Developing a National Nuclear Medicine Phantom QA Program: Lessons Learned over 20 years

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Veterans Health Administration

- US medical care fragmented, mostly private, except for elderly and some indigent.

- Veterans Health Administration = Public Health care, serving about 8 million veterans of the U.S. military. Medical services provided to > 5 million veterans (2008)

- >153 medical centers, 882 ambulatory care and community-based outpatient clinics.

- 200,000 full-time-equivalent employees, including over 13,000 physicians.
• Nuclear medicine practiced at 135 VA sites

• FY 09: 616,691 imaging studies
  (~ 8% increment/yr)
  1100 unsealed source therapies

• 14 tele-nuclear medicine sites served by interpretation at 8 hubs

• >340 imaging devices (gamma cameras and PET-CT)
Location of Nuclear Medicine Services and Program Director’s Office

Nuclear Med Program Office, Ann Arbor, MI
Milton D Gross MD, Program Director
Nuclear Medicine Utilization Trend

Nuclear Medicine Studies

Number of Studies
PET
All Other
Cardiac
VA Quality Improvement & Performance

VA is recognized as a benchmark in healthcare.

2004 RAND Health study*:
“VA patients receive significantly higher quality care than patients in any other healthcare setting in US”.

How do we monitor the quality of VA Nuclear Medicine labs?

WHAT IS NOT MEASURED CANNOT IMPROVE
NO DATA = NO QI

1991 - VA Headquarters Nuclear Medicine Service initiated a national QA program for all VA nuclear laboratories.

Provide a different standard imaging phantom annually to each VA nuclear medicine laboratory.
Topics to be covered:

• Goals of the phantom program
• Administration of a multicenter phantom program
• How the program evolved over time
• Demonstrate selected phantoms and results
• Benefits
• Difficulties/barriers encountered
Goals of the National Phantom Proficiency Program

- Collect metrics of **integrated performance** (analogous to clinical practice)

- Camera/technical performance
- Clinical interpretation of results

Vs.
Goals of the National Phantom Proficiency Program, contd.

- Set national benchmarks for performance
- Reward the laboratories meeting proficiency standards
- Determine factors that lead to poor performance
- Devise corrective actions and education
- Close the loop – re-measure
First phase 1992-99: Focus on success

Results provided to individual laboratories, without detailed analysis of data

1992: Cylindrical Phantom, cold inserts, SPECT/planar
1993: Ventilation-perfusion simulation (planar)
1994: Myocardial perfusion SPECT
1995: Cylindrical phantom
1996: Renal phantom with cold defects
1997: Lumbar spine and sacrum
1998: Pulmonary perfusion
1999: Myocardial perfusion

Vendor: College of American Pathologists, American College of Nuclear Physicians, Society of Nuclear Medicine
Manufacturer: Medical Designs, Inc. (MDI)
PARTICIPATION by individual VA Nuclear Medicine Laboratories has increased during the life of the program.
The vast majority of VA laboratories demonstrate proficiency - their results are comparable or superior to a national private-sector peer group.
Paradigm shift in second decade, 2000- present: Closing the Loop

2000: Myocardial perfusion, rest and stress
2001: Lumbar spine, planar and SPECT
2002: Chest tumor, medium energy isotopes
2003: Myocardial perfusion, rest and stress
2004: Gated SPECT myocardial perfusion
2005: Lumbar spine and sacrum, planar/SPECT
2006: Cylinder phantom with hot and cold foci
2007: Lung perfusion
2008: Thyroid imaging with cold lesions
2009: Myocardial perfusion with TID
2010: Gastric emptying
2011: PET-CT, Chest Tumor
Paradigm shift 2000-2010 – changes

- Detailed analysis of factors leading to failure
- Remediation efforts with lab (focus on education)
- More VA interaction for phantom design and test
- Tailoring the exercise to VA needs
- Providing detailed reports of results
- Posting lessons learned to website
Focus on unsatisfactory performance
Usually multi-factorial and compounding

