

Minimizing Radiation in EOS

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Ionizing Radiation

- Ionizing radiation is defined as high energy radiation that can cause ionization in exposed tissues
- X rays are a form of electromagnetic radiation whose photons are powerful enough to cause ionization

Radiation Dose Measurement

- Absorbed dose
- Based on energy absorption in tissues
 - Measured in milligray (mGy)
- Effective dose
- Takes into account biological effect of absorbed dose on target tissue
 - Measured in millisievert (mSv)

Nomenclature

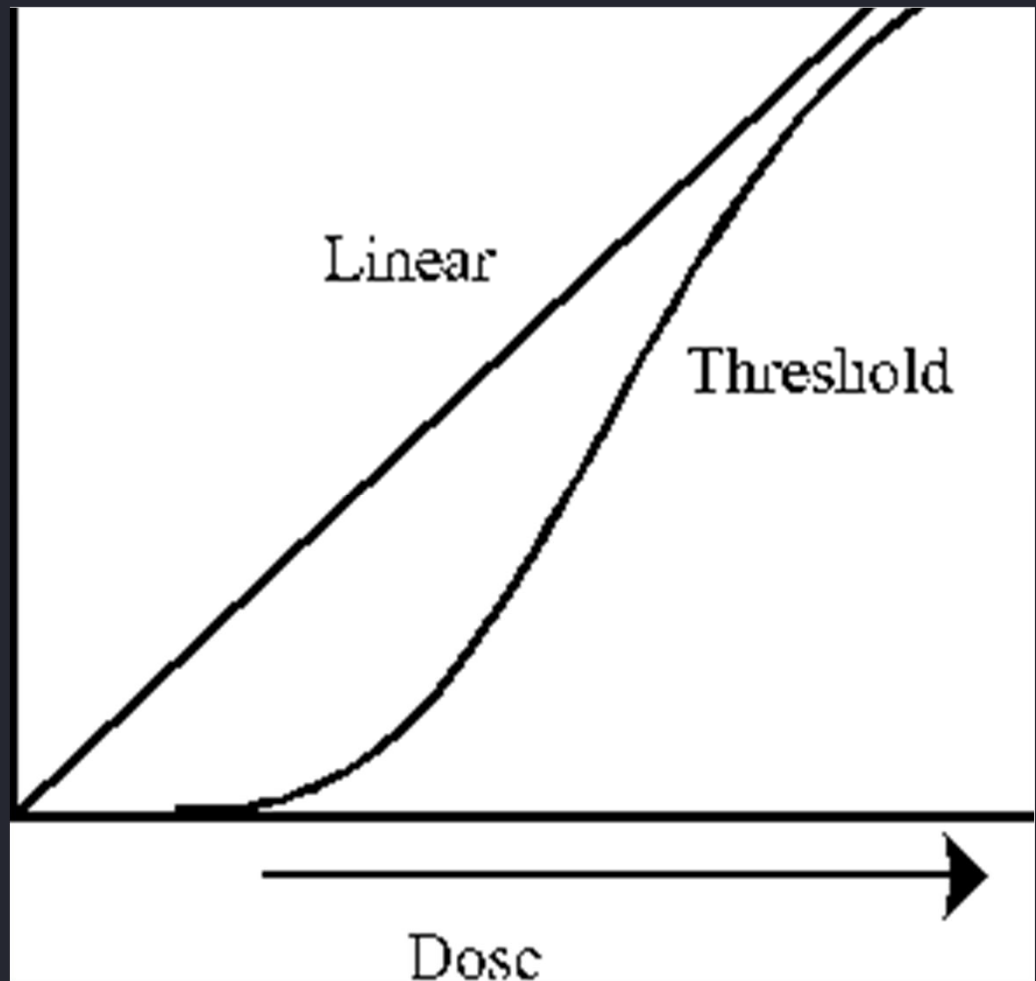
- 1 Gray= the absorption of 1 joule of energy in 1 kg of tissue
- Sievert is Gray multiplied by a quality factor which takes into account the biological effects on specific tissues
- 1 Gray= 100 Rad (radiation absorbed doses)
- 1 Sievert= 100 Rem (radiation equivalent Man)

Deterministic vs. Stochastic

- Deterministic effects
 - Determined by dose
 - Nonrandom
 - No effect below threshold
 - Generally high non-medical doses
 - Burns
 - Cataracts
 - Hair loss
 - Death
- Stochastic Effects
 - Not dose related
 - Random
 - No threshold?
 - Generally low dose
 - severity independent of dose
 - Long latent effect
 - Carcinogenesis
 - Genetic effects

