KV Cone Beam CT Imaging Doses and Associated Cancer Risks

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Conflict of Interest Notification

There is no actual or potential conflicts of interest in association with this work
Because tumor moves

Courtesy of Steve Jiang, UCSD
IGRT is widely used clinically

- To improve local-regional tumor control
- To reduce normal tissue complications
Many Definitions of IGRT

“use of modern imaging modalities, especially those incorporating functional or biological information, to augment target delineation”

and

“use of imaging, particularly in-room approaches, to adjust for target motion and positional uncertainty, and, potentially, to adapt treatment to tumor response”
Broad Definition - 6 D’s of IGRT

- Detection and diagnosis
- Delineation of target and organs at risk
- Determining biological attributes
- Dose distribution design
- Dose delivery assurance
- Decipher treatment response through imaging

Image-Guided Treatment Delivery Platforms
kVCBCT is one of the most applied techniques in IGRT

- Good for patient setup, tumor localization, margin reduction & dose calculation
- But the imaging dose is a major concern

Technologies: X-ray, fluoro, CT, MRI, kVCBCT, MVCBCT, PET, PET/CT, 4D-CT, 4D-PET/CT, 4D-MRI, SPECT, IR, US, MRS, and electromagnetic transponders etc.
The more imaging doses

Figure 2. Estimated Number of CT Scans Performed Annually in the United States.
The most recent estimate of 62 million CT scans in 2006 is from an IMV CT Market Summary Report.³

Source: Radiological Physics Center, M.D. Anderson Cancer Center, University of Texas

The higher risk of death from cancer
With even higher risk* for children

Figure 4. Estimated Dependence of Lifetime Radiation-Induced Risk of Cancer on Age at Exposure for Two of the Most Common Radiogenic Cancers.


*Cancer risk assessment is based on BEIR V and ICRP 60, assuming a linear extrapolation of risks from intermediate to low doses.
Conventional CT

- CT is and will remain the primary imaging modality for radiotherapy treatment planning because
  - soft tissue, bony landmarks, DRRs, electron densities

- By far the largest contribution to the radiation exposure, but may be overtaken due to increased CBCT applications

- A variety of scan protocols have been proposed to reduce the CT doses to the patients while maintaining clinically acceptable image quality

KVCBCT

- Widespread applications in the clinic with additional imaging doses often unaccounted for

- Current site-specific scan protocols offered by the manufacturers provide certain dose reduction, but are essentially non-personalized and non-differentiable with no consideration of individual patient being scanned

- So far, no tool available to help clinicians choose appropriate scan settings efficiently to protect patients while maintaining necessary image quality
A wise man once said:

“Don’t use a cannon to kill a mosquito”
A wise man once said: 

“Don’t use a cannon to kill a mosquito”

Why not?
A wise man once said:
“Don’t use a cannon to kill a mosquito”

Why not?

Overkill and collateral damage
A wise man once said:
“Don’t use a cannon to kill a mosquito”

Why not?

Overkill and collateral damage

We need to find a balanced approach to our current kVCBCT practices
Four questions to be addressed

• How large are the kVCBCT imaging doses and how to reduce them?

• How are the kVCBCT imaging doses dependent on patient size?

• How to optimize the kVCBCT scan protocol to keep the imaging doses low while maintaining acceptable image quality?

• How large is the cancer risk associated with the kVCBCT imaging doses?
Monte Carlo Multiple-Source Modeling

(a) multiple-source modeling, (b) validation, and (c) 3D Monte Carlo absolute dose calculations in patient anatomy.
Benchmark of Monte Carlo

