Radiation Safety, CT Dose Optimization and Safe Procedures for CT Technologists’

Sven Gallo M.Sc., CRE, RSO
Diagnostic Medical Physicist
ProMedica Health System
Joint Commission Requirement

This training must be completed annually by all CT Technologists’
This will be followed by a post test
CT Radiation Dose

- CT Components
- Radiation Quantities and Dosimetry?
- Why is Radiation Dose an issue?
- Radiation dose optimization techniques for pediatrics and adults
- Are newborns and kids more sensitive to radiation when compared to adults?
- What resources and technology do we have available; where radiation dose can be optimized and lowered?
- Pregnancy and Shielding
Components of a CT Scanner

Ref: GE Healthcare MSW DOCo754292 Rev 2
Radiation Quantities

- **Exposure** (Roentgens) – the intensity of the radiation in the air
- **Absorbed dose** (Rads or Grays) – the amount of energy absorbed in tissue per unit mass
- **Effective dose** (Rems or Sieverts) – biological effectiveness of the dose (1 mSv = 100 mrem)

1 R ~ 1 rad ~ 1 rem (for x-rays)
CT Dosimetry

- $\text{CTDI}_{100}$
- $\text{CTDI}_W$
- $\text{CTDI}_{VOL}$
- DLP
- Effective Dose
Review of CT Dosimetry

- CTDI stands for CT Dose Index
- CTDI\textsubscript{100} is measured by the physicist annually with a 32 cm and 16 cm diameter PMMA phantom (PMMA is the type of plastic that makes up this phantom), using 100 mm pencil chamber.

- The CTDI\textsubscript{Weighted} is then calculated as:

\[
CTDI_w = \frac{1}{3} CTDI\textsubscript{100,center} + \frac{2}{3} CTDI\textsubscript{100,edge}
\]
Review of CT Dosimetry

- $CTD_{volume}$ is lastly calculated by dividing the $CTD_{weighted}$ by the pitch.

\[ CTD_{vol} = \frac{CTD_{w}}{Pitch} \]

- Pitch is defined as the ratio of table travel per 360° rotation ($I$) to the beam width ($N \times T$)

\[ Pitch = \frac{I}{(N \times T)} \]

- Pitch of 0.5 results in doubling the CT dose
- Pitch of 2.0 results in half the CT dose
Review of CT Dosimetry

Q – What is the pitch if table increment (I) per 360 degree rotation is 60 mm and beam width (N x T) is 40 mm?

\[ \text{Pitch} = \frac{I}{(N \times T)} \]

- 60 mm / 40 mm = 1.5
- So the pitch is 1.5
Review of CT Dosimetry

- DLP is the Dose Length Product
  - DLP is derived by multiplying the total scan length traveled (in cm) by the CTDI\textsubscript{Volume} (in mGy) and is then converted into Effective Dose (mSv) by multiplying the DLP with a k-factor

- CTDI\textsubscript{Vol} is the most often used dose metric to assess the technical settings of a given scan protocol (i.e., kVp, mA, rotation time, detector configuration, and pitch)

- Remember that CTDI\textsubscript{Vol} number in mGy (milliGray) is the measured value to our 32 cm or 16 cm diameter phantom, not specific to patient size and dose.
Effective Dose

- Effective dose attempts to quantify the potential biological effectiveness of the dose by taking into account the radiosensitivity of the body part being exposed.

- Effective Dose = DLP x k
  - where k is a body part and age specific conversion factor