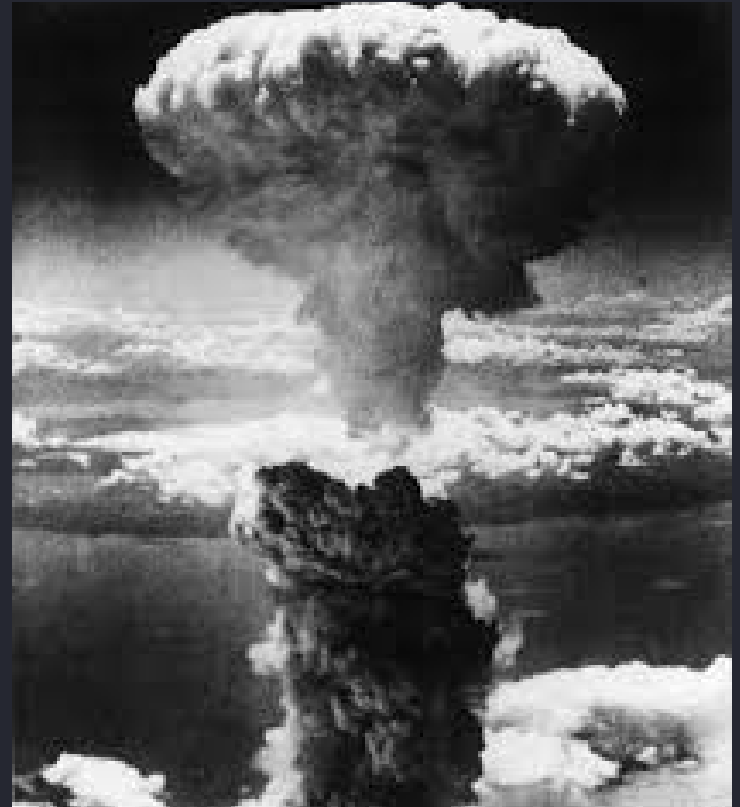
The Question

- Is there a threshold?



What is Evidence for No Threshold

- Data from Hiroshima periphery
 - Cancer rates increased in those exposed to lower levels of radiation
- Average exposure was high relative to diagnostic radiation dose and was administered all at once



Australian Study

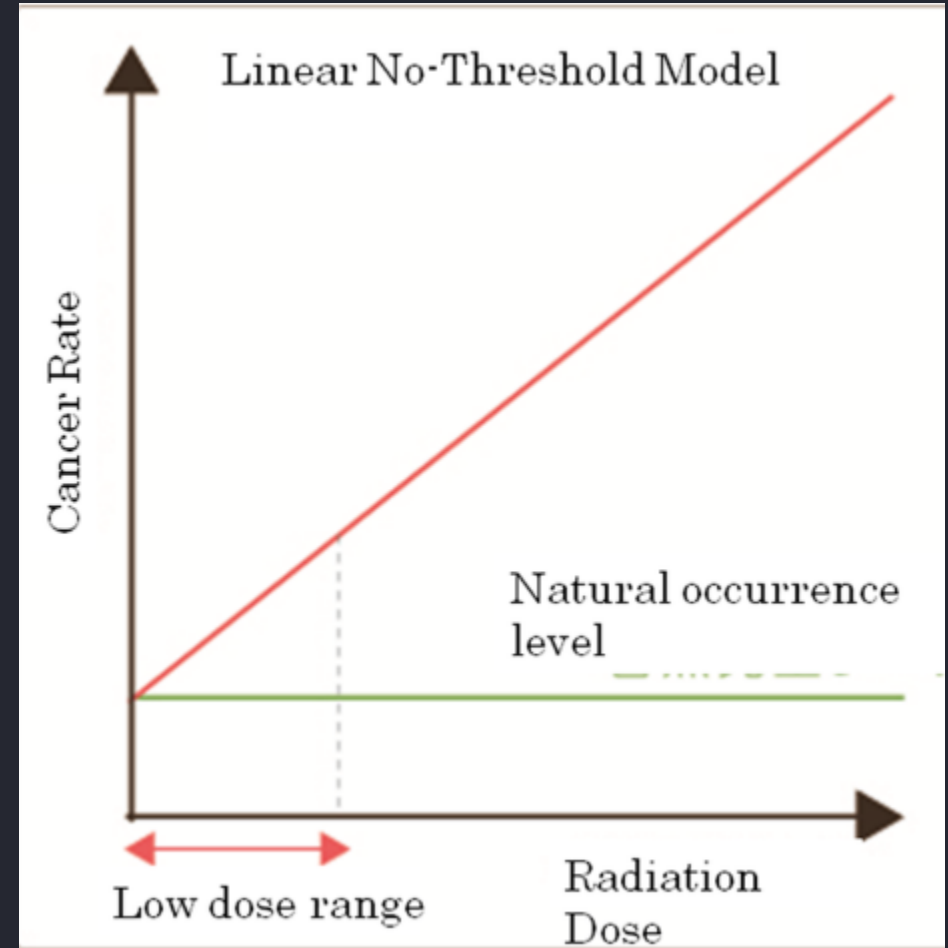
- N= 680,000
- Only exposure is diagnostic radiation
- Average dose 4 mSv
- 9.38 excess cancers per 100,000 people

CONCLUSION: radiation even at low dose diagnostic radiation levels causes cancer

Mathews et al BMJ
2013

Most Accepted Model

- Linear No Threshold is the most accepted model
- Note that background cancer risk and cosmic radiation confounds analysis



Sievert in Context

- USA background dose at sea level= 3 mSv/year
- Denver= 2 x sea level dose (6mSv)
- Flight from NYC to Seattle = 26 mSv
- Flight from DC to LAX= 17mSv

Sievert in Context

- Set of dental films = 5-10 μSv
- Estimated maximum dose to those evacuated from close around Fukushima = 68 mSv
- Highest dose to worker responding to Fukushima crisis = 0.67 Sv
- Average fatal dose Goiania incident 4.5-6 Sv

Sample Doses

• 3 view ankle	.0015 mSv	1/14 cxr
• 2 view chest	.02	1
• AP, Lat abdomen	.05	2 ½
• Head CT	4	200
• Abdomen CT	5	250
• PA scoliosis	.140	7
• CT spine	4-12	200-600

Tissue Radiosensitivity

High	Medium	Low
Lymphoid Tissue	Skin	Muscle
Bone Marrow	Lens	Bone
GI Epithelium	Lung	Connective tissue
Gonads	Kidney	Cartilage
Embryo / Fetus	Liver	Brain

