3); % -dz/dt
ch4 = data(:,4); % ECG
```

D. References

U. R. Bagal, P. C. Pandey, S. M. M. Naidu, and S. P. Hardas, "Detection of opening and closing of the aortic valve using impedance cardiography and its validation by echocardiography," Biomed. Physics Eng. Express, 4 (1), 015012, 2018. Link: doi.org/10.1088/2057-1976/aa8bf5

S. M. M. Naidu, P. C. Pandey, U. R. Bagal, and S. P. Hardas, "Beat-to-beat estimation of stroke volume using impedance cardiography and artificial neural network," Medical & Biological Engineering & Computing, vol. 56 (6), pp. 1077-1089, 2018. Link: doi.org/10.1007/s11517-017-1752-5

S. M. M. Naidu, "Beat-to-beat estimation of stroke volume using impedance cardiography," Ph.D. thesis, Department of Electrical Engineering, Indian Institute of Technology Bombay, December 2017. Link: www.ee.iitb.ac.in/~spilab/phd_thesis/phd2017_SMM_Naidu_SV_using_impedance_cardiography.pdf

U. R. Bagal, "Detection of characteristic points of impedance cardiogram and stroke volume estimation," Ph.D. thesis, Department of Electrical Engineering, Indian Institute of Technology Bombay, September 2020. Link: www.ee.iitb.ac.in/~spilab/phd_thesis/phd2020_Uttam_R_Bagal_Detection_of_characteristic_points_of_impedance_cardiogram_and_stroke_volume_estimation.pdf

E. Use and Citation

The database may be freely used for research purpose, and the publications using this database should use the following citation:

S. M. M. Naidu, U. R. Bagal, P. C. Pandey, and S. P. Hardas, "IITB-ICG: An impedance cardiography (ICG) database with Doppler echocardiography as the reference", SPI Lab, EE Dept, Indian Institute of Technology Bombay, India, 2025. Link: www.ee.iitb.ac.in/~spilab/databases/IITB-ICG-Database

11. Links

Database Link

IITB-ICG-Database, SPI Lab, EE Dept, IIT Bombay.
https://www.ee.iitb.ac.in/~spilab/databases/IITB-ICG-Database

Research Article/Thesis Links

doi.org/10.1088/2057-1976/aa8bf5

doi.org/10.1007/s11517-017-1752-5

www.ee.iitb.ac.in/~spilab/phd_thesis/phd2017_SMM_Naidu_SV_using_impedance_cardiography.pdf

www.ee.iitb.ac.in/~spilab/phd_thesis/phd2020_Uttam_R_Bagal_Detection_of_characteristic_points_of_impedance_cardiogram_and_stroke_volume_estimation.pdf

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