The Evaluation of the Pelvic Floor Strength: Novel Parameters from Devices and Imaging

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Outline

• Clinical Problem
  Significance of the SUI
  Clinical diagnosis and treatment of SUI

• MRI
  Methods
  Clinical studies

• Vaginal probe (Pelvic Floor Strength)
  Development of novel vaginal probe
  Clinical studies using a prototype probe

• Ultrasound imaging
  Methods
  Results from Clinical trials

• Summary and expectations
Stress Urinary Incontinence (SUI)


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Principal Considerations

• MR Imaging

Voluntary Activation Of Pelvic Floor (Pf) Compresses And/Or Displaces The Bladder, Urethra, Vagina And Levator Ani, Among Other Intra-abdominal Organs.

• The Effectiveness Depends On Integrity Of The Neuro-musculature Structures.

• Need To Measure The Mechanism of PF Contractility in a Way Analogous to Urodynamics
IMAGE PROCESSING OF AXIAL SECTION:

RELAXED

CONTRACTED

DIFFERENCE+RELAXED
Range Of Displacement After Pelvic Floor Contraction [Age Dependence]

A: LEVATOR SLING
B: POSTERIOR BLADDER
G: GLUTEAL SURFACE
Prototype Vaginal Probe

Measurement of the FORCE of contraction during:

• Voluntary PF Contractions
• Cough Reflex
• Valsalva
• Knack

Comparative Studies Done on Same Subject as with Ultrasound imaging in the supine & standing position
Mechanical Operating Principle of Vaginal Probe

- Sensors
- Leaf spring
- Rod

Force transducer
Hall Effect transducer
Leaf spring
Rod
Sensor Location of Vaginal Probe
Measurement of Force/Displacement

Anterior
Pressure sensor
Magnet
Hall effect Displacement sensor

R Lateral

L Lateral

Posterior

23mm
6mm
23mm
23mm
Probe:
Mechanical configuration

Φ = 20mm
150mm
Probe Measurement of Force/Displacement

$\Phi = 60 \text{ mm}$

$\Phi = 7 \text{ mm}$
Knack: Mid Vagina, Controls
Cough: Mid. Vagina, Controls

Supine  Standing

[Graphs showing pressure over time for different positions (Supine and Standing) and orientations (Anterior, Posterior, Right, Left) with angles 30°-45° indicated.]
Mean Vaginal Closure Forces

**Resting** (p=0.05)
- Continent: 1.67 ± 0.13
- SUI: 1.15 ± 0.18

**PFM contraction** (p=0.01)
- Continent: 2.01 ± 0.13
- SUI: 1.35 ± 0.20
3-D Distribution of Contact Pressure (Controls) at ~50% PFM.
Results: Vaginal Contact Pressure Profile

(a) Healthy [Resting]
(b) Healthy PFM [Contraction]
(c) SUI [Resting]
(d) SUI PFM [Contraction]
Ultrasound Imaging of the Pelvic floor

1. Purpose

   Characterize the temporal responses of PF to incontinence stimulus, coughing and prevention like Pelvic Floor Muscle (PFM) contraction.

2. Method

   Digital image processing (motion tracking and segmentation).

3. New dynamic parameters to evaluate the functions of the PF

   (a) Displacement;
   (b) Trajectory;
   (c) Velocity;
   (d) Acceleration.
Coordinate system of image fixed on the posterior symphysis pubis
Segmentation of the urethra

1. Start
   - Choose an initial point

2. Fix one end of the ruler on the initial point

3. Rotate the ruler until it hits a non-zero point

4. Fix one end of the ruler on the non-zero point

5. Segmentation complete?
   - Yes: Smooth the boundary using curve fitting
   - No: Repeat steps 2-4

6. End
Segmentation of the urethra (contraction and valsalva)
ARA and Urethra deformation of a Control Subject

Cough

Stage1

Stage2

Stage3
ARA and Urethra deformation in PFM contraction (Control subject)
ARA and Urethra deformation in Valsalva (healthy subject)
Displacement of the 8 evenly-spaced Positions on the Anterior and Posterior Edges of the Urethra (a typical healthy subject)
Results of Clinical studies (22 healthy and 9 SUI patients)

1. ARA displacements and trajectories in coughs

(a) Displacement

(b) Trajectory
Results of Clinical studies (22 healthy and 9 SUI patients)

2. ARA velocities and accelerations in coughs

(a) Velocity

(b) Acceleration
Results of Clinical studies (22 healthy and 9 SUI patients)

3. ARA and urethra trajectories in contraction

(a) Healthy  (b) SUI
Results of Clinical studies (22 healthy and 9 SUI patients)

4. ARA and urethra trajectories in valsala

(a) Healthy

(b) SUI
5. Response of Normal and SUI subjects

(a) cough

(b) PFM contraction

(c) Knack

(d) Valsalva
Conclusions

1. Ultrasound imaging provides a useful tool to evaluate PF responses to fast SUI inducing provocations

2. The PF responses of healthy subjects and SUI patients are significant different

3. Differences of pelvic floor responses between healthy subjects and SUI patients are more significant in cough, knack and Valsalva than in PFM contraction.
Summary of Diagnostic Approaches

**MRI of Pelvic floor Anatomy (Static)**
- Slow response
- Good resolution
- Expensive

**Perineal Ultrasound (Dynamic)**
- Measures Distances (Derivation of other parameters)
- Responds to fast events
- Non Invasive

**Vaginal Probe**
- Measurement of the Forces of PF Contraction
- Invasive

**EMG**

**Dynamometers/Periniometers**

**Finger**
Future Needs

1. Construct vaginal probe to evaluate the strength PF function during fast events.

2. Develop software to supplement analysis of ultrasound derived data.

3. Establish reliable parameters for evaluation of biomechanics.

4. Validate technology for physical diagnosis and impact of surgery.

5. Innovate Personal Use Probe for systematic training of patients.
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