<table>
<thead>
<tr>
<th></th>
<th>kVCBCT half-fan pelvis protocol</th>
<th>kVCBCT full-fan high-quality head protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60 kVp 680 mAs</td>
<td>60 kVp 720 mAs</td>
</tr>
<tr>
<td></td>
<td>80 kVp 680 mAs</td>
<td>80 kVp 720 mAs</td>
</tr>
<tr>
<td></td>
<td>100 kVp 680 mAs</td>
<td>100 kVp 720 mAs</td>
</tr>
<tr>
<td></td>
<td>125 kVp 680 mAs</td>
<td>125 kVp 720 mAs</td>
</tr>
<tr>
<td>Measurements (cGy)</td>
<td>0.62</td>
<td>0.65</td>
</tr>
<tr>
<td>Monte Carlo (cGy)</td>
<td>0.61</td>
<td>0.67</td>
</tr>
<tr>
<td>(MC-Mea)/Mea (× 100%)</td>
<td>-1.6</td>
<td>3.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>kVCBCT half-fan pelvis protocol</th>
<th>kVCBCT full-fan high-quality head protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60 kVp 1360 mAs</td>
<td>60 kVp 920 mAs</td>
</tr>
<tr>
<td></td>
<td>80 kVp 340 mAs</td>
<td>80 kVp 180 mAs</td>
</tr>
<tr>
<td></td>
<td>100 kVp 170 mAs</td>
<td>100 kVp 720 mAs</td>
</tr>
<tr>
<td></td>
<td>125 kVp 680 mAs</td>
<td>125 kVp 360 mAs</td>
</tr>
<tr>
<td>Measurements (cGy)</td>
<td>1.16</td>
<td>0.76</td>
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<tr>
<td>Monte Carlo (cGy)</td>
<td>1.19</td>
<td>0.74</td>
</tr>
<tr>
<td>(MC-Mea)/Mea (× 100%)</td>
<td>2.4</td>
<td>-2.0</td>
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</tbody>
</table>
KVCBCT Doses to Prostate Patient

Compared to IMRT, kVCBCT-contributed doses to the prostate, rectum, bladder and femoral heads are 1.7%, 3.2%, 3.2% and 8.4%, respectively while dose to the testes is 400% more.

<table>
<thead>
<tr>
<th>Organs</th>
<th>PO-IMRT 10 MV</th>
<th>kVCBCT 60 kV</th>
<th>kVCBCT 80 kV</th>
<th>kVCBCT 100 kV</th>
<th>kVCBCT 125 kV</th>
<th>kVCBCT full-fan high-quality head protocol 60 kV</th>
<th>kVCBCT full-fan high-quality head protocol 80 kV</th>
<th>kVCBCT full-fan high-quality head protocol 100 kV</th>
<th>kVCBCT full-fan high-quality head protocol 125 kV</th>
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</thead>
<tbody>
<tr>
<td>Prostate</td>
<td>203.3</td>
<td>0.4</td>
<td>1.0</td>
<td>1.8</td>
<td>3.4</td>
<td>0.4</td>
<td>0.9</td>
<td>1.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Rectum</td>
<td>117.3</td>
<td>0.5</td>
<td>1.2</td>
<td>2.1</td>
<td>3.8</td>
<td>0.9</td>
<td>1.8</td>
<td>3.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Bladder</td>
<td>126.4</td>
<td>0.7</td>
<td>1.5</td>
<td>2.4</td>
<td>4.1</td>
<td>0.2</td>
<td>0.6</td>
<td>1.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Testes</td>
<td>0.7</td>
<td>1.1</td>
<td>1.5</td>
<td>2.0</td>
<td>2.9</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Left femoral head</td>
<td>69.1</td>
<td>0.8</td>
<td>2.0</td>
<td>3.3</td>
<td>5.8</td>
<td>0.5</td>
<td>1.2</td>
<td>2.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Right femoral head</td>
<td>67.1</td>
<td>0.8</td>
<td>1.9</td>
<td>3.2</td>
<td>5.6</td>
<td>0.7</td>
<td>1.6</td>
<td>2.9</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Full-fan CBCT usually deposits much less dose to organs (except for rectum) than half-fan mode in prostate patients.
KVCBCT Doses to Prostate Patient

**kVCBCT-contributed doses increase exponentially with photon energy**
Reducing CBCT field significantly cuts doses to testes and other organs
KVCBCT Doses to Children

kVCBCT deposits much larger doses to critical structures in children than in adult, usually by a factor of 2 to 3

