# CT Radiation Safety in Adults:
## Where are we now? What can be done?

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Canadian Association of Radiologists Annual General Meeting
Friday April 26, 2013 No conflicts of Interest to declare

# Objectives

- Identify the health risks from radiation doses in diagnostic CT helping radiologists …
  - Optimize protocols
  - Intelligently discuss radiation concerns with patients or referring physicians
- Highlight some features of the “Image Wisely” program
- Review some basics of CT dose optimization

# CT Radiation Dose In the News


- 2 ½ year old male, neck CT following fall
- Technologist repeated sans 151 times for > 1 hour
  - If neck CT 3 mSv - total 453 mSv
- Article also included patients with hair loss after brain perfusion scans

http://www.nytimes.com/2009/10/16/us/16radiation.html October 15, 2009. Accessed April 23, 2013

The New York Times

Health

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THE RADIATION BOOM

# After Stroke Scans, Patients Face Serious Health Risks

By WALT BOGDANICH
Published: July 31, 2010

When Alain Reyes's hair suddenly fell out in a freakish band circling his head, he was not the only one worried about his health. His co-workers at a shipping company avoided him, and his boss sent him home, fearing he had a contagious disease.

Enlarge This Image

Only later would Mr. Reyes learn what had caused him so much physical and emotional grief: he had received a radiation overdose during a test for a stroke at a hospital in Glendale, Calif.

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- Over 400 patients identified with hair loss following CT brain perfusion scans
- 400 patients at eight hospitals, received doses up to 13x higher than usual

http://www.nytimes.com/2010/08/01/health/01radiation.html?pagewanted=1&sq=overdose%20radiation&st=cse&scp=1
July 31, 2010. Access April 23, 2013

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- FDA investigating blames lack of dose controls, inadequate technologist training, and desire for better quality pictures
- Lawyers now involved

http://www.nytimes.com/2010/08/01/health/01radiation.html?pagewanted=1&sq=overdose%20radiation&st=cse&scp=1
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PREVENTION

## Too Many Scans? Use of CT Scans Triples, Study Finds

By Alice Park | June 13, 2012 | 2 Comments

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The use of CT scans, MRIs and other imaging tests has skyrocketed over the last 15 years, leading some experts to raise alarms over the potential risks of patients' increased exposure to radiation.

Dr. Rebecca Smith-Bindman, a professor of radiology and biomedical imaging at the University of California San Francisco, and her colleagues report that between 1996 and 2010, the use of computed tomography (CT) scans nearly tripled, from 52 scans per 1,000 patients to 149 scans per 1,000 patients, and rates of magnetic resonance imaging (MRI) increased fourfold, from 17 scans per 1,000 patients to 65

- UCSF study showing triple rate of use of CT between 1996 and 2011
- "although the test can have great benefit, it can also have the potential to cause real and significant risk", including cancer

http://healthland.time.com/2012/06/13/too-many-scans-use-of-ct-scans-triples-study-finds/
June 13, 2012. Accessed April 23, 2013

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- "given that modern patients and doctors want to be as informed as possible. Its not going to be easy countering the expectation for more and more testing"
- "However, experts warn that it's high time we step back and make sure every scan is justifiable and can provide a justifiable health benefit"

http://healthland.time.com/2012/06/13/too-many-scans-use-of-ct-scans-triples-study-finds/
June 13, 2012. Accessed April 23, 2013


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CT scans produce widely differing radiation doses

CBC News Posted: Nov 14, 2011 4:07 PM ET | Last Updated: Nov 15, 2011 6:21 PM ET 54

CT scan radiation risks 2:05

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A Manitoba study has found the amount of radiation patients receive from a CT scan can vary widely and should be reduced to better protect against the risk of cancer.

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- 2010 Manitoba study by Elbakri and Kirkpatrick
- Manitoba doses 3-25% higher than BC and SK for chest and abdomen
- Wide variation in dose between sites

http://www.cbc.ca/news/health/story/2011/11/14/iteam-ct-scan-radiation-manitoba.html November 14, 2011. Accessed April 23, 2013


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Top News Headlines

- Emphasized importance of newest technologies
- Encourages patients to act as advocates

http://www.cbc.ca/news/health/story/2011/11/14/iteam-ct-scan-radiation-manitoba.html November 14, 2011. Accessed April 23, 2013

IMAGE WISELY®

Radiation Safety in Adult Medical Imaging

- A joint campaign of:
  - Radiologists (ACR, RSNA)
  - Physicists (AAPM)
  - Technologists (ASRT)
- Goals:
  - Address concerns about the increasing public radiation exposure from medical imaging
  - Lower radiation used in medically necessary imaging studies
  - Eliminating medically unnecessary procedures

www.imagewisely.org

LEARN

more about radiation safety specific to Computed Tomography. Be more informed about safe adult CT imaging

# Pledge for Imaging Professionals

Yes, I want to ***image wisely***.

