THE ART OF SHIELDING –
A TACTICAL PERSPECTIVE ON
CT FETAL DOSE REDUCTION TECHNIQUES

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FINANCIAL DISCLOSURE

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OBJECTIVE

➤ Review the current practice guidelines on shielding of pregnant patients undergoing CT scans.

➤ Discuss the benefits and disadvantages of shielding in the context of modern CT scanners with automatic exposure control systems (AECs).

➤ Provide comprehensive review of the current effective fetal dose reduction techniques.

➤ Develop practice guidelines for residents and technologists to improve the quality of fetal dose reduction techniques being performed on pregnant patients.
To limit radiation exposure to pregnant patients, “ACR-SPR Practice Parameter for Imaging Pregnant Women with Ionizing Radiation” States:

• Discuss with the referring physician the indications and necessity for exam
• Consider alternative non-ionizing imaging procedures like US or MRI
• If CT is needed, minimize maternal and fetal dose by:
  – Limiting the number of CT series
  – Using AEC and Tube Current Modulation to give optimized dose to each image slice
  – Using dose reducing Iterative Reconstruction
  – Other useful techniques not mentioned in the ACR document include
    • Reducing the scan length (5 cm reduction in caudal extent may reduce fetal dose by up to 50% in CTA chest)
    • Reducing the kVp in contrast studies of thinner patients
• Providing lead shielding to wrap the pelvis in non-pelvic CT may help the emotional well-being of the patient, but the dose to the uterus (primarily from internal scatter radiation is not materially altered.
Fetal Doses in CTA Chest from literature review:

- Reported fetal doses vary widely depending on trimester and CT technique, but are generally in the range of **13 – 230 uGy**

**Deterministic Fetal Risk in CTA Chest:**

- Deterministic risks (malformations, diminished IQ) from radiation to fetus are generally considered to have a threshold of **50 mGy (50,000 uGy)**
- Therefore negligible risk from CT A chest.

**Stochastic Fetal Risk in CTA Chest:**

BEIR VII estimates the risk of childhood malignancy secondary to in-utero ionizing radiation exposure to be no higher than 0.004% per 100 uGy

Thus **13 uGy** represents increased risk of CA <0.0005%
**230 uGy** represents increased risk of CA <0.009%

Note: background rate of childhood malignancy is about 0.2% - 0.3%
Reduction of Fetal Dose by Use of Lead Apron Shielding:

- Several reports in the literature indicate that the use of a lead apron on the pelvic area of patient undergoing CTA chest can reduce the dose to the fetus by approximately:
  - 35% for an anterior only lead apron
  - 50% for a wrapped lead apron
- The lead apron is attenuating the external radiation scatter from the collimator and from x-ray tube leakage.

Risk Reduction by Use of Lead Apron Shielding:

- Theoretical excess risk of childhood malignancy will also be reduced:
  - 35% for an anterior only lead apron
  - 50% for a wrapped lead apron
  
  but recall the maximum excess risk was only 0.009% without a lead apron compared to background rate of 0.2% - 0.3%

- Very small risk benefit, but may improve patient’s emotional well-being.
Possible Problems in Implementing Lead Apron Shielding in CT:

- When using AEC and Tube Current Modulation, the mAs at each slice is determined by the attenuation properties of the patient measured in the scout view scan.
- If the lead apron is seen on the scout scan, it may cause the AEC or TCM to choose a non-optimum mAs for some or all slices, depending on CT manufacturer, AEC/TCM settings, and software level.

Is the Lead Apron Frequently seen on the Scout View?

- At our institution, all known pregnant patient CTA chest studies over (2014-2015) were reviewed. It was found that in 100% of the studies, the lead apron was visible on the scout view, and 65% of the studies also included lead in the scan field. (see next slide for case examples)
EXAMPLES OF IMPROPER SHIELDING PERFORMED BY TECHNICIANS

Including shielding in the scout and scanned field can significantly increase dose to fetus and to mother, as well as result in slices with unacceptable image quality – Increased Risk with No Benefit. (see slide 10 for estimated radiation dose. This lead shield is also incompletely wrapped around patient (depicted by star), which reduces the expected effectiveness by 15%.)
Testing the Effect on Patient Dose of Lead Apron in Scout:

- Philips Brilliance 64 slice CT with V3.7.1 software
- Tissue equivalent anthropomorphic chest phantom abutted to acrylic abdomen/pelvis phantom with real skeletal bones
- PE protocol; DoseRight AEC ON, Z-DOM TCM ON. 120 kVp, 150 mAs/slice reference dose.

Chest and Abdomen Phantom – no shield

Wrapped shield over abdomen
A Lead shield *not* included in either scout or scan field
mA at breast level: 64
mA at diaphragm: 77
Estimated Dose at uterus: ~100 uGy

B Lead shield in the scout but *not* included in the scan field
mA at breast level: 49
mA at diaphragm: 90
Estimated Dose at uterus: ~60 uGy

C Lead shield included in both the Scout and scanning field
mA at breast level: 103
mA at diaphragm: 146
mA at uterus: 500=max
Measured Dose at uterus: ~2300 uGy

- Lead apron in scout but not scan (B) does alter dose levels
- Inadvertent scan into lead (C) raises all doses and *gives high dose to fetus*
FETAL DOSE REDUCTION TECHNIQUES TO BE CONSIDERED

1. **Use 0.5 mm lead equivalent or greater shielding wrapped around the patient’s abdomen and pelvis.** However, ensure that no part of the shielding is ever included in the scout scan. Main benefit includes comforting the patient with a secondary benefit of up to 50% reduction in fetal dose.

2. **Limit the scan length to the region of interest**, which both reduces the amount of internal scatter produced as well as increases the distance from the primary beam to the fetus.

3. **Use iterative reconstruction** to lower the patient and fetal dose by 25-50%, while maintaining image quality.

4. **Use reduced kVp with an appropriately low mAs**, especially with iodine contrast and thinner patients, to produce an acceptable CNR image while lowering both patient and fetal dose.
CONCLUSIONS

Understanding the principles of dose reduction techniques is imperative in improving patient safety without compromising the qualities of the CT exams. Inappropriate application of dose reduction techniques could result in higher radiation dose to the fetus.

Developing comprehensive guidelines for residents and technologists is essential in ensuring that dose reduction techniques are being carried out to the fullest advantage.