Courtesy Michael Callahan MD

CT Risk

- Primary source of medical radiation is CT
- 1996-2005 saw doubling of exam numbers below age 5yo
 - Triple from age 5-14yo
- 1980 3 million exams
- 2005 68 million



Measuring CT Dose

- Not possible without extra software and machinery
- Dose reported on console is not accurate
 - CTDI vs. DLP

EXM
Exam Description: CT HEAD WO CONTRAST

Dose Report					
Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Axial	14.750-5158.697	40.92	690.36	Head 16
Total Exam DLP:				690.36	

CTDI vs. DLP vs. Effective Dose

- **CTDI**= total dose to a certain size volume measured by phantom
 - Most patients are smaller than a 32 cm phantom
 - Dose therefore larger
- **DLP**= CTDI x the length of the patient scanned
 - Both are helpful in determining dose but are more important to compare scanners and protocols

scription: CT CERVICAL SPINE WO C

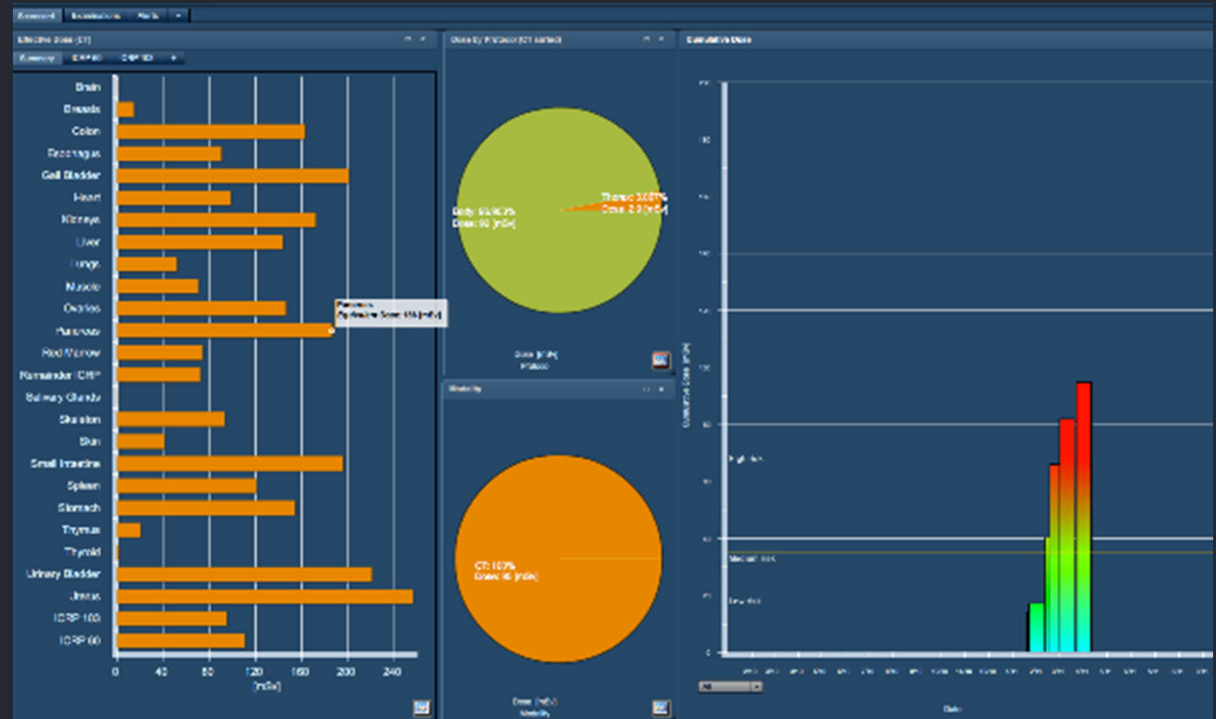
Dose Report				
Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
Scout	-	-	-	-
Helical	15.000-1206.250	7.78	174.46	Body 32
Total Exam DLP:			174.46	

Effective Dose

- Calculated as the sum of the doses to each organ weighted by the radiosensitivity of the organ
- Uses DLP x dose conversion coefficients (k factor)
 - Still does not account for body size (girth)

Radimetrics

- New software which allows reasonably accurate calculation of effective dose
- New software development spurred by California reporting law



Radimetrics

- Also allows analysis of dose by modality and operator



Brenner et al AJR 2001

- Estimates lifetime cancer risk using atomic bomb data
 - 1 abdominal CT=1 in 550
 - 1 head CT= 1 in 1500
 - Strong evidence for increased risk at $> 100\text{mSv}$
 - Good evidence 50-100 mSv
 - Reasonable evidence 10-50 mSv

Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT

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Eric J. Hall¹
Walter E. Berdon²

OBJECTIVE. In light of the rapidly increasing frequency of pediatric CT examinations, the purpose of our study was to assess the lifetime cancer mortality risks attributable to radiation from pediatric CT.

MATERIALS AND METHODS. Organ doses as a function of age-at-diagnosis were estimated for common CT examinations, and estimated attributable lifetime cancer mortality risks (per unit dose) for different organ sites were applied. Standard models that assume a linear extrapolation of risks from intermediate to low doses were applied. On the basis of current standard practice, the same exposures (milliamperes-seconds) were assumed, independent of age.

RESULTS. The larger doses and increased lifetime radiation risks in children produce a sharp increase, relative to adults, in estimated risk from CT. Estimated lifetime cancer mortality risks attributable to the radiation exposure from a CT in a 1-year-old are 0.18% (abdominal) and 0.07% (head)—an order of magnitude higher than for adults—although these figures still represent a small increase in cancer mortality over the natural background rate. In the United States, of approximately 600,000 abdominal and head CT examinations annually performed in children under the age of 15 years, a rough estimate is that 500 of these individuals might ultimately die from cancer attributable to the CT radiation.