**I wish to optimize the use of radiation in imaging patients and thereby pledge:**

1. To put my patients' safety, health, and welfare first by optimizing imaging examinations to use only the radiation necessary to produce diagnostic-quality images;
2. To convey the principles of the Image Wisely program to the imaging team in order to ensure that my facility optimizes its use of radiation when imaging patients;
3. To communicate optimal patient imaging strategies to referring physicians, and to be available for consultation;
4. To routinely review imaging protocols to ensure that the least radiation necessary to acquire a diagnostic-quality image is used for each examination.

# Image Wisely
## For Imaging Professionals

- Includes radiologists, technologists, nuclear medicine & medical physicists
- Manufacturer and model specific CT protocols for dose optimization
- Info on ionizing radiation in medicine
- Ways to limit dose:
  - US or MRI alternatives to CT
  - Appropriateness criteria
  - Pregnant patient

www.imagewisely.org

# Image Wisely
## For Referring Practitioners

- The risks of ionizing radiation
- What to tell patients
- Appropriateness and alternative tests
- Special considerations
  - Pediatrics & Pregnancy
  - Patients requiring repeated imaging

# Image Wisely For Patients

- Links to other sites
- Encourages patients to discuss radiation concerns with doctors
- Medical Imaging History Cards
- List of common exams with dose levels and relative risk

***Before undergoing any X-ray exam or treatment procedure, remember to ask your doctor:***
- Why do I need this exam?
- How will having this exam improve my health care?
- Are there alternatives that do not use radiation and which are equally as good?

**Remember:**
- Be sure to tell the doctor or technologist if you are, or might be, pregnant before having an exam.
- Don't insist on an imaging exam if the doctor explains there is no need for it.
- And, don't refuse an imaging exam if there's a clear need for it and the clinical benefit outweighs the small radiation risk.

www.imagewisely.org

# Low Level Radiation Risk?

- There is risk from a single scan because of no threshold models[1]
- Risks are higher in children

