CT Lung Cancer Screening and the Medical Physicist:
Background, Findings and Participant Dosimetry Summary of the National Lung Screening Trial (NLST)

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Introduction and Background

- Lung Cancer Statistics (American Cancer Society, ACS)¹
  - Excluding skin cancer, lung cancer is the second most common cancer for both men and women in the US
  - 13% of all new cancers (2015 estimate: 221,200 new cases)
  - 27% of all cancer deaths (2015 estimate: 158,040 deaths)
    - More people die from lung cancer than from colon, breast, and prostate cancer combined

  [Percent of New Cases by Age Group]

  *National Cancer Institute SEER 18 2005-2012, All Races, Both Sexes
Introduction and Background

- Lung Cancer Risk (US Preventive Services Task Force, USPSTF)³
  - 85% of new cases are current or former heavy smokers
  - Age is a risk factor, average age at diagnosis is 70
  - Poor prognosis, 90% with lung cancer die of the disease
    - 75% of patients present with advanced local or metastatic disease
    - 17.4% of patients survive 5-years or more after diagnosis

Five Year Relative Survival

³National Cancer Institute SEER 18 2005-2011, All Races, Both Sexes

Introduction and Background

- Lung Cancer Screening – Chronological Review
  - American College of Radiology (ACR)
    - Lung cancer screening center designation (2014)
  - US Preventive Services Task Force (USPSTF)
    - Final approval for annual CT screening (2013)
      - B recommendation, screening covered as a preventive service under the Affordable Care Act
  - National Lung Screening Trial (NLST)
    - Finding and conclusions published 2011-2013
    - Trial period: August 2002 – April 2004
NLST Introduction

- NLST introduction
  - Randomized controlled trial funded by the National Cancer Institute, conducted by two organizations
    - Lung Screening Study (LSS)
    - American College of Radiology Imaging Network (ACRIN)
  - Recruited 53,439 asymptomatic participants that were randomly assigned to one of two study groups
    - Chest radiography (CXR)
      - 26,724 participants
      - 73,733 exams acquired
      - 92 chest imaging systems
    - Low Dose Computed Tomography (LDCT)
      - 26,715 participants
      - 75,133 exams acquired
      - 97 multidetector CT scanners

NLST Demographics

- NLST participant demographics
  - Eligibility criteria
    - Smoking history: current or former heavy smokers with at least a 30 pack-years of cigarette smoking (former smokers within last 15 years)
      - 47% of participants had a >50 pack-year smoking history
    - Participants annually screened for three years
      - Compliance rate 98.5%
    - Age: 55 to 74
      - Males: 31,523 (59%)
      - Females: 21,916 (41%)
  - Multi-centered trial
    - 33 screening centers
    - Enrollment period: 8/02 - 4/04
    - Screening period: 8/02 - 9/07
    - Event reporting through 12/09
    - Findings published 2011-2013
NLST Objectives and Findings

- NLST objective
  - Determine whether lung cancer screening using low-dose multidetector helical CT reduces lung cancer-specific mortality relative to a single view chest radiograph in a high-risk cohort

- NLST findings
  - Reduction in mortality from lung cancer achieved based on low-dose CT screening
  - Demonstrated a 20% reduction in mortality in high-risk patients

NLST CT Summary

- Summary of 97 CT systems utilized

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th># Scanners</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Electric Healthcare</td>
<td>LightSpeed Plus 4</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>LightSpeed Discovery 4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>LightSpeed Qti 4</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>LightSpeed Ultra 8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>LightSpeed 16</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>VCT 64</td>
<td>1</td>
</tr>
<tr>
<td>Philips Healthcare</td>
<td>MX8000 (4)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>MX8000 (16)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Brilliance 64</td>
<td>1</td>
</tr>
<tr>
<td>Siemens Healthcare</td>
<td>Sensation 4 (Volume Zoom)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Sensation 16</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Emotion 16</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sensation 64</td>
<td>2</td>
</tr>
<tr>
<td>Toshiba</td>
<td>Aquillion 4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Aquillion 16</td>
<td>3</td>
</tr>
</tbody>
</table>
### NLST CT Summary

#### CT participant screening parameters

<table>
<thead>
<tr>
<th>NLST Specification</th>
<th>Typical Site Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi detector CT - minimum 4 channels</td>
<td>4 or 16</td>
</tr>
<tr>
<td>kVp - 120 to 140</td>
<td>120</td>
</tr>
<tr>
<td>Pitch - 1.25 to 2.00</td>
<td>1.5</td>
</tr>
<tr>
<td>Effective mAs (mAs / pitch) - 20 to 60</td>
<td>20 - 40</td>
</tr>
<tr>
<td>Total Scan Time (35 cm) - max 25 sec</td>
<td>10 - 20 sec</td>
</tr>
</tbody>
</table>

