Synchrony®: Tumor Tracking with the Radixact® System

Accuray AERO™ Academy

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Introduction

• This presentation summarizes our initial experience with Synchrony® on the Radixact® System
• Accuray and FH&MCW have a research agreement in place
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Outline

• Synchrony®
• Installation
• Motion Tests
• Dosimetry Verification
  – Delta4
  – ArcCheck
• Synchrony® Plan QA
• Summary
How to manage target motion in radiotherapy

- Pre-treatment approaches
  - Expanding PTV margin
  - Immobilizing the patient or target: DIBH, abdominal compression, bladder and bowel preparation, etc
- In-treatment techniques: track the target position, and change the planned treatment delivery to correct for the motion
  - Gating: low treating efficiency
  - Tracking: e.g. CyberKnife®

Synchrony®
- Image-based motion tracking
- Real time motion correction
- On a Radixact® Treatment Delivery System
Synchrony®

**Components**
- A kV x-ray imaging system
- An optical camera system, with LEDs

**Software**
- Components
  - A kV x-ray imaging system
  - An optical camera system, with LEDs

**Additional Information**
- X-ray Generator
- X-ray Detector
- X-ray Tube

**Logo and Text**
- Medical College of Wisconsin
- Froedtert & Medical College of Wisconsin
- Radiation Oncology

**Slogan**
- Knowledge changing life
Synchrony®

• How it works
  – Target tracking
    o Fiducial/target position from x-ray images
    o If respiratory (periodic) motion: marker positions are detected continuously by the camera
  – Motion correction
    o Swing jaws
    o Shift MLC leaves

• Tracking modalities
  – Quasi-static (QSM): irregular motion + fiducial(s)
  – Respiratory with fiducial (RSM WF): respiration motion + fiducial(s)
  – Respiratory with fiducial free (RSM FF): respiration motion + trackable target

• Plan type settings
  – Helical
  – Fixed/dynamic jaws
  – Jaw width: 1.0 cm, 2.5 cm
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Installation

• Installation at FH&MCW
  – 6/14-6/16: Software upgrade
    o Radixact® Treatment Delivery System v2.0 (Treatment Delivery Console Software V7.0)
    o iDMS® Data Management System v3.0
    o Accuray Precision® Treatment Planning System v3.0
  – 6/21-6/23: Synchrony® hardware installation
    o Camera system (6/17)
    o kV imaging system

• QA after Installation
  – kV: The TQA kvQA module is intended as a service-only module. It is not currently intended for customers
    o Align the kV Tube to the Detector Panel
    o Calibrate the kV Detector Panel
    o MV to kV Alignment
  – Re-plan the TomoPhant IMRT dose calibration plans, and verify/adjust output
Installation

• QA after Installation cont’ed
  – Pause/resume functionality for non-motion plan
    o Similar to a delivery interruption test
  – Dosimetric verification of motion tracking and correction for Synchrony® plans
    o Purpose: verify that the 3D distance error is within 1.5 mm
    o Accuray provided TomoPhantom CT images, and plans generated on our system
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Motion Tests

- **Equipment**
  - A CIRS dynamic motion platform
    - **Components**
      - Plastic platform
        - with SI motion of up to 50 mm
        - Phantom up to 70 lbs
      - Surrogate
        - Independent AP motion of up to 50 mm
      - Controller
      - Motion control software
    - To mimic 2D motion, we turn the platform by 30°
  - A TomoPhantom and accessories
    - Regular TomoPhantom
    - A gold fiducial ion chamber plug
    - A titanium density plug
  - Films optional
• Two scans performed
  – One with a gold fiducial IC plug inserted in the cheese phantom
Plan Generation

- Steps associated with motion tracking plan
  - **Select the motion tracking method**
  
  One can change the tracking modality without canceling optimization
Motion Tests

Plan Generation cont’d

- Plans generated for ATP

- Two plans were generated for the fiducial plug scan: QSM, RSM, WF
Motion Tests

- Setup
  - QSM
  - RSM WF
  - RSM FF
- Setup
  - QSM
Motion Tests

• Delivery
  – Workflow: Prepare, Acquire Images, Build Model, Treat
  – Preparation introduction
    o Select a kV protocol and mAs
    o Tracking range (mm)
    o Thresholds
      ❑ Target Outside Jaw Range Threshold (% of time)
      ❑ Measured Δ (mm)
      ❑ Target Offset (mm)
      ❑ Potential Diff (mm)
    o Auto Pause
      ❑ # of images, or time
Delivery cont’d
– QSM

