Impedance Cardiography (ICG)

Application of ICG for Hypertension Management
Impedance Cardiography (ICG)

Non-invasive Beat-to-beat Hemodynamic Monitoring

Sources of the measured impedance change

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
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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

ACM
arterial compliance modulation
Impedance Cardiography (ICG)

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])

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
Impedance Cardiography (ICG)

Equation for Stroke Volume Estimation

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

- **SV**: Stroke Volume
- **V_{EPT}**: Patient related parameter (depending on age, weight, height, gender, ACM etc.)
- **dZ_{\text{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
Impedance Cardiography (ICG) 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
Impedance Cardiography (ICG)

Therapeutic chart

- The Therapeutic chart describes the relation of blood pressure and stroke volume.
- Goal area describing the 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: Vasodilators
- 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 normo-haemodynamic

*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-heatodynamic

Good treatment for this patient
Impedance Cardiography (ICG)

**Therapeutic chart**

- **SI** [ml/m^2]
- **MAP** [mmHg]

<table>
<thead>
<tr>
<th>Hypotension</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normotension</td>
<td>105</td>
</tr>
<tr>
<td>Hypertension</td>
<td>MAP</td>
</tr>
</tbody>
</table>

**Example 3**

- SI of 45 ml/m^2 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**

**SI** [ml/m^2]
Impedance Cardiography (ICG) Hypertension Case Study

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

<table>
<thead>
<tr>
<th>Visit</th>
<th>Symptoms / Exam</th>
<th>CI</th>
<th>SI</th>
<th>SVRI</th>
<th>TFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>No sign or symptoms</td>
<td>2.8</td>
<td>36</td>
<td>3257</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>HR 78, BP 160/100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
Impedance Cardiography (ICG)
Hypertension Case Study – cont.

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

<table>
<thead>
<tr>
<th>Visit</th>
<th>Symptoms / Exam</th>
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<th>SI</th>
<th>SVRI</th>
<th>TFC</th>
</tr>
</thead>
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<tr>
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<td>No sign or symptoms HR 78, BP 160/100 (120)</td>
<td>2.8</td>
<td>36</td>
<td>3257</td>
<td>33.3</td>
</tr>
<tr>
<td>#2</td>
<td>No sign or symptoms One Week later HR 74, BP 129/60 (83)</td>
<td>2.9</td>
<td>39</td>
<td>2124</td>
<td>32.1</td>
</tr>
</tbody>
</table>

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