

# Correlation between Echo-Doppler Study and Impedance Cardiography in Acute Myocardial Infarction

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## ABSTRACT

**Introduction:** Acute Myocardial Infarction (AMI) is quite common and despite lack of adequate infrastructure it is a compulsion for doctors in India to treat patients of AMI even in the rural hospitals due to lack of transportation and communication facilities on round the clock basis. In rural setup usually ECG and Troponin biomarker kits are available. Aim and objective of the present study was to validate impedance cardiography derived haemodynamic parameters against echo-doppler study.

**Material and methods:** 200 patients of AMI were subjected to impedance cardiography and echodoppler study.

**Results:** Echocardiographic Mean±S.D values of LVEDV, LVESV, LVEF, IVCT, IVRT, LVET, Total Diastolic Time, Total Systolic Time & MPI were as follows 80.78±25.554, 40.62±13.062, 41.18±15.669, 46.13±8.5, 50±8.907, 65.93±12.103, 334.11±38.668, 482.97±83.164, 318.4±32.715 & 0.4311±0.0732 respectively. Similarly impedance cardiographic Mean±S.D. values of LVEDV, LVESV, LVEF, IVCT, IVRT, LVET, Total Diastolic Time, Total Systolic Time and MPI are as follows: 102.813±26.006, 53.048±14.773, 39.646±18.095, 40.4786±10.820, 56.953±13.69, 67.153±20.0375, 327.2035±23.91123, 449.4202±91.3202, 349.8660±56.011 and 0.4106±0.08682 respectively.

**Conclusion:** There was strong positive correlation among all the haemodynamic parameters of echocardiography and ICG and the P values were significant in all the parameters studied (<0.001). It can be used for haemodynamic assessment of patients in rural setup where the facility of echo-doppler study or invasive haemodynamic monitoring is not available.

**Keywords:** Echo-Doppler, Cardiography, Myocardial Infarction

## INTRODUCTION

Facilities of Echo-doppler study and coronary angiography or intervention is not available in rural set up. Non-invasive and sometimes Invasive haemodynamic parameters are important in the treatment of AMI. For measurement of haemodynamic parameters usually intravascular (artery/vein) catheters connected to transducers and oscilloscopes are used by expert cardiologists in equipped centers. Cardiac echodoppler study though noninvasive can also give many of the haemodynamic information obtainable from invasive catheter-based parameters in addition to its ability to give cardiac structural and functional information. However derivation of such parameters from both the invasive cath-lab and echo-doppler studies demand not only very costly ultra-modern infrastructure, instruments but also well-trained qualified experts all of which are lacking in majority

of the rural health-care delivery institutions in India. In view of the ever-escalating burden of Coronary Artery Disease in India there is requirement of improving the health care-delivery system at rural level. Cheap but efficient and portable tool which is simple enough that can be handled by less skilled persons or even by lay persons for acquisition of haemodynamic data can appreciably help tiding over the infrastructural and onsite expert availability limitations. Impedance cardiography is such a tool. In this background we had been working in the department of Cardiology of Medical College, Kolkata for last few years with an Impedance cardiography tool designed and provided by School of Medical Science and Technology, IIT, Kharagpur. The technical aspects of this equipment and ANN-based principles of derivation of haemodynamic parameters obtained from this impedance cardiography tool has been discussed in the early publications.<sup>1,2</sup>

Impedance cardiography is the recording of the ionic impedance signals comparable to the electrical conduction signals of ECG (Electrocardiogram). ICG is simpler as well as cheaper than ECG. In ECG the amplitude of cardiac electrical signals (depolarisation-repolarisation of cardiac tissue) with respect to time is graphically recorded to differentiate between healthy and diseased heart through different algorithms. In Impedance cardiography the impedance or resistance is measured in stead where the magnitude of current and voltage is known-Voltage(V)=Current(I) xResistance(R). Blood is the main conductor of ionic impedance signals and the bone, muscle, adipose tissue are poor conductors having higher impedance in human body. The Ascending aorta receives the blood pumped out by the left ventricle during systole just to get it distributed to the rest of the body. The veins carry the blood returning to the

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heart from the periphery. The blood thus pumped out from or returning to the heart flow through the conduits where blood is a fluid rich in water and ions (particles carrying charges). Flow of blood from physicist's viewpoint may be considered as flow of ions. This flow is pulsatile due to the systole and diastole. The impedance to flow of current becomes minimum in diastole and maximum in systole. Thus there is variation in impedance due to change in volume of ionic mass flowing in and out. Placement of four electrodes (outer two excitation electrodes bracketing inner two sensing electrodes in Fig 2) along the course of an artery (e.g. radial artery) will sense the impedance variation during transit of the charge-carrying fluid along the conduits underneath. The signal thus acquired is filtered and differentiated and subjected to ANN (Artificial Neural Network) for deriving different haemodynamic parameters.