Prepare
• Delivery cont’ed
  – RSM WF, RSM FF
  ○ Preparation
Motion ATP QA Tool; ACCURAY,

Analysis - QSM

RSM file

MainRawData file

radiographData file

fragment # = -2 or -2 for largest, -1 for all, 0 for last

RMS error (mm) = 1.31924

Calculate

More Info

IEC - X

IEC - Y

IEC - Z

2 Red = tracking path; 1 Blue = phantom path

specific Errors -3 -2 -1 0 1 2 3

Tracked - Actual (mm)

Number - occurrences

X error

Y error

Z error

sqrt(Xerror² + Yerror² + Zerror²) (mm)

Time (seconds)

Occurances
• Synchrony plan delivery with no motion

The previous QSM plan was delivered with no motion.
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Dosimetry Verification with Delta4

- Delta4 Phantom+
  - 1069 p-type detectors distributed on coronal and sagittal plane in a 22 cm diameter and 40 cm long PMMA cylinder
  - Resolution: 5 mm in center (6 cm × 6 cm), 10 mm outer (20 cm × 20 cm)
  - Two cubes
- Delta4 HexaMotion
  - 6D motion (±40 mm in x/y/z; ±10° roll, +3°/-6° tilt)
Dosimetry Verification with Delta4

• Scans
  – With Delta4 Phantom+ on Delta4 HexaMotion
  – Two scans: fiducial cube, lung cube
  – iMAR (Siemens) used on fiducial scan to reduce artifact
Dosimetry Verification with Delta4

- Plan
  - Two plans generated on the fiducial box scan
    - 4 fiducials
    - Two plans have no dosimetry difference
  - One plan generated on the lung cube scan
    - Sphere in lung cube used as tracking target
Dosimetry Verification with Delta4

- Delivery
Dosimetry Verification with Delta4

• Results
  – Gamma criteria
    • QSM: 4 mm, 5% with 5% threshold
    • RSM: 3 mm, 3% with 5% threshold

<table>
<thead>
<tr>
<th>Plans</th>
<th>Gamma Passing Rate (%)</th>
<th>w/ kV dose</th>
<th>w/o kV dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSM</td>
<td>94.1</td>
<td>97.2</td>
<td></td>
</tr>
<tr>
<td>RSM WF</td>
<td>88.7</td>
<td>99.5</td>
<td></td>
</tr>
<tr>
<td>RSM FF</td>
<td>90.5</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Dosimetry Verification with Delta4

- QSM
- RSM WF
- RSM FF
Dosimetry Verification with ArcCheck

- **Equipment**
  - ArcCheck
    - Cylindrical diode array (1386 diodes) in helical pattern with 21 cm diameter and 21 cm length, and 2.9 cm depth
    - Inside a 15 cm diameter inner cavity
  - Cradle
  - MultiPlug
    - 25 possible positions for the 2×2×22 cm³ pieces
    - 6 different heterogeneity inserts: bone, lung, muscle, adipose, titanium, hollow
    - Ion chamber insert
    - Film cassette
  - CIRS dynamic motion platform
  - Customized extension plate
Dosimetry Verification with ArcCheck

- Scans
  - Gold fiducial IC plug
  - Titanium insert
Dosimetry Verification with ArcCheck

• Plan
• Setup and Delivery
## Dosimetry Verification with ArcCheck

### Results

<table>
<thead>
<tr>
<th>Plans</th>
<th>Gamma Passing Rate (%)</th>
<th>With kV dose</th>
<th>kV dose subtracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSM</td>
<td>94.0</td>
<td>94.5</td>
<td></td>
</tr>
<tr>
<td>RSM WF</td>
<td>95.1</td>
<td>96.5</td>
<td></td>
</tr>
<tr>
<td>RSM FF</td>
<td>90.5</td>
<td>94.8</td>
<td></td>
</tr>
</tbody>
</table>
Dosimetry Verification with ArcCheck

- QSM
- RSM WF
- RSM FF

Summary (Gamma Analysis)
- Total Points: 108
- Passed: 88
- Failed: 20
- % Passed: 81.5
- DTA/Gamma is using 2D Mode