CONCLUSION. The best available risk estimates suggest that pediatric CT will result in significantly increased lifetime radiation risk over adult CT, both because of the increased dose per milliamperes-second, and the increased lifetime risk per unit dose. Lower milliamperes-second settings can be used for children without significant loss of information. Although the risk-benefit balance is still strongly tilted toward benefit, because the frequency of pediatric CT examinations is rapidly increasing, estimates that quantitative lifetime radiation risks for children undergoing CT are not negligible may stimulate more active reduction of CT exposure settings in pediatric patients.

The use of CT has increased rapidly in the past two decades, fueled in part by the development of helical CT [1]. For example, the estimated annual number of CT examinations in the United States rose approximately sevenfold from 2.8 million in 1981 [2] to 20 million in 1995 [3]. By their nature, CT examinations contribute disproportionately to the collective diagnostic radiation dose to the population; for example, in Britain it has been estimated that approximately 4% of diagnostic radiology procedures are CT examinations, but their contribution to the collective dose is approximately 40% [4].

Figure 1 shows a breakdown of the number of CT examinations by age at examination, based on the results of a 1989 British survey

[5]; in this survey, approximately 4% of CT examinations (which corresponds to about 10^6 /year in the United States) were performed on children under the age of 15 years. The proportion of childhood CT examinations is rapidly increasing (linked), an average value of 6% was estimated in 1993 [6]; for example, Corn et al. [7] reported a 63% increase in requests for pediatric CT between 1991 and 1994.

The recent increase in pediatric CT examinations is particularly marked in the United States. Figure 2 shows the number of abdominal and pelvic CT examinations of children under a given age at a major American children's hospital for 1996 through 1999. This figure shows, for example, a 92% increase between 1996 and 1999 in abdominal and pelvic CT examinations on children less

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Lancet 2012

- N=178,000 people
- 1 head CT before the age of 10 YO = 1 excess leukemia and 1 brain tumor/10,000 people

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

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Summary

Background

Although CT scans are very useful clinically, potential cancer risks exist from associated ionising radiation, in particular for children who are more radiosensitive than adults. We aimed to assess the excess risk of leukaemia and brain tumours after CT scans in a cohort of children and young adults.

Methods

In our retrospective cohort study, we included patients without previous cancer diagnoses who were first examined with CT in National Health Service (NHS) centres in England, Wales, or Scotland (Great Britain) between 1985 and 2002, when they were younger than 22 years of age. We obtained data for cancer incidence, mortality, and loss to follow-up from the NHS Central Registry from Jan 1, 1985, to Dec 31, 2008. We estimated absorbed brain and red bone marrow doses per CT scan in mGy and assessed excess incidence of leukaemia and brain tumours cancer with Poisson relative risk models. To avoid inclusion of CT scans related to cancer diagnosis, follow-up for leukaemia began 2 years after the first CT and for brain tumours 5 years after the first CT.

Findings

During follow-up, 74 of 178 604 patients were diagnosed with leukaemia and 135 of 176 587 patients were diagnosed with brain tumours. We noted a positive association between radiation dose from CT scans and leukaemia (excess relative risk [ERR] per mGy 0.036, 95% CI 0.005–0.120; $p=0.0097$) and brain tumours (0.023, 0.010–0.049; $p<0.0001$). Compared with patients who received a dose of less than 5 mGy, the relative risk of leukaemia for patients who received a cumulative dose of at least 30 mGy (mean dose 51.13 mGy) was 3.18 (95% CI 1.46–6.94) and the relative risk of brain cancer for patients who received a cumulative dose of 50–74 mGy (mean dose 60.42 mGy) was 2.82 (1.33–6.03).

Interpretation

Use of CT scans in children to deliver cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy might triple the risk of brain cancer. Because these cancers are relatively rare, the cumulative absolute risks are small: in the 10 years after the first scan for patients younger than 10 years, one excess case of leukaemia and one excess case of brain tumour per 10 000 head CT scans is estimated to occur. Nevertheless, although clinical benefits should outweigh the small absolute risks, radiation doses from CT scans ought to be kept as low as possible and alternative procedures, which do not involve ionising radiation, should be considered if appropriate.

Funding

Risk Estimates

- Vary greatly
 - National research council
 - 0.10% increase for a 10mSv exam
 - FDA estimates 0.05% risk increase
- One best guess
 - 1 in 500-1000 risk of cancer death from a single CT



Bottom Line

- Risk is miniscule compared to background risk of cancer (1 in 3)
- If the study is indicated the benefits always outweigh risk
- If study is NOT indicated, benefit never outweighs risk



Things To Consider

- Does exam need to be done
- Is there another way to get the appropriate data
- How can dose be decreased and still have diagnostic exam

AS

LOW

AS

REASONABLY

ACHEIVABLE

ALARA

Does Exam Need to Be Done

- Will information obtained change the approach
- Will information obtained benefit the patient?



