Assessment of Local Tissue Edema in Arms of Women with Postmastectomy Lymphedema

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The Third Circulatory System

- Lymphatic System
  - Lymphatic Vessels
  - Lymph Nodes
  - Lymphatic Capillaries

- Arterial System
  - Venous System
  - Blood Capillaries

CO₂ → O₂
Normal Fluid Balance

Resorption

Blood Capillary

~27 liters/day

Filtration

~30 liters/day

TISSUE AND CELLS
Normal Fluid Balance

Filtration

Resorption

Blood Capillary

~27 liters/day

~30 liters/day

~3 liters/day (10% of filtered)

Lymphatic Capillary

protein

Back to Venous System
Overload = Edema + [Protein] = Lymphedema

If Net Filtration Exceeds Lymphatic Transport Capacity

Fluid + Protein → Excess - Lymphatics

capillary

Net Filtration
Complications

Excess - Lymphatics

Fluid + Protein

Excess - Lymphatics

capillary

System Works OK Here

System Not OK Here
Excess - Lymphatics

Fluid + Protein

Proteins Accumulate if Lymphatic Dysfunction

Complications

Lymphatic vessel/node
- Trauma
- Removal
- Radiation
- Blockage
- Overload
- Genetic - Primary

More Filtration

PROTEINS
Excess - Lymphatics

Fluid + Protein

PROTEINS

Proteins Accumulate if Lymphatic Dysfunction

Macrophages

Fibrosis

More Filtration

Complications

capillary

Excess - Lymphatics
Excess - Lymphatics

Fluid + Protein

PROTEINS

Proteins Accumulate if Lymphatic Dysfunction

Macrophages

Stimulus for Chronic Inflammation

Vasodilation
- Increased filtration
- Tissue warming

Bacterial Growth

Bacterial/Fungal Infections

More Filtration

Fibrosis
Postmastectomy Lymphedema

“Recognizing lymphedema early and treating it promptly is the best way to manage the condition”

Judith R. Casley-Smith & J.R. Casley-Smith

- Develops secondary to surgery and/or radiation therapy
- Occurs in 20-40% of persons treated for breast cancer
- Onset can be from months to years after surgery
- If untreated, gets progressively worse
Surgery
Radiation

Lymphedema Severity

Ultimate Goal - Catch it Early
More Treatable – Less Complications

↑ Surgery
↓ Radiation

60 - 80 % of patients at risk = 0 lymphedema

Time

Ultimate Goal - Catch it Early
More Treatable – Less Complications
Surgery
Radiation

Ultimate Goal - Catch it Early
More Treatable – Less Complications

Symptoms

- Feeling of heaviness
- Tingling
- A ring or watch gets tight
- Skin feels “tight”
- Diminished flexibility
- Limb more easily fatigued
- Visual swelling

60 - 80% of patients at risk = 0 lymphedema
Ultimate Goal - Catch it Early
More Treatable – Less Complications

- Surgery
- Radiation

Symptoms

Fibrosis

Reduce & Arrest

Seek Therapy

CDP

Lymphedema Severity

Time

60 - 80% of patients at risk = 0 lymphedema
Ultimate Goal - Catch it Early
More Treatable – Less Complications

Early Detection “Sub-Clinical”

Surgery
Radiation

60 - 80 % of patients at risk = 0 lymphedema

Lymphedema Severity

Symptoms
Seek Therapy
Reduce & Arrest
Fibrosis

Time
Tissue Water via Dielectric Constant

- Low power 300 MHz incident wave
- Reflected wave depends on the tissue’s dielectric constant
- Dielectric constant depends on total tissue water (free + bound)
- Pure water has a dielectric constant of about 80
- Calibrated for each probe from 1 - 80

Penetration Depth (0.5 – 5 mm)
Forearm: 1.5 mm depth probe
Target: 7 cm distal to antecubital crease
Distal and Proximal: ± 2 cm from target
40 sequential measures at 15 sec intervals
Order: Target-Distal-Proximal

Short-Term Reproducibility

Coeff of Variation
Target: 2.87%
Distal: 1.72%
Proximal: 2.52%
Subjects and Protocol

12 women with unilateral arm lymphedema (74 ± 16 yrs)
12 premenopausal women (25.5 ± 3.7 yrs)
12 postmenopausal women (61.0 ± 6.7 yrs)

- Triplicate dielectric values on each arm with each probe
- Segment volumes determined based on frustum model
- Segmental percentage edema

\[
100 \times \frac{V_A - V_C}{V_C}
\]

Measurements on lymphedema patients prior to treatment
Measurements on premenopausal 4 days after menses
Segmental Volumes

Premenopausal     Postmenopausal       Lymphedema

Volume (ml)

Right or Control Arm
Left or Affected Arm

%Edema
P<0.001

39 ± 16%
Relative Tissue Water (0.5 mm)

Dielectric Constant

<table>
<thead>
<tr>
<th>Condition</th>
<th>Right or Control Arm</th>
<th>Left or Affected Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premenopausal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postmenopausal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphedema</td>
<td></td>
<td><strong>P&lt;0.001</strong></td>
</tr>
</tbody>
</table>
Relative Tissue Water (1.5 mm)

Dielectric Constant

- Premenopausal
- Postmenopausal
- Lymphedema

- Right or Control Arm
- Left or Affected Arm

P < 0.001
Relative Tissue Water (2.5 mm)

- Dielectric Constant

Premenopausal: Right or Control Arm (green), Left or Affected Arm (blue)
Postmenopausal: Right or Control Arm (green), Left or Affected Arm (blue)
Lymphedema: Right or Control Arm (green), Left or Affected Arm (blue)

P < 0.001
Relative Tissue Water (5.0 mm)

Dielectric Constant

- Premenopausal
- Postmenopausal
- Lymphedema

Right or Control Arm
Left or Affected Arm

P<0.001
Depth Variation

* = p<0.001 vs. Contralateral and Normal Arms

Dielectric Constant vs. Tissue Depth (mm)

- **Premenopausal**
- **Postmenopausal**
- **Lymphedema-Control**
- **Lymphedema-Affected**

R² = 0.991
R² = 0.923
Diagnostic Utility

No overlap
Normal vs. Patients

Patients
Affected/Control
1.600 ± 0.315

Dominant/Non-Dominant

Premenopausal
1.021 ± 0.068

Postmenopausal
1.014 ± 0.063
Threshold-like Properties

Dielectric Difference (%) vs. Segmental Edema (%)

1.5 mm depth

Actual:

Anticipated:

$R^2 = 0.03$
Conclusions

- This local tissue water method can serve as a rapid quantitative assessment procedure to document edema and lymphedema.
- May also have utility for early detection of incipient lymphedema not yet clinically seen.
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- May also have utility for early detection of incipient lymphedema not yet clinically seen.

Criteria as of now for the limited data set:
- For at-risk unilateral cases: Arm TDC ratio > 1.2
- For bilateral cases or using absolute values: Threshold depends on depth (3 sd)

<table>
<thead>
<tr>
<th>Depth</th>
<th>0.5 mm</th>
<th>1.5 mm</th>
<th>2.5 mm</th>
<th>5.0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDC</td>
<td>&gt;42</td>
<td>&gt;37</td>
<td>&gt;37</td>
<td>&gt;32</td>
</tr>
</tbody>
</table>
Thank you for your attention!

Dawn Brown-Cross

Zee Washington