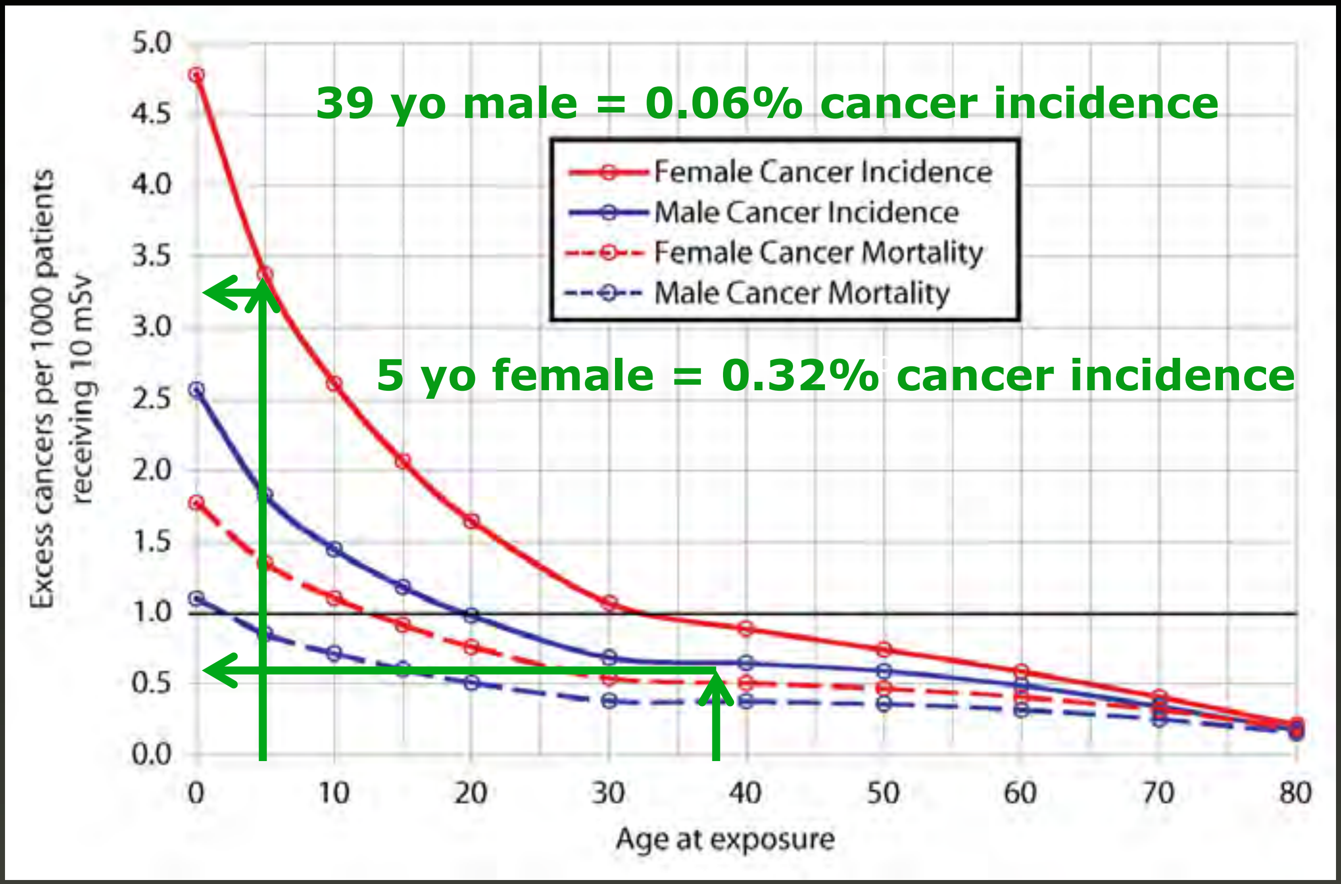
1. National Research Council (U.S.). Committee to Assess Health Risks from Exposure to Low Level of Ionizing Radiation. Health risks from exposure to low levels of ionizing radiation: BEIR VII Phase 2. Washington, D.C.: National Academies Press, 2006.

# Demographic Studies

- Atomic bomb survivors with mean 40 mSv dose (range 5-150 mSv) show 'significant increase risk of malignancy' (1,3)
- Radiation workers in nuclear industry with mean dose 19.4 mSv (range 5-150 mSv) show 'significant association between dose & development of cancer' (2,3)

1. National Research Council (U.S.). Committee to Assess Health Risks from Exposure to Low Level of Ionizing Radiation. Health risks from exposure to low levels of ionizing radiation: BEIR VII Phase 2. Washington, D.C.: National Academies Press, 2006.
2. Vrijheid M et al. The 15 country collaborative study of cancer risk among radiation workers in the nuclear industry; Design, Epidemiological Methods and Descriptive Results. Radiat Res. 2007; 167: 361-379
3. Brenner DJ, Hall EJ. Computed Tomography: An Increasing Source of Radiation Exposure. NEJM. 2007; 357:2277-2284