Dose Values in cGy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArcCHECK</td>
<td>158.09</td>
<td>158.09</td>
</tr>
<tr>
<td>Plan</td>
<td>145.31</td>
<td>145.31</td>
</tr>
<tr>
<td>ArcCHECK</td>
<td>12.78</td>
<td>12.78</td>
</tr>
</tbody>
</table>

Notes
- Plan: QSM-0629
- Radiograph dose subtracted

Reviewed By:
# Dosimetry Verification with ArcCheck

- Comparison with motion free plans

<table>
<thead>
<tr>
<th>Plans</th>
<th>Gamma Passing Rate (%)</th>
<th></th>
<th></th>
<th></th>
<th>Motion free</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w/ motion</td>
<td>Only surrogate in motion</td>
<td>w/ motion</td>
<td>Only surrogate in motion</td>
<td>w/ motion</td>
</tr>
<tr>
<td></td>
<td>w/ kV dose</td>
<td>w/o kV dose</td>
<td>w/ kV dose</td>
<td>w/o kV dose</td>
<td>w/ kV dose</td>
</tr>
<tr>
<td>QSM-0629</td>
<td>95.1</td>
<td>96.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSM WF-0629</td>
<td>99.3</td>
<td>99.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSM FF-0702</td>
<td>98.0</td>
<td>97.5</td>
<td>99.3</td>
<td>98.8</td>
<td></td>
</tr>
<tr>
<td>RSM FF-MF-0703</td>
<td>98.9</td>
<td>99.6</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>RSM FF-0703A</td>
<td>87.0</td>
<td>92.8</td>
<td>84.1</td>
<td>92.3</td>
<td></td>
</tr>
<tr>
<td>RSM FF-0703B</td>
<td>99.3</td>
<td>99.4</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
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Dosimetry Verification with ArcCheck

**Dosimetry Verification with ArcCheck**

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Dosimetry Verification with ArcCheck
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Synchrony® Plan QA

- QA templates
  - One QA template for each of the 3 Synchrony methods

- With Delta4

<table>
<thead>
<tr>
<th>ArcCheck Plans</th>
<th>Gamma Passing Rate (%)</th>
<th>ArcCheck plans</th>
<th>TomoPhantom plans</th>
</tr>
</thead>
<tbody>
<tr>
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<td>w/ kV dose</td>
<td>w/o kV dose</td>
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<td>97.4</td>
</tr>
<tr>
<td>RSM WF</td>
<td>91.5</td>
<td>98.4</td>
<td>77.6 (75.5)</td>
</tr>
<tr>
<td>RSM FF</td>
<td>94.6</td>
<td>99.7</td>
<td>95.2 (98.5)</td>
</tr>
</tbody>
</table>
• With Delta4 cont’ed
– QSM
– RSM WF
– RSM FF
• With Delta4 cont’ed
– QSM

4 cont’ed
## Synchrony® Plan QA

• With ArcCheck

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### Notes

- **RADIATION ONCOLOGY**
- **Medical College of Wisconsin**
- **knowledge changing life**
- **Froedtert**

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**With ArcCheck**

- **RSM WF**:
  - Delta4 Plans: 87.6% (w/ kV dose), 92.4% (w/o kV dose)
  - TomoPhantom Plans: 91.9% (w/ kV dose), 92.1% (w/o kV dose)

- **RSM FF**:
  - Delta4 Plans: 98.3% (w/ kV dose), 97.7% (w/o kV dose)

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**QSM**

- Delta4 Plans: 98.3% (w/ kV dose), 97.7% (w/o kV dose)
- TomoPhantom Plans: 98.3% (w/ kV dose), 97.7% (w/o kV dose)
Synchrony® Plan QA

- With ArcCheck cont’ed
  - More fiducials?
    - Hard to run
    - Put soldering wires in registration holes of the film cassette (sealed with wax)
    - Scanned the ArcCheck again
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• Summary
• Synchrony® was successfully installed at FH&MCW
  – Fiducial and target tracking accuracy is within 1.5 mm
    o With fiducial/target motion
    o Without motion
  – Dose verified to be consistent with that of plan
    o With fiducial/target motion
    o No fiducial/target motion
    o Non-synchrony plan
  – QAs are in general passing
• Utilization of ArcCheck in Synchrony® is questionable
• Ready for patient treatment with Synchrony®
Acknowledgement

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