Image Registration: The Challenge for QA Centers

Kenneth Ulin, Ph.D.
Marcia M. Urie, Ph.D.
Quality Assurance Review Center

Imaging Studies Used for:
- Staging
- Protocol Eligibility
- Target Volume Definition
- Adaptive Radiation Therapy
- Treatment Delivery
- Assessment of Response
- Outcome Analysis

Types of 3D Imaging:
- CT
- MRI
- PET

QA for Multi-Institutional Studies Requiring Registration of Different Imaging Sets

Two Approaches to QA:
- Require a credentialing exercise to ensure that an institution has the tools and expertise to adequately perform the image registration required by the protocol.
- Verification of the image registration for individual patients on protocol.

QARC: Image Fusion Benchmark
(Developed For COG Low Grade Glioma Protocol)
MR – CT for Target Delineation
"Fuse" DICOM CT & MR scans

Outline target on 2 MR slices
Display on CT

Report the center of the target and the center of this rod on the most inferior CT slice.

Results from 11 software systems

<table>
<thead>
<tr>
<th>Software System</th>
<th>Type of matching</th>
<th>Software System</th>
<th>Type of matching</th>
</tr>
</thead>
<tbody>
<tr>
<td>BrainScan</td>
<td>automatic</td>
<td>Philips Pinnacle</td>
<td>automatic</td>
</tr>
<tr>
<td></td>
<td>manual &amp; auto</td>
<td></td>
<td>manual &amp; auto</td>
</tr>
<tr>
<td></td>
<td>match points</td>
<td></td>
<td>manual</td>
</tr>
<tr>
<td>Corvus</td>
<td>match points</td>
<td>Pinnacle/Syntegra</td>
<td>automatic</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>manual &amp; auto</td>
</tr>
<tr>
<td>Varian Eclipse</td>
<td>automatic</td>
<td>Plato</td>
<td>match points</td>
</tr>
<tr>
<td></td>
<td>manual &amp; auto</td>
<td>PLUNC</td>
<td>manual</td>
</tr>
<tr>
<td></td>
<td>match points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMS Focal</td>
<td>automatic</td>
<td>Radionics XKnife</td>
<td>match points</td>
</tr>
<tr>
<td></td>
<td>manual &amp; auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>manual</td>
<td>Oncentra MasterPlan</td>
<td>automatic</td>
</tr>
</tbody>
</table>
Acceptability criteria
(from first 17 submissions): 3 mm

True target center: average of all submissions.
The uncertainty (one standard deviation of the mean): 0.2 mm
Average error in the position of the center of the target: 1.4 mm
One standard deviation in the displacement of the target center from the true target center: 1.7 mm

QARC FUSION Benchmark

Error Distribution

<table>
<thead>
<tr>
<th>Error Range (mm)</th>
<th>No. in each range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.5</td>
<td>12</td>
</tr>
<tr>
<td>0.6 - 1.0</td>
<td>10</td>
</tr>
<tr>
<td>1.1 - 1.5</td>
<td>10</td>
</tr>
<tr>
<td>1.6 - 2.0</td>
<td>7</td>
</tr>
<tr>
<td>2.1 - 2.5</td>
<td>4</td>
</tr>
<tr>
<td>2.6 - 3.0</td>
<td>1</td>
</tr>
<tr>
<td>3.1 - 3.5</td>
<td>0</td>
</tr>
</tbody>
</table>

QARC FUSION Benchmark

<table>
<thead>
<tr>
<th>Registration Method</th>
<th># benchmarks</th>
<th>Average Error (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>11</td>
<td>1.1</td>
</tr>
<tr>
<td>Automatic</td>
<td>27</td>
<td>1.6</td>
</tr>
<tr>
<td>Manual &amp; Automatic</td>
<td>8</td>
<td>1.3</td>
</tr>
<tr>
<td>Match Points</td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>Overall</td>
<td>51</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Results:

51 submissions from 45 institutions
15 by dosimetrists
36 by physicists
1 by radiation oncologist

~80% approved on first submission
QARC FUSION Benchmark

Conclusion: Studies requiring registration of MR and CT for target delineation need to add 2-3 mm to PTVs and PRVs to account for registration uncertainties.

Credentialing of institutions for use of image registration in a clinical trial can be best accomplished by:

20% A. A questionnaire that asks detailed questions about the institution’s software and procedures.
20% B. Distribution of two scan sets of a specially designed phantom, for which the correct transformation matrix is known.
20% C. Re-registering the image sets for the first patient enrolled on the study.
20% D. Distribution of two scan sets of an actual patient, for which the correct transformation matrix is approximately known.
20% E. Requiring the involvement of radiation oncologist, physicist, and dosimetrist in the credentialing exercise.

Answer: (D) Credentialing of institutions for use of image registration in a clinical trial can be best accomplished by distribution of two scan sets of an actual patient, for which the correct transformation matrix is approximately known.

Explanation:
A. A questionnaire does not test ability to perform the image fusion.
B. A phantom test is too easy.
C. Re-registering the image sets for the first patient enrolled on the study is labor intensive, and the correct answer is not known.
D. Involvement of radiation oncologist, physicist, and dosimetrist in the process is desirable, but is not a credentialing test and does not usually happen in practice.
Fiducial markers: mark alignment locations for PET and CT study.

Clinical trials (and QA centers) allowing subjective expertise of radiation oncologists for correlation of PET with CT planning scans.

Quantitative PET

SUV calculations (Standardized Uptake Values): great interest in clinical trials to assess staging, response, outcome.

SUV calculation: DICOM standard does not include all required information for SUV calculations, so recalculation by QA centers is difficult.
**Image Guided Adaptive Therapy**

- Tomotherapy
- MV CT
- kV CT
- Cyberknife
- Ultrasound

**Challenge for QA Centers of Image Guided Adaptive Therapy**

- Planning CT → MV CT
- Planning CT DRR → on-board plain images

- Planning CT → kV CT on board imaging
Challenge for QA Centers of Image Guided Adaptive Therapy

Currently QA centers are concentrating on verifying the accuracy of the entire process for each institution.

ATC (Advanced Technology Consortium) is developing credentialing criteria.

CT → Ultrasound

Challenge for QA Centers of Image Guided Adaptive Therapy

Cost-benefit of individual patient review must be weighed relative to the time & labor to:
- gather
- transmit
- organize
- archive
- review

We wish to acknowledge the companies that have provided many of the images shown in this presentation.

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Challenge
- verifying institutions’ systems and capabilities (credentialing)
- verifying individual protocol patient’s treatment
References