# NON-INVASIVE MEASUREMENT OF CARDIAC PARAMETERS IN OUTPATIENT DEPARTMENT

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**Abstracts**: **Background & objectives**: Hypertension, heart failure, ischemic heart diseases and valvular heart diseases are among the prevalent cardiovascular diseases in India as well as foreign countries. Impedance Cardiography (ICG) is very easy and effective non-invasive method to measure cardiac parameters like stroke volume, cardiac output, systemic vascular resistance, left ventricular ejection time and few others. Aim of this study is to check the utility of ICG in outpatient department for progression or improvement of heart diseases, change or modification of treatment and to check overall hemodynamic status of patients. Objectives are to measure all cardiac parameters in normal healthy persons as well as heart disease patients and to see the effect of disease on these cardiac parameters. **Methods:** This study was carried out in 80 normal healthy adult volunteers and 80 adult patients of various heart diseases like HT, IHD, CCF or Valvular heart diseases. Recording of cardiac parameters was done in Nivomon computerised automatic machine at Government Medical College & Sir T. Hospital, Bhavnagar. **Results:** All cardiac parameters' values were consistent with normal standard values in healthy volunteers. There was no significant difference between 2 groups for SV & SI. Both CO & CI were significantly lower in disease patients. Further, both SVR & SVRI were significantly higher in patients. So CO values were low because heart has to work against higher after load (SVR**). Interpretation & conclusion**: There was significant correlation between different parameters & different factors affecting those parameters. All cardiac parameters were measured effectively in normal healthy volunteers as well as in patients according to their hemodynamic status. ICG is very easy and accurate non-invasive technique and so it should be promoted more in country like India with less man power and more patients load.

**Key Words**: Cardiac Output, Heart Disease, Impedance Cardiography, Non-invasive.

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**Introduction:**

Cardiovascular diseases are now the major burden of society and they are frequently accompanied by morbidities as well as mortalities.[1] Hypertension, heart failure, ischemic heart diseases and valvular heart diseases are among the prevalent cardiovascular diseases in India as well as foreign countries.[2, 3] Most of these patients have to come to the hospital OPD (outpatient department) regularly for follow up regarding progression or recovery of diseases and for the changes in doses or types of medications. Only taking pulse and blood pressure is not sufficient to assess the hemodynamic status of these types of patients because fluctuations in pulse and blood pressure are common even in normal non diseased patients.[4]

Impedance Cardiography (ICG) is the answer or solution for assessing hemodynamic status of patients suffering from various cardiovascular diseases. Assessment can be done in hospital ICU as well as in outpatient department. ICG is very easy and effective non-invasive method to measure cardiac parameters like stroke volume (SV), cardiac output (CO), systemic vascular resistance (SVR), left ventricular ejection time (LVET) and few others. It is based on impedance plethysmography which uses principle of Ohm's law (Voltage V = Current I X Resistance R).[5]

In this technique, known amount of current is passed into the body by current passing electrodes because body fluids are good conductor of electricity. There will be some resistance to this current while passing through fluids. And this resistance is according to fluid volume present in respective part of the body. Voltage will be sensed by voltage sensing electrodes according to resistance present. So impedance (Z) values are obtained from the value of sinusoidal current I and sensed voltage V.[5] This Z value when put into some formula, we can get the value of SV. CO value is obtained by multiplying SV with Heart Rate. SVR is

obtained from the value of CO & BP. LVET is obtained from the waveform which is recorded in the computerised automatic instrument after placing current passing and voltage sensing electrodes on appropriate parts of the body.

