PATIENT DOSE COMPARISON FOR INTRAOPERATIVE IMAGING DEVICES USED IN ORTHOPEDIC LUMBAR SPINAL SURGERY

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As the population gets heavier, spinal complications rise.

In order to more accurately assess locations, intraoperative imaging is on the rise.

Clinical protocols are typically borrowed from diagnostic procedures or manufacturer recommendations.

Many of these machines are purchased independently by physicians and orthopedic departments.

Patient dose usually not factored into purchasing decisions due to a lack of information.
• Determine patient radiation dose in a two and four level lumbar fusion
  • Dose determined on five systems available at our institution: MDCT scanner A, two mobile CT units – CT B & CT C, C-Arm D and Flouro E.
1. Male anthropomorphic phantom loaded with 25 MOSFET dosimeters at a number of organ locations.
2. Phantom scanned multiple times, with appropriate clinical protocols, to determine average organ dose per scan.
3. A fat equivalent phantom was used to simulate a patient with overweight and obese BMI, then steps 1 & 2 repeated.
4. A modified effective dose was computed from the measured mean organ doses.
CIRS, INC. MODEL 701-D PHANTOM

- Adult Male Anthropomorphic Phantom
- 160 lb, 5' 8'' (72.6 kg, 1.73 m)
  - BMI: 23.0
    - Normal (18.5 – 24.9)
- Equivalent Materials
  - Lung
  - Soft tissue
  - Bone
INVESTIGATED ORGANS

- Liver
- Spleen
- Active Bone Marrow (T Spine)
- Pancreas
- Kidneys (Left)
- Gall Bladder
- Kidneys (Right)
- Active Bone Marrow (L Spine)
- Stomach
- Colon
- Active Bone Marrow (Pelvis)
- Active Bone Marrow (Sacrum)
- Skin
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### IMAGING PARAMETERS

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MDCT A</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tube Potential (kVp)</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Beam Current (mAs)</td>
<td>150</td>
<td>308</td>
<td>632</td>
</tr>
<tr>
<td><strong>CT B</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tube Potential (kVp)</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Beam Current (mAs)</td>
<td>110</td>
<td>127.6</td>
<td>141</td>
</tr>
<tr>
<td><strong>CT C</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tube Potential (kVp)</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Beam Current (mAs)</td>
<td>128</td>
<td>320</td>
<td>400</td>
</tr>
</tbody>
</table>

* Tube current modulation used

**Due to low dose, dose modeled using commercial software.
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ADIPOSE EQUIVALENT LAYERS

• CIRS, Inc.
• 2x 4 cm thick layers
  • 1 layer – 179 lb (81.2 kg)
  • **BMI: 27.2**
    • Overweight (25 – 29.9)
  • 2 layers – 198 lb (89.8 kg)
  • **BMI: 30.1**
    • Obese (≥ 30)
METHODOLOGY

1. Male anthropomorphic phantom loaded with 25 MOSFET dosimeters at a number of organ locations.

2. Phantom scanned multiple times, with appropriate clinical protocols, to determine average organ dose per scan.

3. A fat equivalent phantom was used to simulate a patient with overweight and obese BMI, then steps 1 & 2 repeated.

4. A modified effective dose metric was computed from the measured mean organ doses.
EFFECTIVE DOSE CALCULATION

\[ ED (mSv) = \sum PVCF_T \times W_T \times PD_T, \text{ where:} \]

- Partial Volume Correction Factor (PVCF\(_T\))
  - “Rule of Nines” for skin
  - Mass percentage for bone marrow
  - Partial volume to point dose for others
- \( W_T \) from ICRP 103 (2007)
- \( PD_T \) is point dose for each organ, determined experimentally
RESULTS

Two Level Inferior (L3-L5)

Two Level Superior (L1-L3)

Two Level (Inferior) Lumbar Fusion

Two Level (Superior) Lumbar Fusion
RESULTS

Four Level Fusion

- MDCT A had significantly higher dose than other four machines
- The variability in patient dose increases with patient weight.
- Maximum dose ≈25 mSv.
FOUR LEVEL FUSION
CONCLUSIONS

Lumbar Fusion Procedure

ED (mSv)

Normal  Overweight  Obese

Four Level Fusion Procedure

MDCT A  CT B  CT C  C-Arm D  Fluoro E
CONCLUSION

- There is a major need for improved protocol optimization in intraoperative imaging.
- Patient dose should be a factor in purchasing decisions for new imaging systems.

Medical physicists need to have a presence in the OR.
SIMPSONS GUIDE TO RADIATION

Bequerel [Bq]
How brightly your Cesium glows

Gray [Gy]
How brightly Cesium will make you glow

Sieverts [Sv]
How many extra eyes will you have after glowing?
BEAM CHARACTERISTICS

\begin{itemize}
  \item $f_{\text{soft tissue}} \left( \frac{cGy}{R} \right) = 0.869 \times \frac{\left( \frac{\mu}{\rho} \right)_{\text{soft tissue}}}{\left( \frac{\mu}{\rho} \right)_{\text{air}}}$
  \item $f_{\text{bone}} \left( \frac{cGy}{R} \right) = 0.869 \times \frac{\left( \frac{\mu}{\rho} \right)_{\text{bone}}}{\left( \frac{\mu}{\rho} \right)_{\text{air}}}$
\end{itemize}
LIVER, SPLEEN, THORACIC SPINE
PCXMC2.0.1.2

STUK – Radiation and Nuclear Safety Authority (Helsinki, Finland)

- Mathematical Phantom
  - Scale w/ mass increase
- Requires accurate input
  - Beam characteristics
  - Field size
  - Field position
- Utilizes above information and:
  - Incident air kerma (mGy)
  - DAP (mGy-cm^2)
  - Entrance Exposure (mR)
  - EAP (R-cm^2)
  - Current-time product (mAs)*