- **Technical factors**
  - Failure to follow instructions
  - Lack of attention to detail in filling the phantom
  - Suboptimal equipment
  - Inadequate quality control procedures
  - Acquisition errors e.g. inappropriate matrix, inadequate time per stop
  - Processing errors e.g. inappropriate filters

- **Interpretative errors**
  - Not answering all questions
  - Misinterpretation of right vs. left
  - Misinterpretation of head vs. foot
  - Over-calling or under-calling of “lesions”
Phantom Failure Rate

3 Sigma

2 Sigma

Mean

%
Thyroid imaging phantom 2008
Filled with 300 uCi Tc-99m pertechnetate
10 mm cold nodules in R lower pole and L upper pole

Improper filling/mixing of the phantom
% laboratories identifying cold defects
% identification of BOTH thyroid nodules
Lessons Learned from Thyroid Phantom - Forgotten Knowledge: Current practice patterns of thyroid scintigraphy.

- 44 VA labs do not own a pinhole collimator yet perform thyroid imaging. Why?

- Parallel hole collimator with electronic zoom is not equivalent to pinhole.

- Action?
Fill phantom with Tc-99m tracer into the 2 fill ports
Image with clinical protocol
Segmental perfusion defects:

- Right middle lobe
- Superior segment of the right lower lobe

Small non-segmental defects in lower lobes.
Identification of perfusion defects followed by determination of probability of acute PE in 3 clinical scenarios.
Determine the probability of acute PE: normal, v. low, low, intermediate, indeterminate, high.

Assume ventilation study is normal

Assume perfusion defects match ventilation

Assume perfusion defects match ventilation
Lessons learned from lung perfusion phantom:

- Problems with interpretation of VQ studies:
  - Review literature and current recommendations for interpretation
  - Review lung segmental anatomy

- Use of non-standard protocols: 60% labs did not use at least 500,000 counts for the initial posterior lung view, suggesting inadequate counts.
  - Review standard protocol guidelines

- Camera quality control procedures varied significantly.
  - Follow professional society guidelines
Gastric insert filled with Tc-99m

Ant and post attenuators simulate gastric emptying over 4 hours
lead attenuators

phantom chamber filled with 99mTc mixed in water

PHANTOM DESIGN
Gastric Emptying phantom 2010: Goals

- Check acquisition and processing
- Interpretation of results and clinical scenarios
- Highlight consensus protocol: “Consensus Recommendations for Gastric Emptying Scintigraphy” Am J Gastroenterol 2008
**Quantitative Analysis**: Processing included quantification of the steps involved in calculating residual activity remaining in the stomach at the various time points.

<table>
<thead>
<tr>
<th>Scan start time (hh:mm)</th>
<th>Scan duration (seconds)</th>
<th>RAW Anterior Gastric Counts</th>
<th>RAW posterior Gastric Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2 h</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4 h</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geometric Mean</th>
<th>Decay Corrected Geometric Mean</th>
<th>Percent Residual Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td></td>
<td></td>
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<td>2 h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td></td>
<td></td>
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</tbody>
</table>
LESSON: Most common error was failure to apply appropriate decay correction – at 18% laboratories
### Quantitative Analysis

<table>
<thead>
<tr>
<th>Time (hh:mm)</th>
<th>Scan Duration (seconds)</th>
<th>RAW Anterior Gastric Counts</th>
<th>RAW Posterior Gastric Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0h 8:00 a.m.</td>
<td>60 sec</td>
<td>24333</td>
<td>22741</td>
</tr>
<tr>
<td>1h 9:00 a.m.</td>
<td>60 sec</td>
<td>20492</td>
<td>17889</td>
</tr>
<tr>
<td>2h 10:00 a.m.</td>
<td>60 sec</td>
<td>12919</td>
<td>11919</td>
</tr>
<tr>
<td>4h 12:00 p.m.</td>
<td>60 sec</td>
<td>11372</td>
<td>10180</td>
</tr>
</tbody>
</table>

*use 24 hour clock format*

- **Geometric Mean**
  - 0h 47074.0
  - 1h 38381.0
  - 2h 24836.0
  - 4h 21552.0

- **Decay Corrected Geometric Mean**
  - 0h 47074
  - 1h 34197
  - 2h 19721
  - 4h 13586

- **Percent Residual Solid (%)**
  - 0h 100%
  - 1h 73%
  - 2h 42%
  - 4h 29%

- **Image Export**
  - 75-87
  - 46-62
  - 35-55
Gastric Emptying phantom 2010: yet another paradigm shift – Physician-specific performance

Healthcare organizations are asking for metrics of individual providers for credentialing.