Is There Another Way To Get Information

Ultrasound



Physical Exam

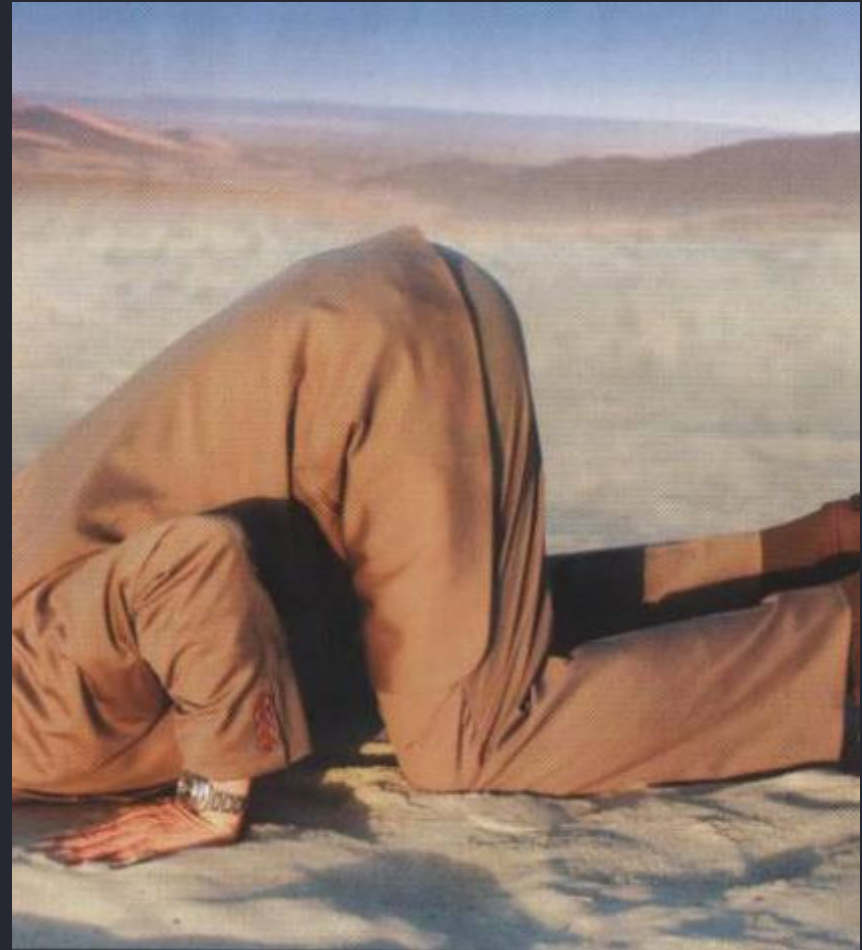


MRI



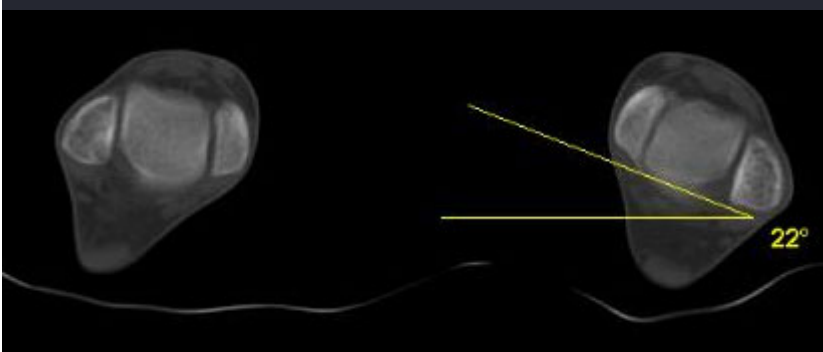
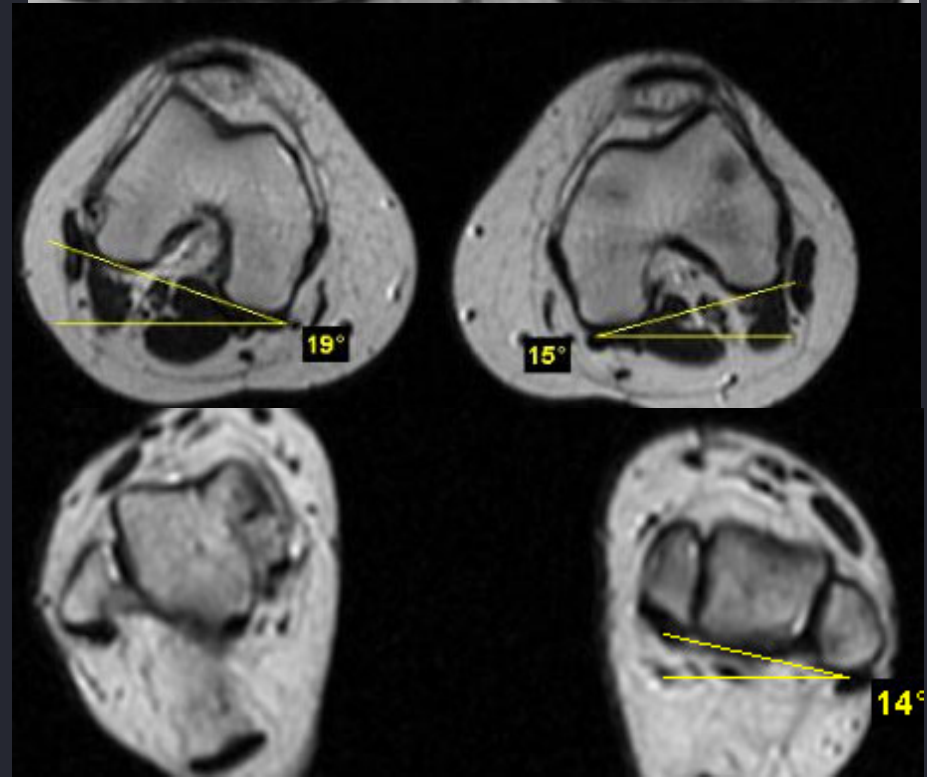
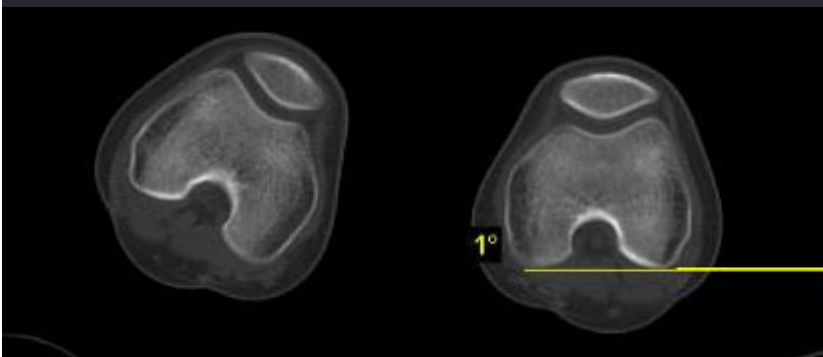
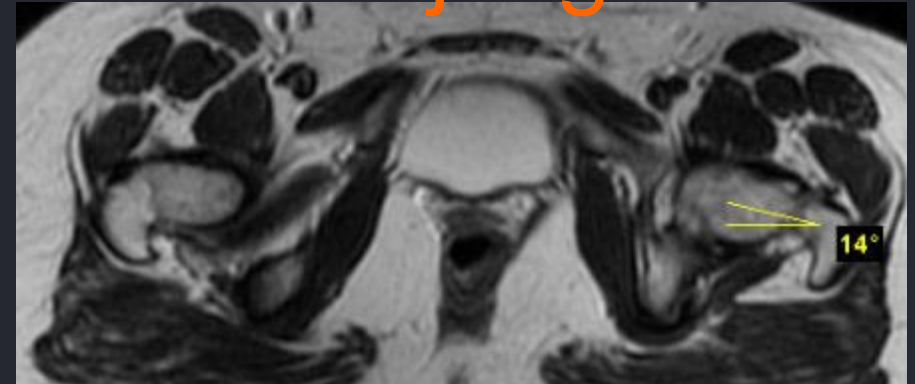