### NLST CT Summary

#### ACR lung cancer screening specifications

<table>
<thead>
<tr>
<th>Scan Parameter</th>
<th>Parameter Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT scanner type</td>
<td>multidetector, detector rows ≥ 4</td>
</tr>
<tr>
<td>kV</td>
<td>100 - 140</td>
</tr>
<tr>
<td>Pitch (IEC Definition)</td>
<td>0.7 - 1.5</td>
</tr>
<tr>
<td>Current adjustment</td>
<td>manual or automatic (patient size)</td>
</tr>
<tr>
<td>CTDIvol</td>
<td>CTDIvol(standard size patient) ≤ 3 mGy</td>
</tr>
</tbody>
</table>
NLST CT Summary

- Measured CTDI$_{vol}$ for CTs used in NLST

![CTDI$_{vol}$ graph]

Average CTDI$_{vol}$ = 3.3 mGy (Std Dev = 1.5 mGy)
Published in AJR, November 2011

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NLST CXR Participant Dosimetry: Introduction

- Chest radiography participant dose study published
  - AJR, July 2013
- Study Objective
  - Determine effective dose associated with individual NLST chest x-ray examinations
NLST CXR Participant Dosimetry: Methods and Materials

- **CXR Quality Control (QC)**
  - 92 CXR acquisition systems at 33 sites
  - Included film-screen, CR and DR devices
  - Certification requirements were adapted from published ACR standards and consensus among the participating facilities
  - Initial and annual QC activities
    - Focused on verification of output calibration
    - Machine-specific measurements (annually)
      - HVL and radiation output (mR/mAs)

NLST CXR Participant Dosimetry: Methods and Materials

- NLST CXR protocol specified the collection of a participant’s acquisition parameters
  - Imaging parameters
    - Tube potential,
    - Current and mAs
    - Exposure time
    - Detector system
  - Participant factors
    - Height and weight
    - Average BMI = 28
NLST CXR Participant Dosimetry: Methods and Materials

- Monte-Carlo program
  - PCXMC, developed by the Finnish Radiation and Nuclear Safety Authority, Helsinki, Finland
    - PC based special purpose code for diagnostic radiology only dose calculations
    - Hermaphrodite mathematical phantom
- Effective dose assessment methodology
  - Product of exam entrance skin air kerma (ESAK) and the ratio [effective dose per ESAK]
  - Exam ESAK is the product of mAs and average x-ray tube output, measured annually by medical physicist

NLST CXR Participant Dosimetry: Results and Conclusions

- 73,733 CXR examinations performed
- A CXR effective dose assessment was determined based on 66,157 exams
  - Data from 31 sites utilizing 90 CXR systems
  - Data from 26,732 CXR participants utilized
  - Mean Effective Dose (ED): 0.052 mSv
- Variations in tube potential and filtration had a minor influence on assessed ED
  - ED changed <20% at the max/min boundaries
NLST CXR Participant Dosimetry: Results and Conclusions

Comparison to other published studies

<table>
<thead>
<tr>
<th>Study or Location</th>
<th>Effective Dose (mSv)</th>
<th>Reference</th>
<th>View</th>
<th>Effective Dose Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Cancer Institute for Prevention, Oncology, and Education (NCI)</td>
<td>0.016</td>
<td>11</td>
<td>Posteroanterior</td>
<td>Coefficient of variation, 39%</td>
</tr>
<tr>
<td>National Lung Screening Trial (NLST)</td>
<td>0.025</td>
<td>21</td>
<td>Posteroanterior</td>
<td>0.054 (0.007) in 0.5 mSv</td>
</tr>
<tr>
<td>NLST-CARR, Japan (2001)</td>
<td>0.037</td>
<td>12</td>
<td>Multi-detector</td>
<td>Variance range, 0.09-0.14 mSv</td>
</tr>
<tr>
<td>National Lung Screening Trial (NLST)</td>
<td>0.037</td>
<td>13</td>
<td>Multi-detector</td>
<td>Variance range, 0.09-0.14 mSv</td>
</tr>
<tr>
<td>Norwegian (2004)</td>
<td>0.046</td>
<td>15</td>
<td>Posteroanterior</td>
<td>Variability not reported</td>
</tr>
<tr>
<td>NLST-CARR, Netherlands (2004)</td>
<td>0.063</td>
<td>13</td>
<td>Multi-detector</td>
<td>Variance range, 0.10-0.16 mSv</td>
</tr>
<tr>
<td>NLST-CARR, Norway (2004)</td>
<td>0.033</td>
<td>13</td>
<td>Multi-detector</td>
<td>Variance range, 0.09-0.14 mSv</td>
</tr>
<tr>
<td>NLST-CARR, Sweden (2001)</td>
<td>0.056</td>
<td>13</td>
<td>Multi-detector</td>
<td>Variance range, 0.10-0.16 mSv</td>
</tr>
<tr>
<td>NLST-CARR, Germany (2000)</td>
<td>0.071</td>
<td>13</td>
<td>Multi-detector</td>
<td>Variance range, 0.10-0.16 mSv</td>
</tr>
</tbody>
</table>

Note: [Reference to the National Scientific Commission on the Effects of Radiation Exposure]

Questions?

Cited and significant references: