Performance testing for Precision 500D Classical R/F System

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Outline

• System background

• Image Quality Signature Test (IQST) tool

• Evaluation/debug for sites with image quality complaints

• Dose considerations

• Conclusion

• Appendix of tables related to system performance testing
Precision 500D

- Classical R/F System
- Focus on fluoro/digital spot
  1. Overtable imager
  2. Undertable tube
- Overtable imager
  1. X-ray Image Intensifier (XRII)
  2. Optics assembly (lens + iris)
  3. CCD camera
Completely Automated X-Ray Technique Selection

• Algorithm
  1. Patient thickness calculation
  2. Technique mapping for thickness and selected contrast agent
  3. Technique mapping based upon:
     - imaging metric (e.g., CNR, contrast)
     - patient skin dose
     - regulatory tube and generator limitations
     - customer feedback

• Feedback Signal
  1. Average signal over a region of interest (ROI)
  2. Compensation for raw beam/collimated areas

• User controls (via a protocol editor)
  1. Contrast agent (5 total)
  2. ROI size and position

• All techniques (including spectral filtration) for fluoro are determined and continually updated

• Same for spot except exposure time (AEC)

Skill of clinician (positioning, collimation, SID) still very important
Image Processing

Acquisition → Processing → Storage

- CCD Digital Data
- rescale + encoding LUT
- Fluoro Noise Reduction (FNR)
- Presentation
- Display Monitor

- User controls:
  1. FNR level
  2. Edge enhance level
  3. Window/level values
  4. Inversion
  5. Image "look" (for spot/fluoro and DSA)

- Fluoro only
  - Includes motion compensation

- Default settings available for all user controls

- edge enhance
- window/level
- inversion
- user "look" LUT
- DSA functions
  1. Subtraction
  2. Landmark
  3. roadmapping
- monitor LUT (Barten correction)
Image Quality Signature Test (IQST)

Precision 500 D System

Phantoms
- Copper sheet (placed on table)
- Composite (mounted)

Mounted composite phantom
Image Quality Signature Test (IQST)

Measures and QA Parameters

Dark Images (Offset)

Flat Fields

Phantom

QA Parameters

Electronic Noise

Noise (versus dose)
Brightness Uniformity

Spatial MTF
Resolution Uniformity
Small Signal Contrast
Large Signal Contrast
Signal Level Accuracy
CNR
Image Quality Signature Test (IQST)

Quality Assurance Phantom

Lead Ring (phantom detection)

Aluminum Steps w/ Holes (contrast, CNR)

Steel Mesh Coupons (resolution non-uniformity)

Position Tab

Lead Fiducial Markers (feature location)

Tungsten Coupon (MTF)

Copper Steps (level accuracy)

Lead Slug & Through Hole (large signal contrast)
IQST - Other Points

• Data is analyzed post CCD (tests primarily XRII, optics, and CCD)

• Frequency of use is up to the user (monthly is o.k.)

• GE service CD required for display of numerical values for individual test results (otherwise, gives a global PASS/FAIL)

• Recommend trending data
Evaluation/debug for sites with image quality complaints

Three Step Process

1. Definition of imaging issue
   - issue with images acquired in the room or with PACs image or printed film

2. Verify the system is operating to design
   - processing parameter check
   - protocol check
   - calibration check

3. Adjust processing (if necessary)
Processing Parameter Check

Procedure
1. Check processing parameters
   - user preferences screen
   - via service interface, config -> digital -> setup

Test
1. Compare fluoro and spot techniques with expected values
   (listed at end of talk)

1. Investigate any values which significantly vary from default
   - e.g., W/L values more than 50 counts away. Other values more than 2 settings away
Protocol Check

Procedure
1. Enter protocol editor
2. For each protocol, investigate:
   a. contrast agent selection
   b. ROI selection for 'digital' steps of protocols

Test
1. ROI should be either the large, centered square or the large, centered rectangle
2. Contrast agent should be relevant for the protocol, e.g.
   Barium --> most penetration --> higher kVps
   Ba/Air  --> less penetration --> lower kVps
Calibration check - monitor check

Procedure
1. Perform 'Monitor LUT' calibration

What this does
1. Verifies luminance for white and black levels are set correctly so that the monitor is calibrated
   - jnd versus DDL is linear
   - contrast ratio is 'fixed' (white ~ 375 Cd/m²; black ~ 0.8 to 1.2 Cd/m²)
Calibration check - "load" test

**Setup**
1. Put 15 cm stack of lucite on table (area should be >= 25 x 25 cm²)
2. MAG = 0
3. Grid = 'in'
4. Contrast Agent = Ba/Air
5. SID = min
6. Open collimator blades to full FOV
7. Center lucite stack

**Test**
1. Compare fluoro and spot techniques with expected values

**Procedure**
1. Apply continuous fluoro until techniques settle (1 to 2 s)
2. Note down fluoro techniques (kVp, mA, spectral filter)
3. Take 1 fps spot exposures and record actual techniques of last image

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In case of failure, redo:
1. Iris Calibration
2. Fluoro CF Calibration
3. Record CF Calibration
4. mR/mAs calibration
Calibration check - limiting resolution test

Suggested Setup
1. Tape resolution wedge to the input of the XR11 at a 45 degree angle to the table axis
2. Grid = 'in'
3. SID = min
4. Open collimator blades to full FOV
5. Set FNR = 3, Edge = 1 or 0

Test
1. Compare limiting resolution values with expected values

Procedure
1. For a given MAG, apply fluoro
2. Verify limiting line pairs are near the center of the field
3. While applying fluoro, record limiting resolution perceived
4. Repeat for each MAG

In case of failure, redo:
1. Camera focus calibration
2. IL Sizing and focus calibration
Processing Adjust - Image "Appearance"

• Five settings are available

• Most common adjustment; usually done in conjunction with edge enhance

• Not designed in isolation (based upon customer feedback and x-ray technique selection)

• Each trades off various parameters
  - contrast at nominal dose,
  - detail in higher dose regions of the image (near skin line, for example)
  - noise
  - blackness of contrast agent

• In addition, for each image appearance, one can double the anatomic over-range by setting the dynamic range parameter to 'extended' (not common)
Edge enhancement - examples

- **smoothed**: Smoother edges (less noise)
- **enhanced**: Crisper edges (more noise)
Dose considerations

- Compared to previous GE system (Legacy), Precision 500 D offers two features for dose reduction:
  - use of spectral filtration (to filter out low energies)
  - pulsed fluoro
  - improved FNR
  - inclusion of spectral filter in automated technique design

- The user can reduce dose rate by:
  - working at lower magnifications and collimating (rather than mag up)
  - using pulsed fluoro (7.5 fps (40 to 50%), 3.75 fps (60 to 70%))
    (NOTE: 15 fps is more designed for image quality (motion stopping relative to continuous) and gives only small (5 to 15%) dose reduction)
  - grid removal typically gives ~50% more
    (recommended for newborns/toddlers)
  - keeping fluoro time to a minimum

- No "high, medium, and low" selections (as with previous Legacy system)
Dose considerations

• For quality control and general performance evaluation, measure dose in applications mode (figure below)

• Vary as desired system variables (MAG, collimation, contrast agent, lucite thickness, grid position) and measure dose, kVp, mA, ....
Summary

• Precision 500D is a highly integrated and automated system

• Correct calibration is important to ensure the system operates to design
  - can monitor via load test, limiting resolution test, and monitor calibration

• In addition, the performance of the XRII can be evaluated via the IQST tool supplied with the system

• Adjustment to image quality is primarily achieved via processing parameters
  - image appearance, window/level, edge setting, and FNR
### Specified Values for "Load" Test. Where applicable, typical values are in parentheses.

<table>
<thead>
<tr>
<th>II Size (cm)</th>
<th>Mode</th>
<th>kVp</th>
<th>mA</th>
<th>spectral filter (mm)</th>
<th>ms</th>
<th>mAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>fluoro</td>
<td>74 +/- 3</td>
<td>no spec. (1)</td>
<td>0.3</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>40</td>
<td>spot</td>
<td>74 +/- 3</td>
<td>no spec. (45)</td>
<td>0.2</td>
<td>10 to 20 (13)</td>
<td>0.1 to 1.4 (0.6)</td>
</tr>
<tr>
<td>32</td>
<td>fluoro</td>
<td>74 +/- 3</td>
<td>no spec. (0.8)</td>
<td>0.3</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>32</td>
<td>spot</td>
<td>74 +/- 3</td>
<td>no spec. (50)</td>
<td>0.2</td>
<td>10 to 20 (12)</td>
<td>0.1 to 1.4 (0.5)</td>
</tr>
</tbody>
</table>

### Typical Limiting Resolution Values (lp/mm)

<table>
<thead>
<tr>
<th>II Size (cm)</th>
<th>MAG</th>
<th>limiting res. (lp/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0</td>
<td>1.2 to 1.5</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>1.6 to 2.0</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>2.0 to 2.5</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
<td>2.5 to 3.0</td>
</tr>
<tr>
<td>32</td>
<td>0</td>
<td>1.6 to 2.0</td>
</tr>
<tr>
<td>32</td>
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<tr>
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<td>2</td>
<td>2.5 to 3.0</td>
</tr>
<tr>
<td>32</td>
<td>3</td>
<td>3.0 to 3.5</td>
</tr>
</tbody>
</table>
### Default Processing Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoro Window/Level</td>
<td>512/512</td>
</tr>
<tr>
<td>Spot Window/Level</td>
<td>512/512</td>
</tr>
<tr>
<td>Fluoro Edge</td>
<td>1</td>
</tr>
<tr>
<td>Spot Edge</td>
<td>1</td>
</tr>
<tr>
<td>Image Appearance</td>
<td>Contrast Detail</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>Normal</td>
</tr>
<tr>
<td>DSA Contrast</td>
<td>Normal</td>
</tr>
<tr>
<td>DSA Window/Level(^1)</td>
<td>256/512</td>
</tr>
<tr>
<td>FNR - 30 fps</td>
<td>3</td>
</tr>
<tr>
<td>FNR - 15 fps</td>
<td>1</td>
</tr>
<tr>
<td>FNR - 7.5 fps</td>
<td>1</td>
</tr>
<tr>
<td>FNR - 3.75 fps</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^1\) For systems without a DSA Contrast setting, it is recommended to set the default window/level to: 120/532.

The chart below summarizes the impact to the image of the different image appearance settings. *Note all descriptors are relative to the default 'contrast detail' image appearance setting.*

<table>
<thead>
<tr>
<th>Look</th>
<th>Blackness of Contrast Agent</th>
<th>Contrast at nominal dose</th>
<th>Detail in the higher dose regions</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detail Plus</td>
<td>Less</td>
<td>Less+</td>
<td>More</td>
<td>Less+</td>
</tr>
<tr>
<td>Detail</td>
<td>Same</td>
<td>Less</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>Contrast</td>
<td>Same</td>
<td>More</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Contrast Plus</td>
<td>More</td>
<td>More+</td>
<td>Less+</td>
<td>More+</td>
</tr>
</tbody>
</table>
"Physics" or Manual Mode

• Many tests/protocols carried out by physicists require manual control of x-ray techniques (kVp, mA, etc.)

• Currently, the Precision 500D does not offer such a mode

• However, for a few calibration units, one can control various technique factors. These are listed on the following page.
Appendix

Calibration units with manual techniques

1. Step 1 of Iris calibration  
   (30 fps fluoro, 70 kVp, no spectral filter, manual mA control)

2. Step 2 of II Sizing & Focus calibration  
   (30 fps fluoro, 60 kVp, 0.3 mm Cu filter, manual mA control)

3. mR/mAs cal (fixed techniques)  
   Step 2: 75 kV, 50 mA, 100 msec, SF = 0  
   Step 3: 75 kV, 50 mA, 100 msec, SF = 0.1  
   Step 4: 75 kV, 50 mA, 100 msec, SF = 0.2  
   Step 5: 75 kV, 50 mA, 100 msec, SF = 0.3

4. Fluoro CF (fixed techniques)  
   Step 2 and 3: 75 kV, 0.0133 mAs, SF = 0

5. Record CF (fixed techniques)  
   Step 2 and 3: 75 kV, 0.3 mAs, pw = 10, SF = 0