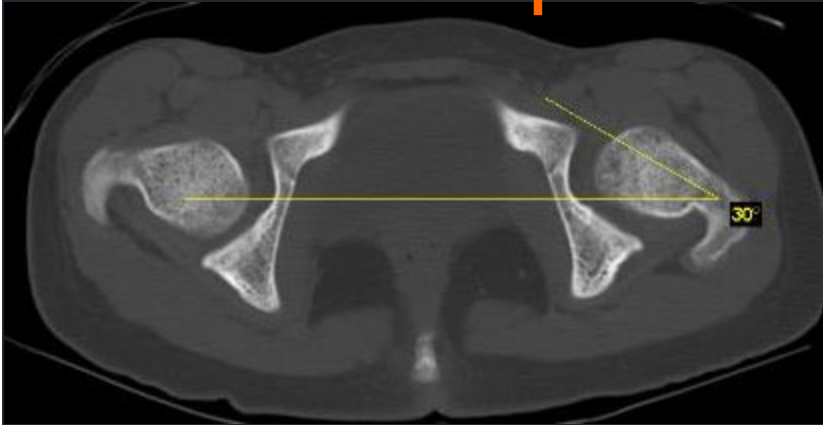
Am I The Problem

- Lack of willingness to change and adapt
 - MRI can replace much of CT information
 - Can provide critical information of bone structure and form
- Think of goals and make decisions based on necessity not rote