<table>
<thead>
<tr>
<th>OARs</th>
<th>kVCBCT half-fan pelvis protocol</th>
<th>60 kV</th>
<th>80 kV</th>
<th>100 kV</th>
<th>125 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testes</td>
<td></td>
<td>1.2</td>
<td>1.6</td>
<td>2.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Liver</td>
<td></td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
<td>4.7</td>
</tr>
<tr>
<td>Kidneys</td>
<td></td>
<td>2.4</td>
<td>3.9</td>
<td>5.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Femur Heads</td>
<td></td>
<td>3.5</td>
<td>5.9</td>
<td>7.7</td>
<td>10.5</td>
</tr>
<tr>
<td>Spinal Cord</td>
<td></td>
<td>1.9</td>
<td>3.7</td>
<td>5.5</td>
<td>8.8</td>
</tr>
<tr>
<td>Brain</td>
<td></td>
<td>1.6</td>
<td>3.2</td>
<td>4.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Eyes</td>
<td></td>
<td>3.3</td>
<td>4.5</td>
<td>5.5</td>
<td>7.7</td>
</tr>
<tr>
<td>Lens</td>
<td></td>
<td>4.7</td>
<td>5.4</td>
<td>6.0</td>
<td>7.8</td>
</tr>
<tr>
<td>Optical Nerves</td>
<td></td>
<td>1.6</td>
<td>3.1</td>
<td>4.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

KVCBCT Doses to Children

Increasing the distances from OARs to kVCBCT field border greatly reduces doses to OARs
Depending on OARs, kVCBCT-induced doses increase linearly or exponentially with photon beam energy.
KVCBCT Doses to Children

The testicular shielding works more efficiently at lower kV energies.
Answer to question #1

- How large are the kVCBCT imaging doses and how to reduce them?
  - 1-12 cGy per scan depending on beam energy kVp, mAs, scan range, scan protocol and OARs
  - Reduce kVp
  - Reduce mAs
  - Reduce scan range
  - Choose appropriate scan protocol
  - Use shielding for more protection of OAR
# Typical Imaging Doses to OARs

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Technique</th>
<th>Dose Range</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elekta</td>
<td>kVCBCT</td>
<td>1 - 6 cGy</td>
<td>1-3</td>
</tr>
<tr>
<td>Siemens</td>
<td>MVCBCT</td>
<td>5.5 - 6.5 cGy</td>
<td>4-5</td>
</tr>
<tr>
<td>Tomotherapy</td>
<td>MV-CT</td>
<td>1 - 4 cGy</td>
<td>6</td>
</tr>
<tr>
<td>Varian</td>
<td>kVCBCT</td>
<td>1 - 12 cGy</td>
<td>7-10</td>
</tr>
</tbody>
</table>

Size-dependent kVCBCT Doses

Head Scan

![Graph a](image-a)

![Graph b](image-b)

<table>
<thead>
<tr>
<th>Tissue</th>
<th>$y_0$</th>
<th>$a$</th>
<th>$b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Head</td>
<td>7.807</td>
<td>-4.619E-2</td>
<td>2.875E-4</td>
</tr>
<tr>
<td>Brain Stem</td>
<td>5.687</td>
<td>-4.120E-2</td>
<td>3.033E-4</td>
</tr>
<tr>
<td>Eyes</td>
<td>3.594</td>
<td>-3.295E-2</td>
<td>2.392E-4</td>
</tr>
<tr>
<td>Lenses</td>
<td>3.624</td>
<td>-3.464E-2</td>
<td>2.417E-4</td>
</tr>
<tr>
<td>Optical Nerves</td>
<td>3.614</td>
<td>-2.043E-2</td>
<td>1.007E-4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tissue</th>
<th>$y_0$</th>
<th>$a$</th>
<th>$b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Head</td>
<td>31.491</td>
<td>-0.746</td>
<td>5.278E-03</td>
</tr>
<tr>
<td>Brain Stem</td>
<td>14.568</td>
<td>-0.226</td>
<td>8.176E-04</td>
</tr>
<tr>
<td>Eyes</td>
<td>28.281</td>
<td>-0.838</td>
<td>6.773E-03</td>
</tr>
<tr>
<td>Lenses</td>
<td>27.893</td>
<td>-0.818</td>
<td>6.515E-03</td>
</tr>
<tr>
<td>Optical Nerves</td>
<td>12.674</td>
<td>-0.263</td>
<td>1.581E-03</td>
</tr>
</tbody>
</table>