<table>
<thead>
<tr>
<th>Region of Body</th>
<th>0 year old</th>
<th>1 year old</th>
<th>5 year old</th>
<th>10 year old</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and neck</td>
<td>0.013</td>
<td>0.085</td>
<td>0.0057</td>
<td>0.0042</td>
<td>0.0031</td>
</tr>
<tr>
<td>Head</td>
<td>0.011</td>
<td>0.067</td>
<td>0.0040</td>
<td>0.0032</td>
<td>0.0021</td>
</tr>
<tr>
<td>Neck</td>
<td>0.017</td>
<td>0.012</td>
<td>0.011</td>
<td>0.0079</td>
<td>0.0059</td>
</tr>
<tr>
<td>Chest</td>
<td>0.039</td>
<td>0.026</td>
<td>0.018</td>
<td>0.013</td>
<td>0.014</td>
</tr>
<tr>
<td>Abdomen &amp; pelvis</td>
<td>0.049</td>
<td>0.030</td>
<td>0.020</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Trunk</td>
<td>0.044</td>
<td>0.028</td>
<td>0.019</td>
<td>0.014</td>
<td>0.015</td>
</tr>
</tbody>
</table>
Example of Effective Dose Calculation

Q: - What is the effective dose for an adult abdomen scan where the CTDIvol is 20 mGy and total length traveled by the x-ray path was 25 cm?

DLP = 20 mGy x 25 cm = 500 mGy-cm

k = 0.015 for Adult Abdomen (chart below)

Then, DLP x k = effective dose

A: - Effective Dose = 500 x 0.015 = 7.5 mSv

<table>
<thead>
<tr>
<th>Region of Body</th>
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<td>0.014</td>
<td>0.015</td>
</tr>
</tbody>
</table>
CTDI$_{vol}$ Limits by ODH (Ohio Department of Health) and ACR

<table>
<thead>
<tr>
<th>Examination</th>
<th>Pass/Fail Criteria CTDI$_{vol}$ (mGy)</th>
<th>Reference Levels CTDI$_{vol}$ (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Head</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>Adult Abdomen</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Pediatric Head (1 year old)</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Pediatric Abdomen (40-50 lb.)</td>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>
Example of a CT Dose Report that should always be sent to PACS, for each patient

<table>
<thead>
<tr>
<th>Series</th>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTDIvol (mGy)</th>
<th>DLP (mGy·cm)</th>
<th>Phantom cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scout</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Axial</td>
<td>1157.500–1121.957</td>
<td>68.44</td>
<td>278.02</td>
<td>Head 16</td>
</tr>
<tr>
<td>2</td>
<td>Axial</td>
<td>1116.750–120.277</td>
<td>50.21</td>
<td>509.84</td>
<td>Head 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Total Exam DLP:</strong> 787.86</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1/1
Radiation from CT scans linked to cancers, deaths

Updated 12/14/2009 8:41 PM | Comments 187 | Recommend 63

Weighing the CT threat

THEIR popularity as efficient, relatively cheap, and quick medical diagnostic tools that produce 3D pictures may make it difficult for doctors to think outside the CT scan. But for the extended welfare of their patients, especially pediatric ones, physicians should start exercising restraint when ordering the fast, souped-up scans that can deliver 50 to 100 times more radiation than conventional X-rays.

A dramatic growth in the use of CT scans has brought an equally dramatic increase in exposure to radiation and its associated risks of all CT scans ordered may be nonessential. And if that many CT scans can’t be justified by medical need, they argue, perhaps 20 million adults and 1 million children in the United States are being irradiated.

In a few decades, a number of persons who regularly get CT scans might have a higher risk of cancer. There is even a cost to radiation when it comes to the cost of radiation. The tests are often put off for x-rays and CT scans, with a higher risk because of the amount of radiation from the scans.

How Dangerous Are CT Scans?
By Catherine Guthrie | Friday, June 27, 2008

Do you need that CT scan?
The popular imaging technology carries a worrisome cancer risk. How to avoid being overexposed.
Why is Radiation Dose an issue?

- As we can see, the largest contributor to radiation exposure comes from CT scans at 49%, when compared to all other radiology modalities.
Why is Radiation Dose an issue - Utilization of CT Scans

- There has been a rapid increase in the utilization of CT scans from 1980’s to today’s date! **Over 80 Million scans performed in the US in 2011**
Radiation Dose Optimization

- Concern issues with CT exposure
  - Abdominal CT is equivalent to 200 chest x-rays on a CT Scanner without Dose Reduction Technology
- Many of our newer CT scanners have dose reduction technology (ASiR – Adaptive Statistical Iterative Reconstruction, we will see slides in more detail of this)
- These technologies utilize reconstruction software, which allows for dose reduction on all types of scans performed
  - About a 20% dose reduction for Head CT
  - About a 30 to 40% dose reduction for Abdomen/Pelvis CT
Why is Radiation Dose an issue?