Zero radiation vs. direct gonadal exposure...you be the judge

For Example

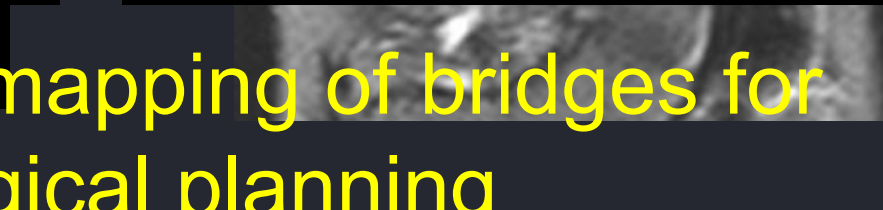
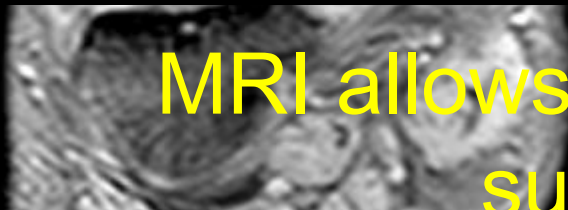
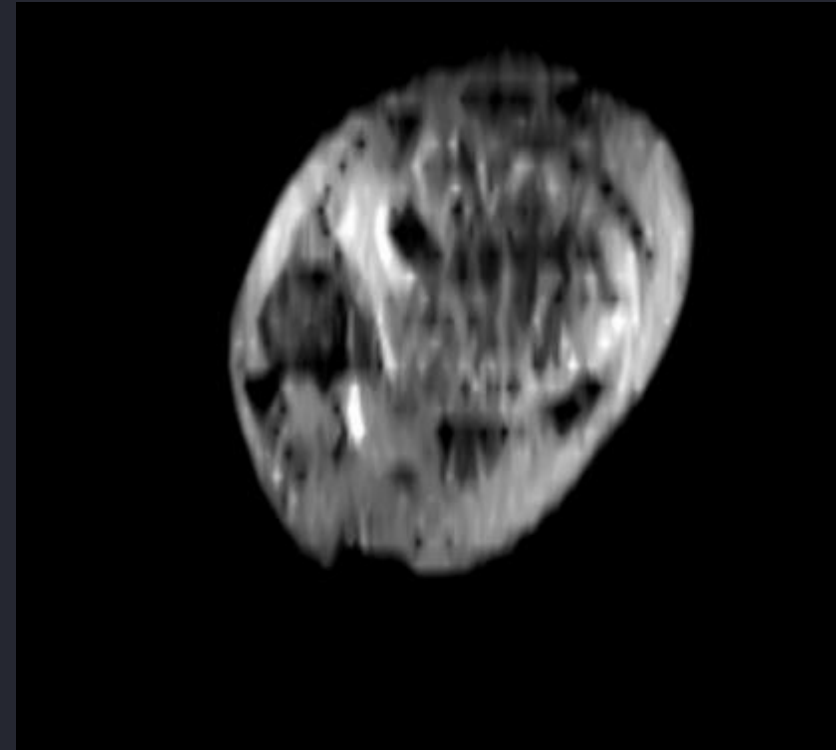
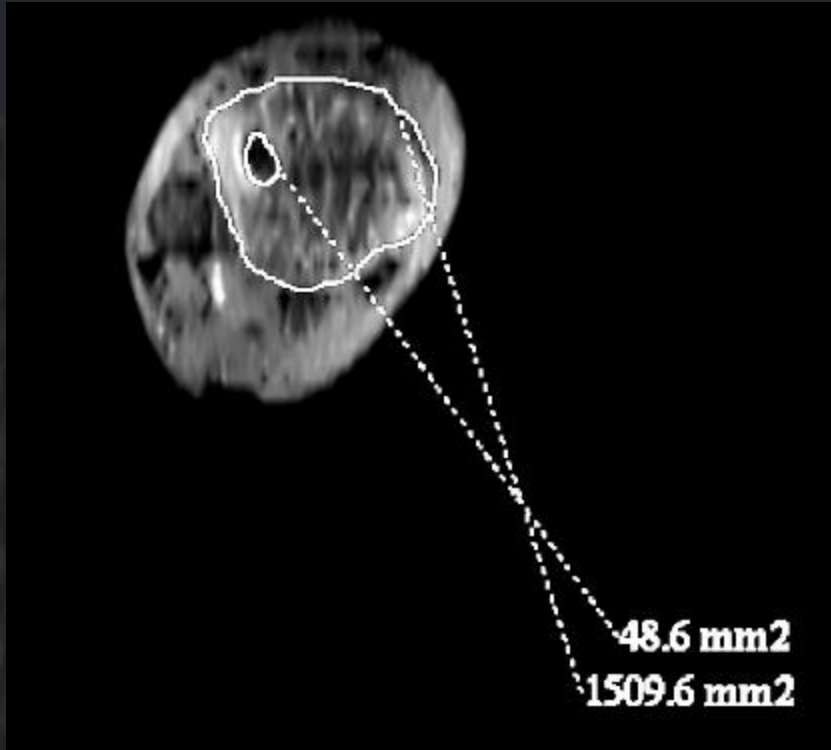


Zero radiation vs. low dose radiation to an extremity plus scatter, what would you want?
Another Example



