Focused Impedance Method (FIM)

Innovative medical diagnostics and imaging for health stations in developing countries

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Body is a fluid both positive & negative ions move to carry electrical current

Unlike metals, where atoms do not move, only electrons flow
Current bends around the cells

at dc and at low frequency ac:

With an insulating membrane, a CELL acts like an insulated object

Current bends around the cells

→ High resistance
Current pattern in biological tissues

at high frequency ac:
cell membrane acts as a capacitor - sandwitched between conducting fluids, inside and out

current enters the cells → Low resistance

Capacitive reactance $\alpha \frac{1}{freq}$
Impedance (Z) in biological tissues

Log normalised frequency vs Impedance graph:
- Low frequency impedance is constant.
- High frequency impedance decreases.

- Resistance is frequency independent.
- Reactance is frequency dependent.
- Impedance = Resistance + Reactance.
# Electrical resistivity of body tissues (at low freq)

<table>
<thead>
<tr>
<th>Tissue</th>
<th>(Ω-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSF</td>
<td>0.65</td>
</tr>
<tr>
<td>Blood</td>
<td>1.46-1.76</td>
</tr>
<tr>
<td>Skeletal muscle (longitudinal)</td>
<td>1.25-3.45</td>
</tr>
<tr>
<td>Skeletal muscle (transverse)</td>
<td>6.75-18.0</td>
</tr>
<tr>
<td>Lung – full inspiration</td>
<td>17.0</td>
</tr>
<tr>
<td>Lung – full expiration</td>
<td>8.0</td>
</tr>
<tr>
<td>Brain – grey matter</td>
<td>2.8</td>
</tr>
<tr>
<td>Brain – white matter</td>
<td>6.8</td>
</tr>
<tr>
<td>Fat</td>
<td>20</td>
</tr>
<tr>
<td>Bone</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>

Potential in identifying different types of tissues
Tetra-Polar Electrode Impedance Measurement (TPIM)

Alternating current (I) is passed through outer pair of electrodes, Potential (V) is measured across the inner pair.

Impedance of shaded zone, $Z = V / I$

If I is kept constant, then $Z$ is proportional to $V$.

Main advantage: Since voltmeter takes no current, effect of electrode contact impedance is eliminated. $Z$ is that of the bulk region.

Advantage: Simple instrumentation and measurement

Disadvantage: Wide zone in volume conductor (not focused)
Focused Impedance Method (FIM)

(6 electrode)

-a new idea from
Biomedical Physics Lab
Dhaka University

Current, $I_1$ and $I_2$ in two perpendicular directions (in phase, but isolated). Potential, $V$, measured across two diagonally placed electrodes at centre, $V = Z_1 + Z_2$

$(Z_1 + Z_2)$ has more contribution from central region (green), hence, ‘Focused’
4-Electrode FIM

\[ Z_1 = \frac{V_1}{I_1} \]  Horizontal sensitive zone

\[ Z_2 = \frac{V_2}{I_2} \]  Vertical sensitive zone

\[ Z_1 + Z_2 \]  gives focused impedance
  (central green zone is focused)
3D sensitivity allows deeper organ study
Sensitivity Map of FIM (Phantom study)

- Current electrode
- Potential electrode

Focusing evident
GASTRIC EMPTYING USING FIM
TEST: GASTRIC EMPTYING AFTER A DRINK OF SALINE

EIT
Gold standard

FIM

Could eliminate effect of neighbouring dudenum
Lungs ventilation study

Comparison with Spirometric study:
First breathe in, then breathe out a little & hold, volume of air measured using spirometer.
FIM is linearly related to air volume
FIM: potential in Diagnosis and Physiological study

- Study lung ventilation, perfusion and disorders
- Monitor respiration (very useful in artificial respiration)
- Study gastric emptying
- Measure gastric acid secretion
- Measure localized edema
- Measure abdominal fat thickness
- Detection of cervical cancer
- Characterisation of breast tumours – benign or malignant?
- Monitor tissue ablation in cancer therapy; irreversible electroporation using same electrodes
- Do we require high quality imaging to achieve similar diagnoses?
Recommendaations

Section 1
Conclusions and Recommendations

- Drastic need for improved communication with health stations.
- Telemedicine to play a vital role in diagnostics and training.
- Focused impedance method could become an important low cost diagnostic method for Health Stations.