Many studies had been done in the past for the comparison of invasive and non-invasive techniques for the measurement of CO. ICG has been proved as an accurate technique and results were similar to those invasive techniques like Fick's method, thermodilution and dye dilution.[6, 7, 8] In some studies, reliability of ICG was questionable.[9,10] All these studies were about use of ICG in ICU for critically ill patients. Very few studies have been done for the utility of ICG in outpatient department.[11, 12]

So aim of this study is to check the utility of ICG in outpatient department for progression or improvement of heart diseases, change or modification of treatment and to check overall hemodynamic status of patients. Objectives are to measure all cardiac parameters in normal healthy persons as well as heart disease patients and to see the effect of disease on these cardiac parameters. Other objective is also to check the utility of ICG for the modification of treatment and follow up purpose.

**Material and Methods:**

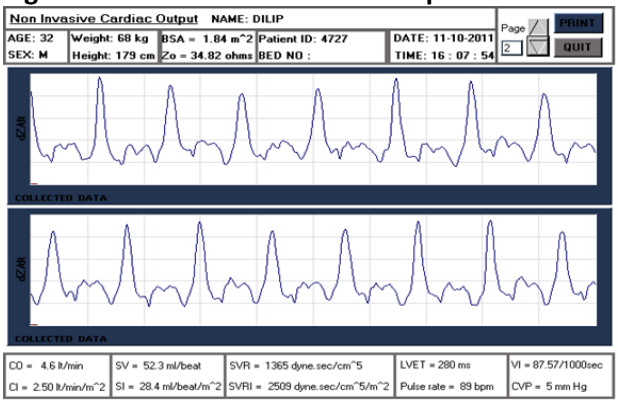
After obtaining consent from IRB (Institutional Review Board) ethics committee, this study was carried out in 80 normal healthy adult volunteers and 80 adult patients of various heart diseases like HT, IHD, CCF or Valvular heart diseases. Healthy group was containing 50 males & 30 females. Mean age was 65.01 + 10.19 yrs. Patient group was containing 50 males & 30 females. Mean age was 67.57 + 10.73 yrs. Total 14 subjects were excluded due to anticipatory tachycardia. Recording of cardiac parameters was done in Nivomon computerised automatic machine at Government Medical College & Sir T. Hospital, Bhavnagar. All patients' data of cardiac parameters as well as recorded waveforms are permanently stored in computerised machine. We can review as well as print these data.

Total 8 surface stick on types of electrodes were put on subjects and patients in supine position. Outer 4 electrodes are current passing and inner 4 electrodes are voltage sensing. Electrodes placements is as shown in figure no. 1:

**Figure No. 1: Electrode placements on body for recording ICG**

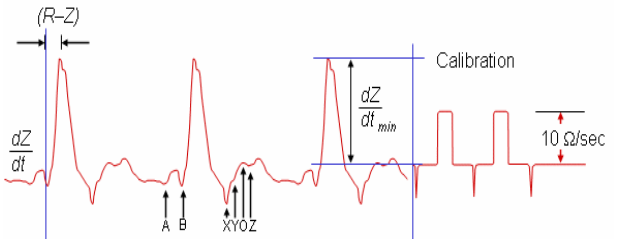
Waveform recorded in computer is as shown in figure no. 2:

**Figure No. 2: ICG waveform in computer**




The details of waveform are shown in figure no. 3:

**Figure No. 3: ICG waveform in detail**




Lababidi et al. carefully studied the timing of each significant notch in the first derivative curve of the thoracic impedance signal and assigned them to certain events in the heart cycle.[13] According to their study, the relationship is as shown in below Figure no. 4:

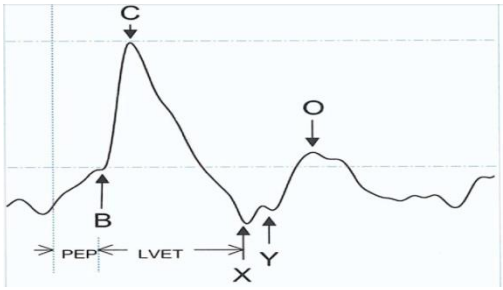
**Figure No. 4: ICG waveform indicators**