CLINICAL VIGNETTE
The patient is a 40 year-old female with diabetes who describes a 6 month history of post-prandial nausea, vomiting, and bloating. The patient was referred to nuclear medicine to evaluate for gastroparesis.

<table>
<thead>
<tr>
<th>PHYSICIAN RESULTS/SCORE</th>
<th># PHYSICIANS WITH SCORE</th>
<th>%</th>
<th>DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>145</td>
<td>45%</td>
<td>Perfect Score</td>
</tr>
<tr>
<td>80-99%</td>
<td>165</td>
<td>51%</td>
<td>Pass</td>
</tr>
<tr>
<td>&lt;80%</td>
<td>14</td>
<td>4%</td>
<td>Fail</td>
</tr>
<tr>
<td>TOTAL</td>
<td>324</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
Lessons learned from gastric emptying phantom:

- Problems with calculations (very unexpected finding!)
  - Education efforts throughout VA

- Use of non-standard protocols: 88% labs did fully follow consensus guidelines from SNM and GI Specialty Societies. JNM 2011:52 abstract.

Review standard protocol guidelines
Follow-up one year later – 35% labs reported change

<table>
<thead>
<tr>
<th>What was changed</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed meal composition</td>
<td>58%</td>
</tr>
<tr>
<td>Changed imaging times</td>
<td>67%</td>
</tr>
<tr>
<td>Changed calculations</td>
<td>51%</td>
</tr>
<tr>
<td>Changed interpretative criteria</td>
<td>58%</td>
</tr>
</tbody>
</table>
Usage of different myocardial perfusion phantoms

1994: Myocardial perfusion, rest and stress
1999: Myocardial perfusion, rest and stress
2000: Myocardial perfusion, rest and stress
2003: Myocardial perfusion, rest and stress
2004: Gated SPECT myocardial perfusion
2009: Myocardial perfusion with TID

Image with usual clinical protocols and interpret study in same way as would for a patient.

Myocardial perfusion imaging >75% of NM studies
apex  mid mid  base

mid - basal
MYOCARDIAL PERFUSION PHANTOM

- Three-dimensional cardiac simulator with rest and stress inserts.
- Designed to test the ability to acquire and process stress and rest myocardial perfusion studies.
- Tests interpretative skills.
• Imaged phantom using lab’s routine 2 day MPI SPECT protocol for Tc-99m tracers

• Reported acquisition parameters and identified perfusion abnormalities – results scored

• Compared reported acquisition parameters with published SPECT guidelines
2009 IMAGE OUTCOME?

- 7 labs failed the exercise due to poor image quality
- Of these, 4 (57%) did not follow one or more parameters of recommended SNM/ASNC MPI procedure guidelines
Lessons learned: Do VA labs follow published guidelines?

Collimator: 75% use the ASNC recommended High Resolution (LEHR) collimator; 25% use an all-purpose (LEAP) or similar

Time/stop varies: within group using 60-64 stops, 11% labs image longer than ANSC recommended on stress (>30 sec/stop) while 4.2% image shorter (<20 sec/stop)

Action: VA has promoted use of LEHR collimators and will survey in 2011 to determine compliance.
Gated SPECT phantom – 2005

Gated SPECT simulator “motorized beating heart” used to calculate LV ejection fraction and heart wall motion

Tests ability to acquire, process and determine the ejection fraction and interpret the wall motion in a simulated patient
Images and heart function measures from gated SPECT phantom. This site did not meet criteria for passing.
Grading the gated SPECT phantom

Facilities' Reported Ejection Fraction of Simulator

True EF = 45.8%
Maximum, minimum and mean simulator ejection fraction by processing software