The cardiac cycle consists of systole and diastole. Each of systole and diastole is divisible into several components which can be characterised in pressure tracings (amplitude versus time). The haemodynamic parameters obtained from impedance cardiography in the patients of acute myocardial infarction have been studied in the present work.

**Aims and Objectives:** To collect parameters predicted by Impedance Cardiography (ICG) Instrument and cardiac Echo-doppler studies from patients with acute myocardial infarction and finding out correlation between ICG and echo-based haemodynamic parameter to decide whether it can be used in assessment of haemodynamics in rural health set up.

## MATERIAL AND METHODS

Present study was done in Department of Cardiology, Medical College, Kolkata.

**Inclusion criteria:** Classical Chest Pain (Angina of coronary origin), ECG Changes like ST elevation in two or more contiguous leads, Biomarker positivity (CPK-MB or Troponin T), Echocardiographic evidence of Regional Wall Motion Abnormality etc and Coronary angiographic evidence of CAD.

**Exclusion Criteria:** Subjects unwilling to participate after knowing that ICG is an experimental tool and is not going to contribute to the treatment process. Moribund and critically ill subjects with heart failure, arrhythmia etc who needed urgent therapeutic intervention and who were unstable enough for subjecting to additional investigations.

**Methods:** History of chest pain and risk factors of coronary artery disease were taken. Clinical Examination was done. ECG Criteria of acute ST elevation Myocardial infarction, Biomarker Criteria (Troponin T, CPK-MB), Echocardiographic criteria and Coronary angiographic criteria were used to evaluate the patients of Acute Myocardial Infarction.

GE™ Vivid 7 Dimension Echodoppler machine was used. Acquisition of ECG gated echo-doppler imaging was done. Apart from Left Ventricular Ejection Fraction, Regional Wall Motion Abnormality, Diastolic function etc the different measurements and of diameters, volume and time

periods (systolic and diastolic) e.g. LVEDV, LVESV, LVEF, IVCT, IVRT, LVET, Total Diastolic Time, Total Systolic Time & MPI were also recorded. Fig 1 shows the ECG gated echodoppler images.

Impedance Cardiography Tool used in the present study was designed and developed by Sudipta Ghosh et al in the school of Medical Science and Technology of IIT Kharagpur, India and the details has already been published in the journal (Artificial Intelligence in Medicine<sup>1</sup>). Fig 2 shows that C1 and C2 are excitation electrodes and R1 and R2 are voltage-sensing electrodes placed on the forearm along the course of radial artery. Raw ICG signals acquired are subjected to filtering and differentiation. Fig 3 shows Impedance cardiography signal after filtering.

The features extracted after filtering were fed to three-layered Artificial Neural Network (ANN) for deriving output of ICG-predicted values of LVEDV, LVESV, LVEF, IVCT, IVRT, LVET, Total Diastolic Time, Total Systolic Time & MPI.

## RESULTS

Table 1 reveals that Echocardiographic Mean±S.D. values of LVEDV, LVESV, LVEF, IVCT, IVRT, LVET, Total Diastolic Time, Total Systolic Time & MPI are as follows 80.78±25.554, 40.62±13.062, 41.18±15.669, 46.13±8.5, 50±8.907, 65.93±12.103, 334.11±38.668, 482.97±83.164, 318.4±32.715 & 0.4311±0.0732 respectively. Similarly impedance cardiographic Mean±S.D. values of LVEDV, LVESV, LVEF, IVCT, IVRT, LVET, Total Diastolic Time, Total Systolic Time and MPI are as follows: 102.813±26.006, 53.048±14.773, 39.646±18.0957, 40.4786±10.820, 56.953±13.69, 67.153±20.0375, 327.2035±23.91123, 449.4202±91.3202, 349.8660±56.011 and 0.4106±0.08682 respectively.

The table 2 shows strong positive correlation among all the parameters of echocardiography and ICG and P-value is significant in all the parameters studied (<0.001 in all except in case of LVESV in which P value is 0.002).

Our study was a hospital based cross sectional study conducted in two hundred patients admitted in the Cardiology department of Medical College and Hospital Kolkata. Patients admitted with established diagnosis of Acute Myocardial Infarction and undergoing coronary angiography (with intention to treat) were included in the present study. The patients having concomitant shock and/or valvular lesions were excluded from our study. In this study, a novel tool named impedance cardiography (ICG) has been used. Features extracted from the ICG signal was differentiated and subjected to trained Artificial Neural Network (ANN) and that was able to predict certain clinically important echocardiogram parameters. The haemodynamic parameters predicted by ICG, were compared with the haemodynamic parameters observed from the echo-doppler studies.