Physeal Bridge

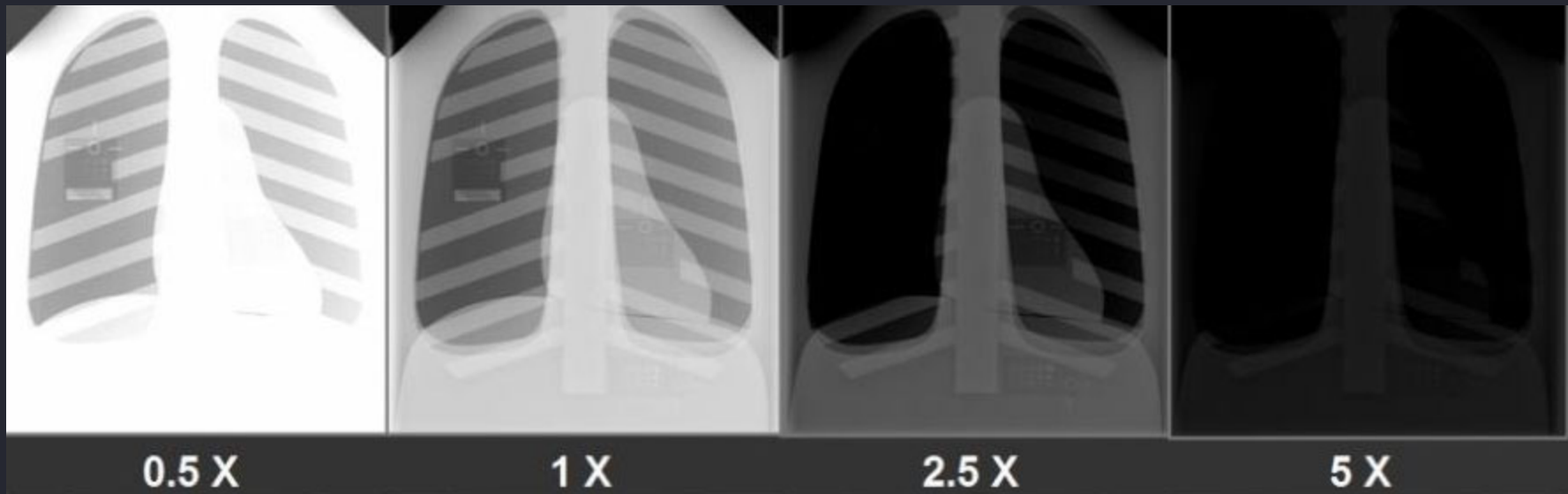
MRI Has A Decided Advantage



MRI allows mapping of bridges for surgical planning

Methods of Decreasing Dose

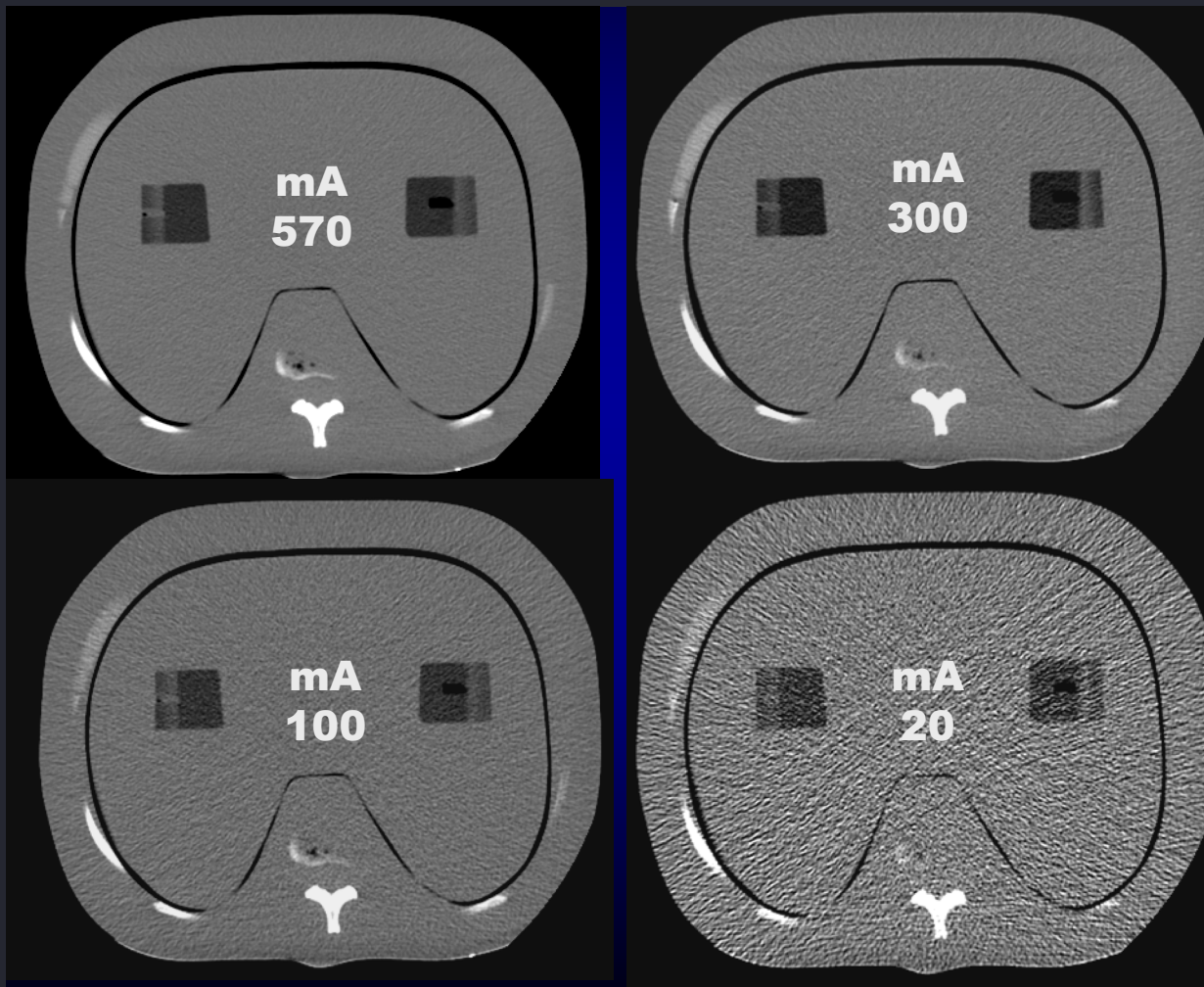
- Decrease the number of surveillance exams
- Decrease dose from each exam
 - Technique
 - Raising mA in radiographs does not improve image



<http://www.upstate.edu/radiology/education/rsna/radiography/issues/>

But which image is good enough

Increasing mA does improve CT image



Decrease Dose From Each Exam

- Collimate
 - Immediate decrease
- Shield
 - Underutilized
 - 7-10x reduction
- PA vs. AP
 - Once patient can stand
- Decrease technique
 - Doesn't have to look pretty



EOS System

- Uses low dose radiation to obtain frontal and lateral images as well as 3 D images in a fraction of dose (7x lower)



EOS System

- Two thin fan shaped beams
- Two detectors
- Moving beam
- Excellent dose suppression
- Large reduction



How Is Reduction Achieved

- Thinly collimated beams
 - 0.5mm thick
 - Decreased scatter
- Detector changes
 - Detector signal amplification



EOS

Artifacts

- Slow acquisition can yield summation artifacts



The Bottom Line

- Risk from diagnostic radiation is there but very low
- An indicated exam will always have a better benefit for the risk
- An unindicated exam will never have a benefit that outweighs the risk
 - For an unindicated exam the benefit is zero and it will remain zero

Image Gently