Size-dependent kVCBCT Doses

\[ Dose = y_0 + a \cdot e^{-b \cdot \text{weight}} \]

\[ Dose = y_0 + a \cdot e^{-b \cdot \text{HIP}} \]

<table>
<thead>
<tr>
<th></th>
<th>( y_0 )</th>
<th>( a )</th>
<th>( b )</th>
<th>( y_0 )</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Pelvis</td>
<td>3.36</td>
<td>8.65</td>
<td>2.80E-2</td>
<td>5.18E-9</td>
<td>18.47</td>
<td>1.34E-2</td>
</tr>
<tr>
<td>Rectum</td>
<td>3.80</td>
<td>6.96</td>
<td>4.00E-2</td>
<td>1.89</td>
<td>13.81</td>
<td>1.67E-2</td>
</tr>
<tr>
<td>Bladder</td>
<td>4.10</td>
<td>6.83</td>
<td>3.60E-2</td>
<td>1.63</td>
<td>13.56</td>
<td>1.41E-2</td>
</tr>
</tbody>
</table>
Answer to question #2

- How are the kV CBCT imaging doses dependent on patient size?
  - kV CBCT doses to OARs are highly correlated with patient size
  - Weight is primary index for dose assessment
  - Occipital-frontal circumferences (OFC) and hip circumference (HIP) are secondary indexes
  - With empirical functions, a personalized quantitative dose evaluation will be possible without exposing unnecessary radiation to pediatric patients
Imaging Doses vs. mAs and kVp

\[
\ln\left(\frac{D}{D_{\text{default}}}\right) = \ln f(mAs, kVp) = a + b \ln(mAs) + ckVp
\]

<table>
<thead>
<tr>
<th>Fitting of empirical functions</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>Coefficients of determination (R²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-fan</td>
<td>-7.6537</td>
<td>0.9861</td>
<td>0.009710</td>
<td>0.9992</td>
</tr>
<tr>
<td>Full-fan</td>
<td>-7.1082</td>
<td>0.9399</td>
<td>0.009378</td>
<td>0.9975</td>
</tr>
</tbody>
</table>
CBCT Scan Protocol Optimizer

- A conjugated gradient searching algorithm in multi-dimensions has been implemented to minimize an objective function which incorporates mAs and kVp in both dose and image quality components

\[
F_{obj} = \sum_{\lambda \in \text{organs}} \left( u_{\lambda} \frac{D_{\lambda}}{TD_{\lambda}} + v_{\lambda} \frac{D_{\lambda}^{\text{default}}}{D_{\lambda}} \right)
\]

\[
D_{\lambda} = D_{\lambda}^{\text{default}} \cdot f(mAs, kVp)
\]

\[
\ln f(mAs, kVp) = a + b \ln(mAs) + ckVp
\]

Zhang Y, Nath R, Bao S, Deng J, Med Phys 2012 (to be submitted)
CBCT Scan Protocol Optimizer

• Input to optimizer
  - Monte Carlo-calculated mean organ doses due to kVCBCT at default mode in patient CT anatomy
  - User-defined weighting factors for normal tissue sparing and image quality
  - Organ-specific tolerance doses from literature

• Output of optimizer
  - Recommended mAs and kVp settings
CBCT Scan Protocol Optimizer

- Based on user-defined weighting factors, three major scenarios can be generated for each patient:
  - best image quality for soft tissues, but highest doses
  - maximum soft tissue sparing, but worst image quality
  - balanced protocol with much reduced imaging doses and acceptable image quality

- The most appropriate scan protocol for a patient may be the tradeoffs among a variety of factors, and often requires an informed decision from the clinician who is clear about the treatment goal of his/her patient
CBCT Image Quality Analysis