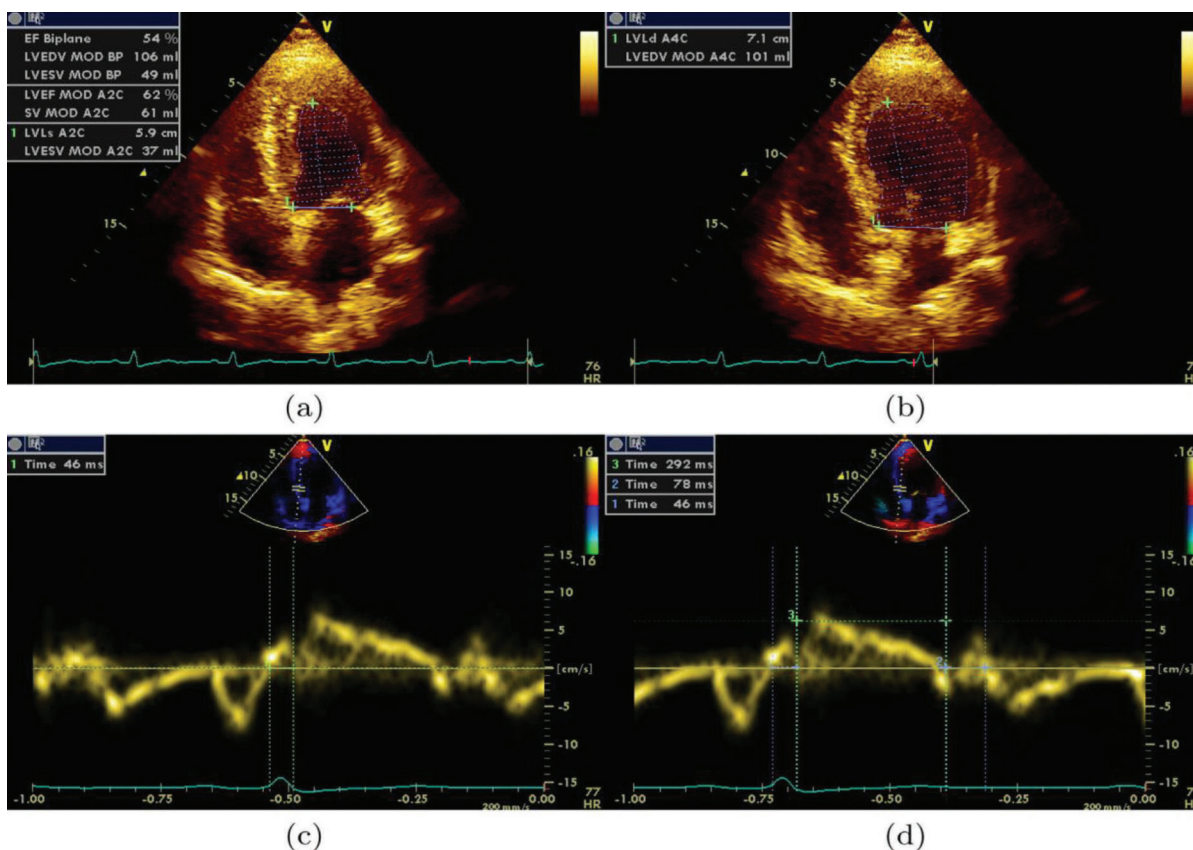
In our study 48% were female and 52% were male. The Mean±S.D. age was 50.32±8.125 years. Mean±S.D. height was 163.85±8.158 cm among the population. Mean±S.D. weight & BMI was 64.94±8.348 kg & 24.1182±3.11

| Parameters  | ECHO    | ECHO   | Impedance<br>Cardiography | Impedance<br>Cardiography |
|---|---------|--------|---------------------------|---------------------------|
|   | Mean    | S.D.   | Mean                      | S.D.                      |
| LVEDV (ml)  | 80.78   | 25.554 | 102.8132                  | 26.00671                  |
| LVESV (ml)  | 40.62   | 13.062 | 53.0484                   | 14.77398                  |
| SV (ml)   | 41.18   | 15.669 | 39.6463                   | 18.09579                  |
| LVEF(%)   | 46.13   | 8.5    | 40.4786                   | 10.82077                  |
| IVCT (msec)   | 50      | 8.907  | 56.9530                   | 13.69005                  |
| IVRT (msec)   | 65.93   | 12.103 | 67.1533                   | 20.03759                  |
| LVET (msec)   | 334.11  | 38.668 | 327.2035                  | 23.91123                  |
| Total Diastolic Time (msec)                           | 482.97  | 83.164 | 449.4202                  | 91.32028                  |
| Total Systolic Time (msec)                            | 318.4   | 32.715 | 349.8660                  | 56.01105                  |
| MPI (Myocardial Performance Index) = (IVCT+IVRT) LVET | 0.43118 | .07329 | 0.4106                    | 0.08682                   |