At the time of the Oct. 8, 2009 Initial Communication, the FDA knew of 206 patients exposed to excess radiation at one facility, the Cedars-Sinai Medical Center. As of October 26, 2010, the agency is aware of approximately 385 patients from six hospitals who were exposed to excess radiation during CT brain perfusion scans.

CT Overexposure can cause deterministic effects if doses exceed 2000 mGy (i.e., brain perfusion scans)
Why is Radiation Dose an issue?

- Most of our scanners, but not all, that have the XR-29 compliance package will also have Dose Check.
- This dose check will indicate an alert value of a CTDI$^\text{vol}$ of greater than 1000 mGy (FDA Recommendation), which is half of the 2000 mGy dose level, where the onset of skin injury will happen.
Dose Alert Example

- This is password protected. The superuser/lead CT tech would have this password to override.
- If this alert value pops-up, please see your lead tech and have the physicist/radiologist involved **prior to scanning the patient.**
- Effective dose is the best metric to cross-compare radiation risk of various types of radiology exams

<table>
<thead>
<tr>
<th>Examination</th>
<th>Effective Dose (mSv)</th>
<th>Effective Dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoral dental x-rays</td>
<td>0.005</td>
<td>0.5</td>
</tr>
<tr>
<td>Extremity x-ray</td>
<td>0.005</td>
<td>0.5</td>
</tr>
<tr>
<td>2-view chest x-ray</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>C-spine x-ray</td>
<td>0.2</td>
<td>20</td>
</tr>
<tr>
<td>Mammography</td>
<td>0.4</td>
<td>40</td>
</tr>
<tr>
<td>Abdomen x-ray</td>
<td>0.7</td>
<td>70</td>
</tr>
<tr>
<td>L-spine x-ray</td>
<td>1.5</td>
<td>150</td>
</tr>
<tr>
<td>Head CT</td>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>Upper GI exam</td>
<td>6</td>
<td>600</td>
</tr>
<tr>
<td>Nuclear bone scan</td>
<td>6</td>
<td>600</td>
</tr>
<tr>
<td>Barium enema exam</td>
<td>8</td>
<td>800</td>
</tr>
<tr>
<td>Abdomen CT</td>
<td>8</td>
<td>800</td>
</tr>
<tr>
<td>Nuclear cardiac rest/stress test</td>
<td>10</td>
<td>1000</td>
</tr>
<tr>
<td>PCTA</td>
<td>15</td>
<td>1500</td>
</tr>
<tr>
<td>Coronary angiography CT</td>
<td>16</td>
<td>1600</td>
</tr>
<tr>
<td>Pelvic vein embolization</td>
<td>60</td>
<td>6000</td>
</tr>
<tr>
<td>TIPS</td>
<td>70</td>
<td>7000</td>
</tr>
</tbody>
</table>
What can we do to optimize (lower) Radiation Dose?

- **Use Tube Current Modulation**
  - Basic Idea:
    - System will choose proper mA off the scout scan *(must set-up proper iso-centering of patient!)*
    - System will increase tube current (mA) for more attenuating area (i.e., Lateral views)
    - System will decrease tube current (mA) for less attenuating area (i.e., A/P views)
  - **Main GOAL** = Reduce dose to patient while maintaining optimal image quality
What can we do to optimize Radiation Dose – Use Tube Current Modulation

- As we can see, dose is increased through thicker body parts which cause more attenuation (i.e., shoulder/abd/pelvis) and is reduced through thinner body parts or less attenuating body parts (i.e., lungs).
What can we do to optimize Radiation Dose – Use Tube Current Modulation