- Usually CNR and SNR, but lacks organ dose info
- Dose-to-noise ratio (DNR) to analyze image quality
  \[ \text{DNR} = \frac{\text{mean organ dose}}{\text{mean background dose}} \]
- The higher the organ dose, the higher the DNR, and the better image quality
- The first time that a dose-based ratio is used for image quality analysis
Image Quality Analysis - DNR
Testing of Optimizer on Catphan

default head protocol
720 mAs, 100 kVp

recommended head protocol
400 mAs, 95 kVp

default pelvis protocol
680 mAs, 125 kVp

recommended pelvis protocol
310 mAs, 108 kVp

doses reduced by 51% and 60% for head and pelvis protocol, respectively, with excellent image quality maintained
# Testing of Optimizer on Patients

<table>
<thead>
<tr>
<th>Pelvis Patients</th>
<th>Scanning Protocols</th>
<th>CBCT half-fan pelvis protocol</th>
<th>CBCT full-fan high-quality head protocol</th>
<th>Head Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td></td>
<td>Rectum</td>
<td>Bladder</td>
<td>Femur</td>
</tr>
<tr>
<td>Age = 3 yrs</td>
<td>Default</td>
<td>7.5</td>
<td>8.6</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>Optimized</td>
<td>1.1</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>(Opt-Def)/Def (× 100%)</td>
<td>-85</td>
<td>-86</td>
<td>-86</td>
</tr>
<tr>
<td>Patient 2</td>
<td>Default</td>
<td>6.6</td>
<td>7.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Age = 6 yrs</td>
<td>Optimized</td>
<td>1.0</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>(Opt-Def)/Def (× 100%)</td>
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<td>-85</td>
<td>-84</td>
</tr>
<tr>
<td>Patient 3</td>
<td>Default</td>
<td>1.2</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Age = 19 yrs</td>
<td>Optimized</td>
<td>0.45</td>
<td>0.34</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>(Opt-Def)/Def (× 100%)</td>
<td>-63</td>
<td>-62</td>
<td>-63</td>
</tr>
<tr>
<td>Patient 4</td>
<td>Default</td>
<td>1.6</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Age = 42 yrs</td>
<td>Optimized</td>
<td>0.30</td>
<td>0.28</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>(Opt-Def)/Def (× 100%)</td>
<td>-81</td>
<td>-81</td>
<td>-81</td>
</tr>
<tr>
<td>Patient 5</td>
<td>Default</td>
<td>1.9</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Age = 69 yrs</td>
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<td>0.40</td>
<td>0.30</td>
<td>0.23</td>
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<tr>
<td></td>
<td>(Opt-Def)/Def (× 100%)</td>
<td>-79</td>
<td>-79</td>
<td>-79</td>
</tr>
</tbody>
</table>
Answer to question #3

• How to optimize the kVCBCT scan protocol to keep the imaging doses low while maintaining acceptable image quality?
  - Organ dose and dose-to-noise ratio of each organ can be incorporated into an optimizer for clinically relevant solution
  - Correlation between clinically acceptable image quality and scan protocol parameters needs to be fine-tuned
  - Different correlations for different kVCBCT imaging devices
KV vs. MV Photons

- **Linear Energy Transfer (LET)**
  
<table>
<thead>
<tr>
<th>Radiation</th>
<th>Linear Energy Transfer, KeV/μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt-60 γ-rays</td>
<td>0.2</td>
</tr>
<tr>
<td>250-kV x-rays</td>
<td>2.0</td>
</tr>
<tr>
<td>10-MeV protons</td>
<td>4.7</td>
</tr>
<tr>
<td>150-MeV protons</td>
<td>0.5</td>
</tr>
<tr>
<td>14-MeV neutrons</td>
<td>Track Avg. 12</td>
</tr>
<tr>
<td>2.5-MeV α-particles</td>
<td>Energy Avg. 166</td>
</tr>
<tr>
<td>2-GeV Fe ions</td>
<td>1,000</td>
</tr>
</tbody>
</table>

- **RBE vs. LET**
  - RBE ranges from 1 to 2 for 40-125 kV photons in CBCT

- **Relative Biologic Effectiveness (RBE)**
  - depends on radiation quality (LET), dose, number of dose fractions, dose rate as well as biologic system

Hall EJ, Radiobiology for the radiologist, 5th ed.
Red Bone Marrow

- Bone and bone marrow doses due to kVCBCT
  - Bone density varies with age and gender
  - Bone marrows at iliac, lumbosacral, and lower pelvic account for >50% of total BM
  - Reducing BM irradiation may reduce CRT toxicity and consequently, improve treatment efficacy

Mell LK et al, IJ ROBP, 1356-65, 2006
Leukemia Risk Attributable to kVCBCT

- Empirical functions proposed to estimate dose deposition to patients due to kVCBCT, based on Monte Carlo study of forty-two patients of various ages and sizes.