**Table** Timing of various notches in the first derivative impedance signal in impedance cardiography.

| Event in the cardiac cycle | Notch |
|---|---|
| Atrial contraction | A |
| Closure of tricuspid valve | B |
| Closure of aortic valve | X |
| Closure of pulmonic valve | Y |
| Opening snap of mitral valve | O |
| Third heart sound | Z |

BCX is called the systolic wave (C wave) & XYOZ is called the diastolic wave (O wave). Left Ventricular Ejection Time (LVET) is measured as shown in figure no. 5:

**Figure No. 5: LVET measurement**




B corresponds to the first heart sound. X corresponds to the second heart sound. BX corresponds to Left Ventricular Ejection Time (LVET). (dz/dt) max is measured as the height of the curve from B to the peak of the systolic wave (C).[6]

Stroke Volume (SV) is measured by the impedance signal recorded from the inner pair of electrodes using Kubicek's equation as, [14, 15, 16]

- Stroke volume ( SV ) = k p ( L / Zo )² [ LVET ( dZ / dt ) max ]
- where k is a constant which accounts for variation in body composition based on age, gender, relative fat content, chest circumference;
- ( dZ / dt ) max is the maximum rate of change of the impedance in Ω/s;
- LVET is the left-ventricular-ejection time in seconds;
- L is the inter - electrode distance in cm;
- Zo is the basal impedance in Ω;
- p is the blood specific resistivity computed using hematocrit as [ 13.5 + (4.29 Hematocrit) ] in Ω-cm.

CO is calculated as SV multiplied with heart rate. SVR is calculated as MAP (Mean arterial pressure) divided by CO. All parameters are calculated automatically in computer and displayed as shown in above figure no. 2. As CO, SV, SVR depends on Body Surface Area (BSA), respective indices like Cardiac Index (CI), Stroke Volume Index (SI) and Systemic Vascular Resistance Index (SVRI) are calculated automatically on entering height and weight of the subject or patient.

All data were calculated & analysed by GraphPad InStat 3 Statistical software.

**Result:** Unpaired t–test was used for comparison of parameters between 2 groups. Mean + SD values of parameters in both groups, p value & significance are shown next in Table No. 1.

**TABLE No. 1: Mean + SD values of parameters in both groups**

| **Groups →** | **Healthy** | **Heart Diseases** | ***t* test** | **Statistical** |
|---|---|---|---|---|
| **Parameters ↓** | **( n = 80 )** | **( n = 80 )** | ***p* value** | **Significance** |
| **Age (Years)** | 65.01 ± 10.19 | 67.57 ± 10.73 | 0.12 | Not |
| **SBP (mmHg)** | 130.22 ± 12.87 | 141.15 ± 13.27 | < 0.0001 | Extreme |
| **DBP (mmHg)** | 81.27 ± 7.88 | 85.25 ± 9.02 | 0.0034 | Very |
| **BSA ( m² )** | 1.65 ± 0.17 | 1.68 ± 0.17 | 0.26 | Not |
| **PR (bpm)** | 78.05 ± 10.29 | 74.2 ± 13.33 | 0.042 | Yes |
| **SV (ml/beat)** | 62.22 ± 13.88 | 62.18 ± 16.17 | 0.98 | Not |
| **SI (ml/beat /m²)** | 37.53 ± 6.88 | 36.63 ± 7.43 | 0.42 | Not |
| **CO (litre/min)** | 5.3 ± 1.03 | 4.6 ± 1.22 | 0.0001 | Extreme |
| **CI (lit./min /m²)** | 3.08 ± 0.46 | 2.76 ± 0.64 | 0.0004 | Extreme |
| **LVET (msecs)** | 367.37 ± 43.94 | 364.5 ± 50.94 | 0.7 | Not |
| **SVR (dyne·sec /cm⁵)** | 1596.49 ± 357.11 | 1840.76 ± 511.87 | 0.0006 | Extreme |

| | | | | |
|---|---|---|---|---|
| **SVRI (dyne·sec /cm$^5$/m$^2$)** | 2605.82 ± 520.84 | 3055.21 ± 765.44 | < 0.0001 | Extreme |

Differences between 2 groups are also shown in the form of following column charts.