- The operator has to select the correct protocol with the already built in Tube Current Modulation parameters
- There are specific age/weight based protocols for **pediatrics**
- These protocols are set up by applications and/or lead techs with the oversight of the radiologist/physicist, to ensure proper image quality and dose are within a tolerance range
- Using the patient scout, the system computes the required mA to be utilized, based upon the selected Noise Index presets
- Image quality parameters have different names by each vendor and are as follows:
  - GE is Reference Noise Index
  - Toshiba is Reference Standard Deviation
  - Siemens is Quality Reference mAs
  - Philips is Reference Image Acquisition

Z axis and X-Y axis modulation

- Most current systems have built in auto modulation both in the z axis and x-y axis
- Auto mA setup on GE units

<table>
<thead>
<tr>
<th>AutomA Off/On</th>
<th>Example:</th>
<th>380</th>
<th>Click mA to open the mA Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>380</td>
<td>AutomA Off Fixed mA at 380</td>
</tr>
<tr>
<td></td>
<td></td>
<td>380</td>
<td>AutomA On Max mA at 380 Noise Index at 22.10</td>
</tr>
</tbody>
</table>

Ref: GE DOC0871895 Rev. 4
Noise Index

- Noise index is a parameter that controls the amount of allowed noise in the image.
- A higher Noise Index correlates to noisier image and lower patient dose.
- A lower Noise Index correlates to a less noisy image at the cost of a higher patient dose.
- On GE systems:
  - Noise Index per step = 5%.
  - mA per step = 10%.
Reference Noise Index

- Reference Noise Index is the Baseline index for that given protocol.
- Any changes to the Dose Steps or Noise Index will be referenced to this value.
Auto mA

- *Auto mA will be disabled if there is no scout OR if the patient orientation for the current series does not match the orientation of the scout*

Summary:
- Auto mA can modulate the mA along the Z-Axis
Smart mA

- Smart mA and Auto mA allows the system to adjust mA along all 3 Dimensions of the patient (X-Y-Z) axis.
- Smart mA modulates 4 times per rotation
Smart mA

As we can see, the dose is lowered more when using the Smart mA and Auto mA (X-Y-Z) Axis modulation.

<table>
<thead>
<tr>
<th>Images</th>
<th>CTDIvol mGy</th>
<th>DLP mGy·cm</th>
<th>Dose Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-73</td>
<td>5.94</td>
<td>234.94</td>
<td>97.40</td>
</tr>
</tbody>
</table>

Dose with AutomA

<table>
<thead>
<tr>
<th>Images</th>
<th>CTDIvol mGy</th>
<th>DLP mGy·cm</th>
<th>Dose Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-73</td>
<td>5.03</td>
<td>198.60</td>
<td>97.40</td>
</tr>
</tbody>
</table>

Dose with AutomA & SmartmA

<table>
<thead>
<tr>
<th>Images</th>
<th>CTDIvol mGy</th>
<th>DLP mGy·cm</th>
<th>Dose Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-73</td>
<td>5.03</td>
<td>198.60</td>
<td>97.40</td>
</tr>
</tbody>
</table>

- SmartPrep: 43.95 mGy, 43.95 mGy·cm
- Projected series DLP: 278.89 mGy·cm
- Accumulated exam DLP: 1934.43 mGy·cm

- SmartPrep: 43.95 mGy, 43.95 mGy·cm
- Projected series DLP: 242.55 mGy·cm
- Accumulated exam DLP: 1934.43 mGy·cm
Auto mA and Smart mA

Lower Dose

No Dose Reduction

Smart mA

Auto mA

Auto mA and Smart mA
Auto mA and Smart mA

Summary

- Smart mA adds modulation along the X-Y Axis to the Z axis modulation of Auto mA.
- This modulation (Smart mA) lowers the dose even more as we have seen in the previous slide.
- The amount of noise that is acceptable is carried out by the Noise Index.
- Noise Index values should only be adjusted by the superuser/lead tech in conjunction with the radiologist/physicist.
Dose Modulation Definitions

As we can see, different vendors have different names for the Automatic mA controls (Dose Modulation):