True EF 45.8%
VA 2011 PET/CT Oncology Phantom

• First use of PET phantom

• Simulation of lung cancer lesions in thorax

• Filled w/ F-18 FDG (2 compartment)

• 2009: 44,409 PET studies in VA
VA 2011 PET/CT Oncology Phantom

**TECHNICAL RESULTS:**
Image quality*
Acquisition, Processing
SUV

**PHYSICIAN RESULTS:**
Lesion localization*
Staging
Knowledge about PET
PET/CT Oncology Phantom: FAILURE

PET results from 90 sites (VA, mobile, contracts) with failure rate of 16%.

Analysis of factors that led to failure:
1. EQUIPMENT
VA 2011 PET/CT Oncology Phantom

Analysis of factors that led to failure:

2. **PROTOCOLS**

   - **Time per bed position**: 3 min 2-D acquisition
Analysis of factors that led to failure:

3. **INTERPRETATIVE ISSUES**

   **Lesion identification:**
   - 88% All 5 lesions
   - 3% > 6 lesions
   - 6% <4 lesions

   **Staging:** IIIb

   **Knowledge questions**
   - Passed: 92%
   - Perfect score 22%
### 4. SUV ISSUES

<table>
<thead>
<tr>
<th>Location</th>
<th>SUV max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Basal LLL</td>
<td>3.1</td>
</tr>
<tr>
<td>Superior Segment LLL</td>
<td>1.4</td>
</tr>
<tr>
<td>Left Paratracheal Node</td>
<td>3.0</td>
</tr>
<tr>
<td>Right Paratracheal Node</td>
<td>1.5</td>
</tr>
<tr>
<td>Left Supraclavicular Node</td>
<td>1.7</td>
</tr>
</tbody>
</table>

- **Calibration issues**
- **Activity correction**

![SUV max +/- 2 SD](image)
VA 2011 PET/CT Oncology Phantom

SUVbw 267
VA 2011 PET/CT Oncology Phantom

Results by site

- % Exceptional
- % Pass
- % Fail

- VA owned site (fixed)
- Community/Private fixed site
- Privately owned mobile
“I'll pause for a moment so you can let this information sink in.”
Benefits of Phantom QA Program - I

- Objective measurement of NM imaging performance.
- Evaluates imaging AND interpretative performance.
- Feedback enables individual practitioner to assess performance in relation to others and self-improve capabilities. Feedback = an essential part of the exercise.
- Within a single facility results may be used to compare results from various interpreting physicians in order to reduce inter-observer variability.
Benefits of Phantom QA Program-II

- Demonstrates the quality of NM services to outside agencies and public.

- Phantom is retained and can be used again for QA exercise for new equipment, physicians and technologists.

- Results of the phantom exercise allow for comparisons of equipment performance which may justify new cameras.

- ENABLES SYSTEMWIDE FACILITY-SPECIFIC (PROVIDER-SPECIFIC) METRICS AND ANALYSIS OF ROOT CAUSES TO REMEDIATE POOR PERFORMANCE.
Barriers to participation – can they be overcome?

- Knowledge e.g. lack of familiarity with procedures
- Attitudes e.g. inertia, habit, lack of motivation, resistance to change
- Behavioral /external barriers e.g. lack of time, organizational constraints, insufficient staff support

Physicians have traditionally thought of quality in terms of the care provided to an individual patient or the quality of reading an individual scan. Need to shift to systems thinking/ organizational processes
Individualized Actions Plans for remediation and retesting

(emphasis on education, not punishment!)

- Repeat exercise
- Educational materials, model protocols
- Qualified physicist assessment of camera performance
- On-site inspection by program office content expert
- Accreditation e.g. ACR, ICANL
- Closure of nuclear laboratory

Very time-consuming!
Conclusions

• Feasible to use imaging phantoms across a large multi-center healthcare system

• Barriers and administrative challenges

Large scale and two decades of experience has afforded us the opportunity to identify system-wide root causes and develop improvement strategies. We owe this to our stakeholders!

Thank you for your attention