**Table-1:** Mean and SD values of Echo and Impedance Cardiography derived parameters(n=200)

| Parameters           | Pearson Correlation coefficient (r) | P-value |
|----------------------|-------------------------------------|---------|
| LVEDV                | 0.441                               | <0.001  |
| LVESV                | 0.303                               | 0.002   |
| SV                   | 0.710                               | <0.001  |
| LVEF                 | 0.615                               | <0.001  |
| IVCT                 | 0.592                               | <0.001  |
| IVRT                 | 0.565                               | <0.001  |
| LVET                 | 0.582                               | <0.001  |
| Total diastolic time | 0.437                               | <0.001  |
| Total systolic time  | 0.367                               | <0.001  |
| MPI                  | 0.569                               | <0.001  |

**Table-2:** Correlation between echocardiography and ICG findings (n=200)



**Figure-1:** ECG gated Echo-Doppler images

respectively Mean±S.D. BSA of patients was 1.7073±0.1269. Among the study population 51% patients were previously

diagnosed hypertensive and 49% were normotensive. Among the study population 35% had diabetes, either type 2 or type

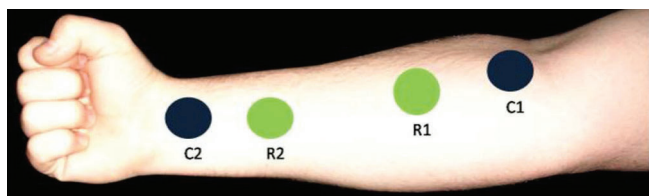


Figure-2: Electrode placement on the fore-arm

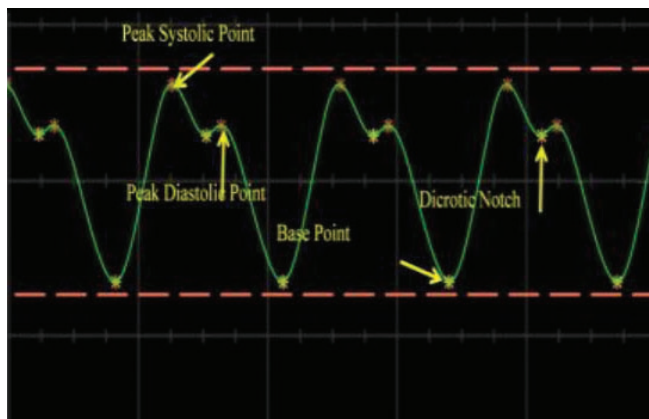


Figure-3: Impedance Cardiography Signal after filtering

1 and 65% were non diabetic. 29% of the subjects were suffering from dyslipidemia.42% of the study population had positive family history of diabetes.34% had positive family history of hypertension and 21.6% had history of AMI among family members. ECG-wise there were 100% cases of ST elevation MI in consonance with the inclusion criteria. According to ECG in our study population there were involvement of wall as follows-Antero-lateral in 23% cases, anterior wall in 26%, inferior wall in 21% anterior with inferior in 3% cases, antero-septal 7%, septal 3%, Inferior with posterior wall 5%, inferior with RVMI in 2% cases, global in 4%, lateral 6%. Troponin T was positive in all cases. Among the other biochemical parameters both of CPK & CPK –MB were elevated in 90% cases .

In our study among the study population we found that there is positive correlation of LVEDV(Left Ventricular End Diastolic Volume) measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r= 0.441$ ,  $p$  value  $< 0.001$ ) and this is also statistically significant. Among the study population we found that there is positive correlation of LVESV(Left Ventricular End Systolic Volume) measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r= 0.303$ ,  $p$  value  $< 0.05$ ) and this is also statistically significant. We found that there is positive correlation of LVSV(Left Ventricular Stroke Volume) measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r= 0.71$ ,  $p$  value  $< 0.001$ ) and this is also statistically significant. In this study there is positive correlation of LVEF (Left Ventricular Ejection Fraction)measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r= 0.615$ ,  $p$  value  $< 0.001$ ) and this is also statistically significant. In present study there is positive correlation of IVCT (Iso Volumetric Contraction Time), IVRT (Iso Volumetric Relaxation Time), LVET (Left Ventricular Ejection Time)