**CHART No. 1: Comparison of Age, SBP, DBP, PR, SV & SI between healthy & heart disease patients**

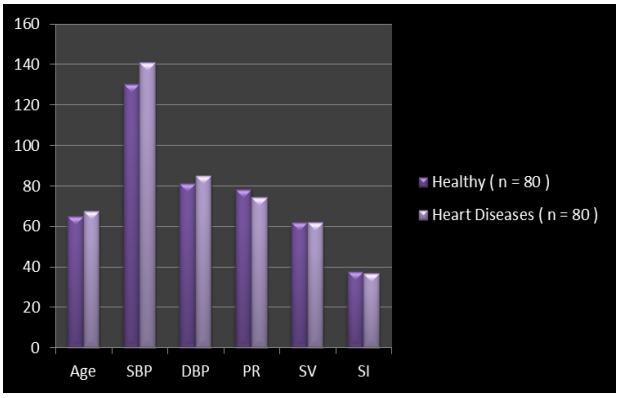



**CHART No. 2: Comparison of CO & CI between healthy & heart disease patients**

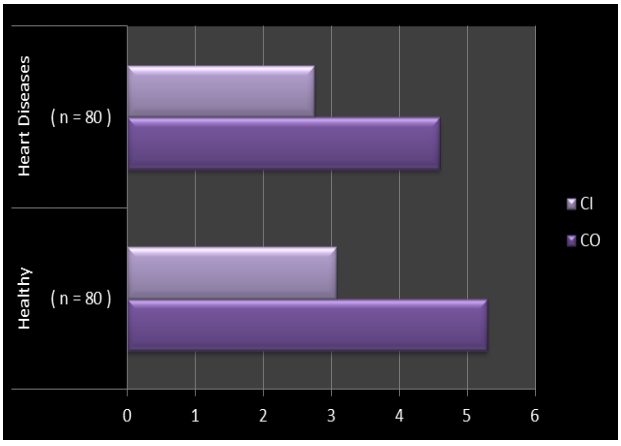
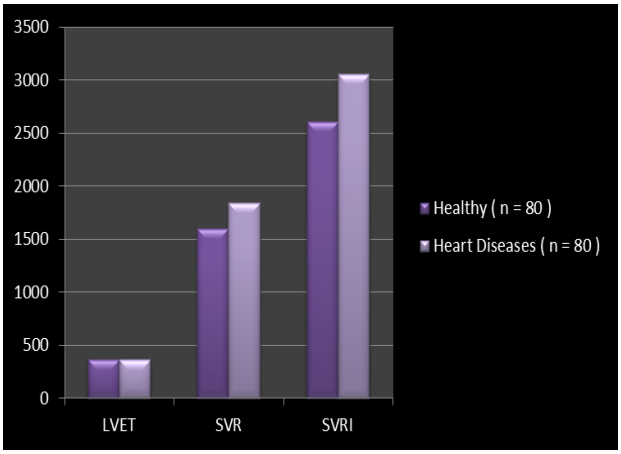



**CHART No. 3: Comparison of LVET, SVR & SVRI between healthy & heart disease patients**




Followings are some recorded waveforms with particular characteristics:

