3D Ultrasound for prostate, GYN, and breast brachytherapy

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Why 3D Ultrasound?

• Improved appreciation of 3D anatomy
• Improved ability to verify brachytherapy needle locations
• More accurate volumetric measurements
• Reduce variability and time of 2D US guidance and verification
• Improved brachytherapy procedure

3D Ultrasound-guided Brachytherapy Developments

• Prostate HDR brachytherapy
• Gynecologic interstitial HDR brachytherapy
• Breast LDR brachytherapy

Current practice: axial 3D ultrasound

- Prostate + organs ✓
- Needle tips ×

Schmid et al. 2013

Current practice: live 2D ultrasound

- Prostate + organs ✓
- Needle tips ✓
Objective

Reduce needle tip localization uncertainty by replacing axial 3D ultrasound with sagittal 3D ultrasound

Sagittal 3D ultrasound

sagittal 3D ultrasound
New technique: live 2D + sagittal 3D

Results: 8 patients, 127 needles

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More information: YIS J. Rodgers at 2:09pm

High-Dose-Rate (HDR) Interstitial Brachytherapy

- Needles inserted into tumour and surrounding area
  - Through the perineal template
  - Radioactive source is inserted into needles

Gynaecologic Brachytherapy Imaging

Pre-operative MRI Post-insertion CT
TUMOUR NEEDLES

Intra-operative Imaging?

NEED:
Patients may be subject to suboptimal dose distributions and a higher risk of complications due to the lack of image guidance for needles
Objective

To develop a 3D ultrasound (3DUS) needle guidance system for high-dose-rate interstitial brachytherapy of gynecologic cancers, which will provide accurate intra-operative assessment of implant.

3D US Imaging Device

3 modes

170° 3D sidefire transrectal US (TRUS)

360° 3D sidefire transvaginal US (TVUS)

3D endfire TVUS

Vaginal Cylinder

Solid Clinical Cylinder

Hollow TPX Cylinder
Real-Time 3D US Image Reconstruction

Pelvic Phantom Study – compared to CT

Mean tip difference: 1.84 ± 0.42 mm
Mean trajectory difference: 0.40 ± 0.35°

3D TVUS: Patient image (vaginal cancer)
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3D Ultrasound–guided Brachytherapy Developments

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  ✓ Together with Kelowna, Canada group

Limitations of current breast LDR brachytherapy

- High operator dependence using 2D US
  1. Requires experienced physician with use of ultrasound
  2. Deformable tissue with few landmarks
  3. Limited information to modify 3D radiation plan

Objective

To develop a 3D US guidance and needle template tracking to reduce operator dependence of PBSI by:
  1) Improving needle visualization
  2) Improving needle placement accuracy
  3) Providing information to modify treatment plan intraoperatively

3D US with Mechatronic Tracking
3D US: Mechanically Swept 2D Transducer

- Validated linear, volumetric accuracy (±1.1%, ±4.1% respectively)
- Pilot study scanning healthy female volunteer
- Positive feedback on device usability and image quality

3D US image of volunteer

Guiding a Phantom Procedure

- Agar phantom with "seroma" matching patient contours
- Surface based registration between 3DUS, matching treatment plan
Guiding a Phantom Procedure

- Planned Needles
- Planned Fiducial
- Observed Needles
- Planned Fiducial

Tip Error:
\[ 2.43 \pm 1.4 \text{ mm} \]

Trajectory Error:
\[ 1.22 \pm 0.59^\circ \]

Summary

- Mechanical 3DUS \textbf{not subject to environmental constraints}
- Accurate assessment of \textbf{needle trajectory in 3D}
- Visualize needles in \textbf{all template areas}
- Approaches compatible with all \textbf{conventional US systems}

Thank You

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3D US Imaging Device

170° 3D sidefire transrectal US (TRUS)  
360° 3D sidefire transvaginal US (TVUS)  
3D endfire TVUS

Combined 3D Sidefire and Endfire TVUS (Phantom)

Mean Needle Tip Difference: 1.91 ± 0.24 mm

Mean Angular Difference: 1.51 ± 0.81 °