Impedance Cardiography (ICG)

Application of ICG for Hypertension Management
**Impedance Cardiography (ICG)**

Non-invasive Beat-to-beat Hemodynamic Monitoring

- Aortic valve is closed
- No blood flow in the aorta
- Red blood cells are orientated randomly

- Aortic valve opens
- Blood flow in the aorta (Windkessel function)
- Alignment of red blood cells

Sources of the measured impedance change

1 mA @ 100 kHz
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ACM – Arterial Compliance Modulation

Latest Technology in ICG

Earlobe sensor:

- Registration of peripheral pulse wave
- Calculation of aortic compliance based on pulse wave velocity and curve shape parameters
- Completion to standard ICG measurement to improve parameter calculation

Patient related arterial stiffness
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ICG waveform and fiducial points

- Automatic detection of fiducial points
- Calculation of hemodynamic parameters (e.g. Stroke Volume [SV], Cardiac Output [CO], Thoracic Fluid Content [TFC])

ICG waveform with fiducial points:
- A-wave - Contraction of atrium
- B - Opening of aortic valve
- C - Max. systolic flow
- X - Closing of aortic valve
- Y - Closing of pulmonal valve
- O - Opening of mitral valve
- PEP - Pre-Ejection Period
- LVET - Left Ventricular Ejection Time
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Equation for Stroke Volume Estimation

\[ SV = V_{EPT} \cdot \frac{dZ_{\max}}{Z_0} \cdot LVET \]

- **SV**: Stroke Volume
- **V_{EPT}**: Patient related parameter (depending on age, weight, height, gender, ACM etc.)
- **dZ_{\max}**: Amplitude of the systolic wave of the ICG
- **Z_0**: Base impedance (overall impedance of the thorax)
- **LVET**: Left Ventricular Ejection Time: time interval between opening and closing of the aortic valve
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Role in Hypertension

Problem
- Only 34% of 50 million U.S. hypertensive patients have controlled BP

Hemodynamic Role
- High BP caused by high CO or high SVR
- Anti-hypertensive medications reduce BP by lowering CO or SVR

Challenges
- In spite of new hypertension medications and awareness, treatment success and patient compliance remain low

ICG Role
- ICG helps determine cause of high BP in order to target, optimize, and validate medications and assess patient risk
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Application in Hypertension

Diagnostic
- Determination of hemodynamic status of patient
- Evaluate cause for hypertension

Treatment
- Target and optimize pharmacological therapy based on underlying cause of hypertension
- Identify quantitative fluid changes with TFC parameter
- Detect hemodynamic changes with compliance to medication and diet
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Hemodynamic Components and Implications for Treatment

- **Blood pressure (MAP)**
  - Hypertensive
  - Hyperdynamic

- **Cardiac Output (CO)**
  - Hyperchronotrophic

- **Heart rate (HR)**
  - Vasoconstricted

- **Stroke Volume (SV)**
  - Hypervolemic
  - Hyperinotrophic

- **Afterload Resistance**
  - ARB, ACEI, CCB, Diuretic, Vaso-D

- **Preload Fluid**
  - BB
  - Diuretic

- **Contractility**
  - BB, CCB
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Therapeutic chart

- The Therapeutic chart describes the relation of blood pressure and stroke volume.
- Goal area describing normohemodynamic state.
- Hypertension treatment depending on position in therapeutic chart.

Example

- Patient with SI of 75 ml/m² and MAP of 120 mmHg.
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Therapeutic chart

Example 1
- SI of 75 ml/m² and MAP of 120 mmHg
- Patient is hypertensive and hyperdynamic

Treatment 1: Vasodillators
- MAP gets normal but patient is still in hyperdynamic state with high workload on the myocardium

Bad treatment for this patient
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Therapeutic chart

Example 1
- SI of 75 ml/m² and MAP of 120 mmHg
- Patient is hypertensive and hyperdynamic

Treatment 2: Negative inotropes
- MAP and SI gets normal and patient status moves to normohaemodynamic

Good treatment for this patient
Impedance Cardiography (ICG)
Therapeutic chart

Example 2

- SI of 25 ml/m² and MAP of 120 mmHg
- Patient is hypertensive and hypodynamic

**Treatment 1: Diuretics**

- MAP gets normal but patient is still in hypodynamic state with low flow

**Bad treatment for this patient**
Impedance Cardiography (ICG)

Therapeutic chart

**Example 2**
- SI of 25 ml/m² and MAP of 120 mmHg
- Patient is hypertensive and hypodynamic

**Treatment 2: Vasodilator**
- MAP and SI gets normal and patient status moves to normo-haemodynamic

**Good treatment for this patient**
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Therapeutic chart

Example 3

- SI of 45 ml/m² and MAP of 120 mmHg
- Patient is hypertensive and normodynamic

Combined Treatment:
- Vasodillator + Negative inotropes

- MAP and SI gets normal and patient status moves to normohaemodynamic

Good treatment for this patient
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Hypertension Case Study

Patient: 41 year old female
History: Hypertension for 1 year
Current therapy: Diuretic (Chlorthalidone 25 mg qd)

Visit Symptoms/Exam CI SI SVRI TFC
#1 No sign or symptoms 2.8 36 3257 33.3
HR 78, BP 160/100

ICG Interpretation: Cause of hypertension is high SVRI
Treatment Decision: Add ACE inhibitor (Lisinopril 5 mg qd)

From John Strobeck, M.D., The Heart Lung Center, Hawthorne, NJ
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Hypertension Case Study – cont.

ICG Interpretation: Addition of ACE inhibitor reduced SVRI, lowering BP to acceptable levels.

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