**Figure No. 6: 80 years old male hypertensive patient**

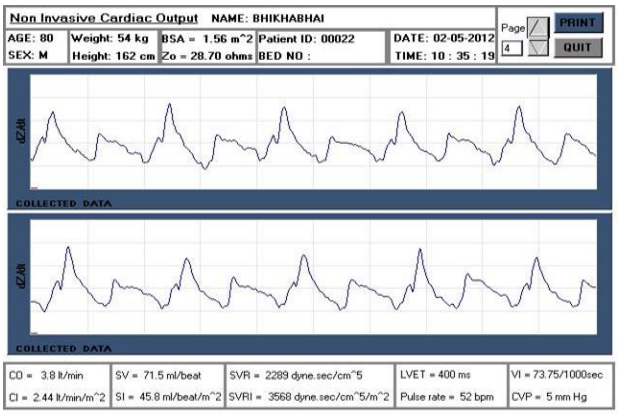



**Figure No. 7: 59 years old male hypertensive patient**

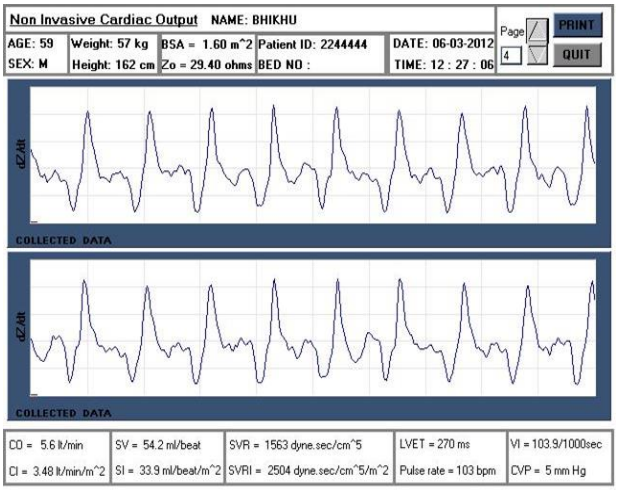



**Figure No. 8: 70 years old female patient of CCF**

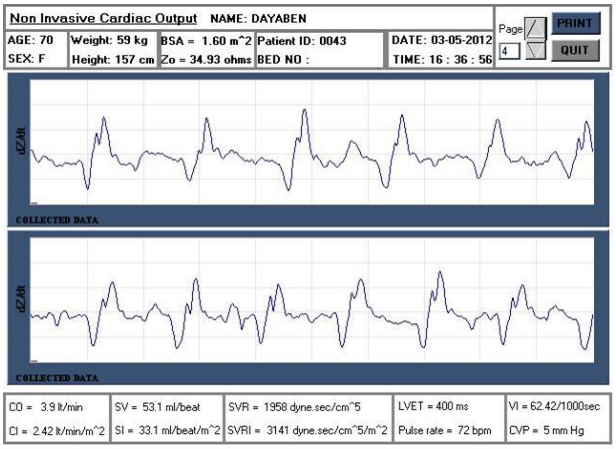



**Figure No. 9: 77 years old male patient of IHD**

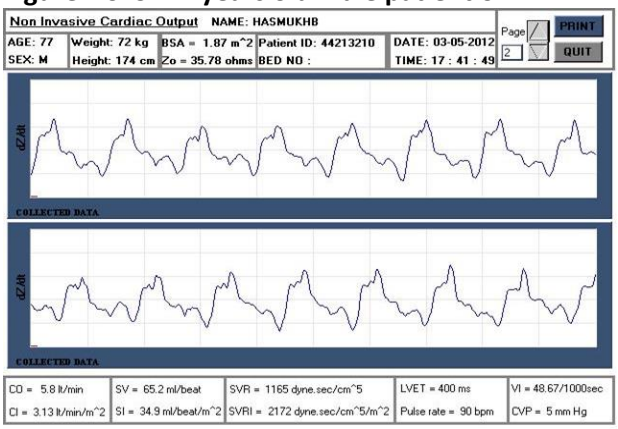
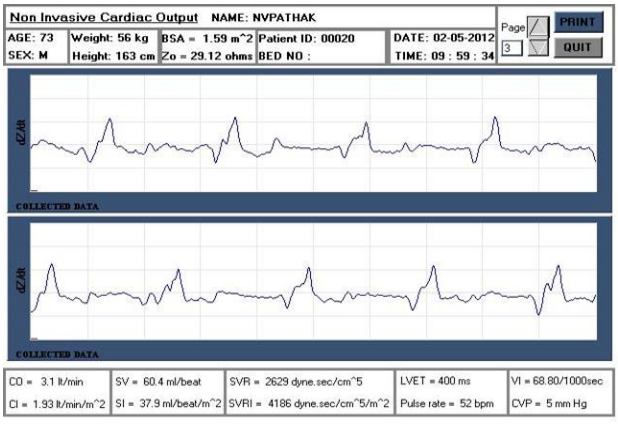