<table>
<thead>
<tr>
<th>Feature</th>
<th>GE LightSpeed VCT</th>
<th>Philips Brilliance CT 64</th>
<th>Siemens Sensation 64</th>
<th>Toshiba Aquilion 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic mA control software</td>
<td>SmartmA</td>
<td>Doseright ACS, Doseright DOM (D DOM, Z DOM) Reference image</td>
<td>CARE Dose 4D</td>
<td>SureExposure</td>
</tr>
<tr>
<td>Method for operator control of AEC</td>
<td>Noise index</td>
<td>Single or dual scout image</td>
<td>Reference mA</td>
<td>Reference mA</td>
</tr>
<tr>
<td>Method for system control of mA</td>
<td>Single or dual scout image, online control</td>
<td>Single or dual scout image</td>
<td>Single scout image, online control</td>
<td>Standard deviation Single or dual scanogram</td>
</tr>
<tr>
<td>mA adjustment for patient size</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>mA adjustment along the z axis</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>mA modulation during rotation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 2: Features of AEC Systems in a 64-section CT Scanner

Source.—Modified from reference 14.
Note.—mA = milliamperage.

Ref: Radiation Dose Modulation Techniques in the Multidetector CT Era: From Basics to Practice pg 1457
Proper Centering is **VERY Important**

- If the patient is not at ISOCENTER, the system will recognize this off-centering as a different size of the actual patient size. **Tube current modulation** that we just spoke about **REQUIRES PROPER CENTERING OF THE PATIENT IN THE GANTRY!**

ASiR

- ASiR is a reconstruction method that is a lot less sensitive to Noise when compared to the traditional Filtered Back Projection processing
- By reducing the mA, image quality will have higher noise
- ASiR will then reconstruct these noisy images and make it a diagnostic quality image for proper/accurate clinical interpretation
ASiR and Veo dose reduction Data of CHEST CT

When comparing a traditional CT Scanner, ASiR and Veo will decrease radiation dose to patients.
ASiR and Veo dose reduction Data
ABDOMEN CT
What Can I do as a Technologist?
"Child-size" the radiation delivered to your pediatric patients!
One size does not fit all!

1. There's no question: CT helps us save kids' lives. But when we image, radiation matters!

2. Children are 5 times more sensitive to radiation when compared to a 60 year old adult.
   (NCRP 168)

3. What we do now lasts their lifetimes.

4. So when we image, let's image gently: More is often not better.

5. When CT is the right thing to do: Child size the kVp and mA.

6. One scan (single phase) is often enough.

7. Scan only the indicated area.

If you have not done so yet, please follow the reference link below and take the pledge.
What are the risks?

5% per Sievert = 0.05% per milliSievert risk for radiation-induced cancer mortality for population.

Pediatrics have higher risk factor due to increased radiosensitivity.

5% per Sievert which is 0.05% per 10 mSv is typically quoted. Remember, about 10 mSv is one single abdomen CT scan.

Natural cancer risk in ones lifetime without radiation is ~ 40%.

Fig. 2.3. Lifetime attributable risk for cancer mortality as a function of gender and age-at-irradiation after a uniform whole-body dose of 1 Gy (derived from Table 12.D.2 in NA/NRC, 2006). For comparison, the nominal 5% per sievert risk factor for cancer mortality that is often applied to the general population is indicated by the dotted line. Lifetime attributable risk as a function of gender and age-at-irradiation for specific organs and tissues are found in Table 12.D.1 (for incidence) and Table 12.D.2 (for mortality) in NA/NRC (2006).
Pediatrics and Risk

- As we can see, infants/pediatrics are more sensitive to radiation, as they have a longer life to live. Chances of carcinogenesis have a longer time to mutate and take place in the pediatric population.
- For this reason, careful attention shall take place when choosing the correct Pediatric protocols.
Pediatrics