parameters measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r= 0.592$ ,  $p$  value  $< 0.001$ ;  $r=0.565$ ,  $p$  value  $< 0.001$ ; &  $r=0.582$ ,  $p$  value  $< 0.001$  respectively) and this are all statistically significant. We found there is positive correlation of Total Diastolic Time & Total Systolic Time measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r=0.437$ ,  $p$  value  $< 0.001$  &  $r=0.367$ ,  $p$  value  $< 0.001$  respectively) and these are statistically significant. In our study we found that there is positive correlation of MPI (Myocardial Performance Index measured by Echocardiography and ICG as suggested by Pearson correlation coefficient ( $r= 0.569$ ,  $p$  value  $< 0.001$ ) and this is also statistically significant.

### DISCUSSION

L.S Silva et al reviewed literature on Accuracy of Impedance Cardiography in Acute Myocardial Infarction.<sup>3</sup> Major studies reviewed demonstrated the efficacy of this method, making possible an early evaluation of heart failure and monitoring of hemodynamic performance in acute myocardial infarction by impedance cardiography.

Chen S J et al<sup>4</sup> Evaluated the heart function with impedance cardiography in 99 acute myocardial infarction patients and demonstrated the capability of impedance cardiography (ICG) in reflecting the cardiac haemodynamic functions of acute myocardial infarction (AMI) patients. Thorax fluid capacity (TFC), pre-ejection period (PEP), left ventricular ejection fraction (LVEF), cardiac output (CO), stroke volume (SV), stroke index (SI), systemic vascular resistance (SVR), systemic vascular resistance index (SVRI), cardiac index (CI), end-diastolic volume (EDV) and systolic time ratio (STR) were measured.The outcomes showed correlation between ICG and echocardiography in SV, SI, EDV, LEVT, STR, LVEF ( $P < 0.01$ ), CO and CI ( $P < 0.05$ ).

Kamath et al<sup>5</sup> studied the Correlation of impedance cardiography with invasive hemodynamic measurements and concluded of mild positive correlation between ICG and cardiac output measured invasively ( $r= 0.4$  to  $0.6$ ) though the Pulmonary artery pressure study by Swan Ganz catheters could not be predicted by ICG data.

Ito et al<sup>6</sup> studied stroke volume predicted by Kubicek's impedance plethysmography method using a computer based simulation. The study was conducted on human subjects as well as on dogs. It reported correlation coefficient ( $r$ ) value of  $0.9$  for human subjects. In our study, we also obtained a correlation co-efficient value ( $r$ ) of  $0.615$ , with human subjects, which corroborates with the the findings of Ito et al.<sup>6</sup>

In this study we had found there is positive correlation in between the different parameters obtained from echocardiography and impedance cardiography. Some previous studies also showed similar results regarding impedance cardiography. The proposed methodology is able to predict the above mentioned parameters, without any expert supervision. So this methodology can be used for acquisition of different cardiological parameters whenever facility or expertise of echocardiography are not available.

## CONCLUSION

The primary objective of this study, was to study the correlation of this novel methodology predicted parameters (SV, LVESV, LVEDV, LVEF, IVCT, IVRT, LVET, TST, TDT, MPI) with those derived from echo Doppler study. Such ICG-derived haemodynamic parameters were found to be in good agreement with the echo-derived parameters. The major advantage of this ICG method is that a single ICG reading, acquired by placing four electrodes on the fore-arm, gives varied range of clinically important echocardiogram parameters. In remote rural health centers where echo-doppler equipment is not available this ICG –parameters can help in assessment and management of patients of myocardial infarction. Presently doppler based echocardiogram is performed by clinicians in order to ascertain the aforementioned parameters. Doppler based echocardiogram is costly and requires the supervision of an experienced clinician. The proposed methodology is able to predict the above mentioned parameters, without any expert supervision, with a fair degree of accuracy. The obtained results are promising and increases the scope of using ICG for prediction of parameters related to heart functioning even in rural health centers and hospitals. The proposed methodology would bring down the cost and make itself widely available in years to come.

## ABBREVIATIONS

AMI=Acute Myocardial Infarction, ICG= Impedance Cardiography, ANN=Artificial Neural Network, LVEDV=Left Ventricular End Diastolic Volume, LVESV= Left Ventricular End Systolic Volume, LVEF= Left Ventricular Ejection Fraction, IVCT=Isovolumic Contraction Time, IVRT= Isovolumic Relaxation Time, LVET=Left Ventricular Ejection Time, MPI=Myocardial Performance Index.

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