An improved Boice’s model developed for customized risk assessment of radiogenic leukemia due to kVCBCT

During a typical RT course, 40 scans of pelvic kVCBCT could lead to increased leukemia risk by 29% to 81%, with higher risk observed for children.

\[
I(D) = \left(a_0 + a_1 D + a_2 D^2\right) \exp\left(b_1 D + b_2 D^2\right)
\]

- \(a_i\) - linear-quadratic induction,
- \(b_i\) - coefficients for exponential term representing a dose-dependent reduction in risk that would result in a downturn of risk at sufficiently high doses (>4 Gy).

\[
RR(D) = \frac{I(D)}{I(0)}
\]

Leukemia Risk Attributable to kVCBCT

- Physical bone density strongly correlated with red bone marrow dose
- Considerable dose overestimation (9%~42%) if the whole bone was used as a surrogate of red bone marrow
- Relative leukemia risk attributable to the 40 pelvic kVCBCT scans varied from 1.29 to 1.82, with higher risks in children
- Personalized assessment of leukemia risk caused by pelvic kVCBCT scans is clinically feasible with proposed empirical functions and an improved Boice’s model
How large is the cancer risk associated with the kVCBCT imaging doses?

- Considerable leukemia risk (29%-82%) is associated with doses to red bone marrows from 40 kVCBCT pelvic scans
- Higher cancer risks for younger patients
- Large uncertainty due to limited number of subjects enrolled
- Benefits of prudent medial imaging procedures at low dose levels outweigh the radiation-induced cancer risks
An initiative of the Alliance for Radiation Safety in Pediatric Imaging

To change practice by increasing awareness of the opportunities to lower radiation dose in the imaging of children

Pause and Pulse: pediatric fluoroscopy imaging
- Pause and child-size the technique
- Use lowest pulse rate possible
- Consider US or MRI when possible

www.imagegently.org
Image Wisely

- Awareness program of ACR, RSNA, AAPM & ASRT

- To change practice by increasing awareness of the opportunities to lower radiation dose in the imaging of adults

- Avoid unnecessary ionizing radiation scans and use lowest optimal radiation dose for necessary studies

www.imagewisely.org
AAPM, ASTRO & RSNA

• CT dose summit (AAPM, RSNA ACR, MITA)
  ➢ An interdisciplinary approach to optimizing image quality and managing patient dose

• Reference CT scan protocols
  ➢ Adult brain perfusion CT:

• Numerous publications
AAPM Position Statement on Radiation Risks from Medical Imaging Procedures

December 13, 2011

The American Association of Physicists in Medicine (AAPM) acknowledges that medical imaging procedures should be appropriate and conducted at the lowest radiation dose consistent with acquisition of the desired information. Discussion of risks related to radiation dose from medical imaging procedures should be accompanied by acknowledgement of the benefits of the procedures. Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the public media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.

AAPM members continually strive to improve medical imaging by lowering radiation levels and maximizing benefits of imaging procedures involving ionizing radiation.
More Comments

• No evidence of a carcinogenic effect for acute irradiation at doses less than 100 mSv or for protracted irradiation of doses less than 500 mSv (1)

• Fears associated with concept of linear no-threshold model and the idea that any dose, even the smallest, is carcinogenic, lack scientific justification (Hendee W, 2011, RSNA)

Conclusions

• KVCBCT imaging doses can be clinically significant and should be incorporated into treatment planning design and decision making

• It is feasible to personalize low-dose kVCBCT for individual patient with acceptable image quality

• More research work is needed to improve the efficiency of kVCBCT and patient safety
  - Better x-ray tube design
  - Better image reconstruction algorithm
  - Better x-ray detector
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Thank You!