**Figure No. 10: 73 years old male patient of Valvular heart disease**




**Discussion:** ICG is cheap, easy and accurate method to measure cardiac parameters with small portable instrument which can be handled by even a trained technician without need of an expert. Further, all complications like infection, haemorrhage, arrhythmias can be avoided which are associated with invasive catheter related techniques. In present study, all cardiac parameters' values were consistent with normal standard values in healthy volunteers. So it indicates that instrument has measured all parameters effectively and accurately. And so we can rely on this for diseased patients also. So, first comparisons between normal and diseased were evaluated.

Table no. 1 & chart no. 1 showed that there was no significant difference in mean age of 2 groups. So our sample was appropriate for comparison without any age related variations. Out of 80 patients, 54 patients were suffering from only hypertension. Total 74 patients were taking antihypertensive medications. Table no. 1 & chart no. 1 showed that SBP & DBP were significantly higher in disease group despite taking medications. There was no significant difference between 2 groups for SV & SI. Table no. 1 & chart no. 2 showed that both CO & CI were significantly lower in disease patients. Table no. 1 & chart no. 3 showed that there was no significant difference for LVET although PR was significantly lower in patients. Further they showed that both SVR & SVRI were significantly higher in patients. So we can conclude that CO values were low because heart has to work against higher after load (peripheral resistance); and that after load is SVR which was significantly high. As blood pressure is equal to CO multiplied by SVR, BP values were higher because of higher SVR. Most probable cause of higher SVR is age related vascular changes like atherosclerosis and arteriosclerosis and so responsible for hypertension. Cause of low CO in IHD, CCF & Valvular Heart Disease is central factor like weak heart which is not able to pump properly. Cause of low CO in hypertensive patients is peripheral factor like increased SVR. And DBP values were also high because of higher SVR. So there was significant correlation between different parameters & different factors affecting those parameters.

Figure no. 6 was showing bifurcated systolic wave with wide diastolic wave. Figure no. 7 was showing systolic wave merging with diastolic wave. Figure no. 8 was showing bifurcated systolic wave merging with multi notched diastolic wave. Figure no. 9 was showing multi notched systolic wave merging with diastolic wave. Figure no. 10 was showing bifurcated systolic wave with almost flat

diastolic wave. So an entire new study can be done on the shape of waveform only. Further earlier study shows that waveform changed in patients of mitral valve regurgitation & then it returned to normal configuration after surgical implantation of a prosthetic mitral valve.[17] So ICG waveform can be used to aid in diagnosis of certain valvular & other cardiac diseases.[18]

According to some earlier studies, we have given suggestions to physian regarding adding or increasing dose of mixed dilators like ACE inhibitors, AT1 antagonists or calcium channel blockers to reduce SVR particularly for hypertensive patients.[19, 20] Doses of beta blocker drugs can be reduced in other patients with low CO.[21] So follow up studies can also be done with physian regarding disease progression and prognosis. It can also be done with pharmacologist regarding mode of action of some drugs acting on heart.

**Conclusion:**

All cardiac parameters were measured effectively in normal healthy volunteers as well as in patients according to their hemodynamic status. Significant differences were also found between 2 groups. ICG can also be used in ICU set up for critically ill heart patients. It can be used in outpatient department for patients as well as in health institutes for some other research purposes. So, ICG is very easy and accurate non-invasive technique but still its' uses are restricted in only few places of India because it's very latest. So ICG should be promoted more in country like India with less man power and more patients load.

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