- Modern CT scanners have pediatric protocols
- GE has a color coded and weight based categories on the Broselow-Luten system
- Proper pediatric protocols need to be utilized, to achieve lowest dose while maintaining optimal image quality.
Image wisely, Image Gently and Choosing Wisely

imagewisely.org
Get the facts about radiation safety in adult medical imaging. Download a printable “Patient Medical Imaging Record” to keep track of your medical imaging procedures. Also watch important public service announcements and learn about questions you should ask your doctor.

imagegently.org
Image Gently® educates parents and caregivers on different types of medical imaging for children and radiation protection regarding these exams. Through the site, you can download free, printable brochures, PowerPoint presentations, practice quality improvement projects and an Image Gently Medical Imaging Record to keep track of a child’s imaging care.

choosingwisely.org
The Choosing Wisely® campaign offers 45 evidence-based recommendations to physicians and patients to help them make wise choices about patient care, including five medical imaging procedures for patients and physicians to discuss.
Repeating CT Scans Due to Artifacts, Patient Motion etc.

- Technologists’ should check with the interpreting physician (radiologist) if there is a concern about the possibility of repeating a CT scan (due to patient motion, artifacts, etc.)
- This decision shall be made by the radiologist, as a repeat may not be necessary and warranted in some cases.
Pregnancy and Shielding

- 30% of all trauma patients are females in childbearing age (10-50 years old)
- Nearly 15% of female trauma victims may be pregnant at the time of injury
- Follow your current hospital policy on pregnancy screening of all childbearing age patients.
- Shielding the patient over the fetus is recommended as long as it does not interfere with the clinical region of interest
  - If the lead shielding is in the primary x-ray beam, it will only increase the dose by maxing out the mA modulation
  - Careful placement of shield and scanning shall take place
  - Most of the scatter radiation that the fetus receives is from internal scatter. This internal scatter is therefore not shielded by the lead apron

Pregnancy and CT Scans

- Fetus is most sensitive at 2 to 15 weeks post conception
- Radiation at this time can cause smaller head size (microcephaly) and mental retardation
- Gross congenital malformations
- Based on risk data from human in-utero exposures, the absolute risks of fetal effects are small at conceptus doses of 100 mGy and negligible at doses of less than 50 mGy
- Typical fetal dose when primary x-ray beam is over the fetus is typically less than 50 mGy
Pregnancy and Radiation

- How do we know this?
- The historical data we use comes from the Atomic bomb survivors irradiated in utero from higher doses.

Hall EJ. Radiobiology for the Radiologist, LWW, 2000
Pregnancy and CT Scans

- Pregnancy Summary
  - Benefits of diagnostic imaging should be weighed as part of the risk assessment for pregnant patients
  - If the fetus is outside the primary x-ray beam, the radiation dose to the fetus would come from scatter only
  - This scatter radiation to the fetus is often considered negligible, but still not zero
  - If the fetus needs to be in the primary x-ray beam, precise analysis is required and optimal lowered techniques shall be used (consult with radiologist or physicist)
Bismuth Shielding

- Bismuth shields are no longer recommended as this can interfere with the scanning region of interest and can cause artifacts/increase dose if not used properly. See below statement from AAPM (American Association of Physicists in Medicine)
- Most of our CT scanners have dose reduction algorithms (i.e., ASiR) and tube current modulation, which will reduce dose in the first place

**AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT scanning**

**Policy Text:** Bismuth shields are easy to use and have been shown to reduce dose to anterior organs in CT scanning. However, there are several disadvantages associated with the use of bismuth shields, especially when used with automatic exposure control or tube current modulation. Other techniques exist that can provide the same level of anterior dose reduction at equivalent or superior image quality that do not have these disadvantages. The AAPM recommends that these alternatives to bismuth shielding be carefully considered, and implemented when possible.

Ref: https://www.aapm.org/publicgeneral/BismuthShielding.pdf
It is your responsibility to report to the Radiation Safety Officer (RSO) any unsafe conditions or radiation safety incidents.

Additionally, any questions pertaining to radiation safety and regulatory compliance can be directed to the RSO.

Radiation Safety Officer
Sven Gallo M.Sc.
Diagnostic Medical Physicist
Phone 419-291-4183
email: sven.gallo@promedica.org