# Individual Cancer Risk at 10 mSv

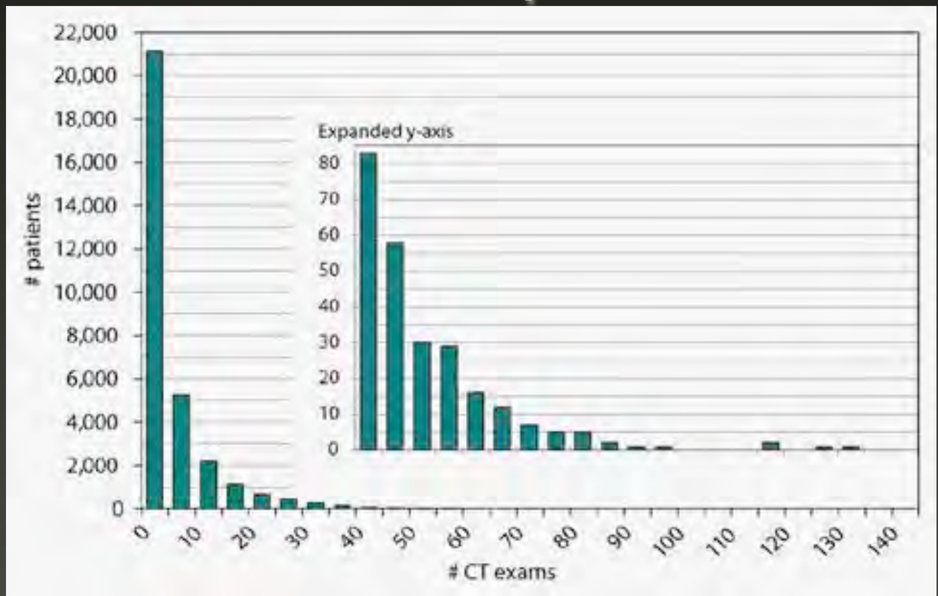



- Extrapolation of BEIR VII data[1]
- Excess cancer risk and mortality per 1000 patients receiving 10 mSv

1. Sodickson et al. Recurrent CT, Cumulative Radiation Exposure, and Associated Radiation-Induced Cancer Risks from CT of Adults. Radiology. 2009; 251: 175-184

# Cumulative CTs

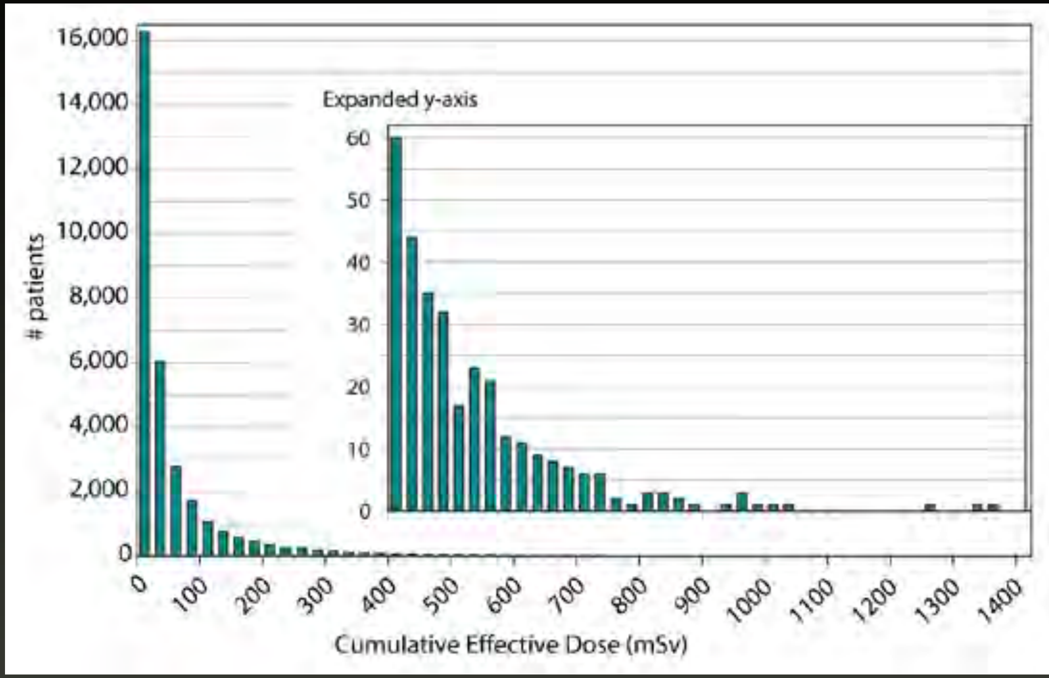
- Patients often require >1 scan at visit or multiple visits
- From imaging history of >30,000 patients receiving CT in 2007[1]
- Percentage of patients with multiple CT's[1]
  - 33% > 5 CTs
  - 5% > 22 CTs
  - 1% > 38CTs
  - Max > 130 CTs




1. Sodickson et al. Recurrent CT, Cumulative Radiation Exposure, and Associated Radiation-Induced Cancer Risks from CT of Adults. Radiology. 2009; 251: 175-184

# Cumulative Dose

- Percentage of patients above certain dose levels[1]
  - 30% > 50 mSv
  - 15% > 100 mSv
  - 1% > 399 mSv





1. Sodickson et al. Recurrent CT, Cumulative Radiation Exposure, and Associated Radiation-Induced Cancer Risks from CT of Adults. Radiology. 2009; 251: 175-184
2. Brenner DJ, Hall EJ. Computed Tomography: An Increasing Source of Radiation Exposure. NEJM. 2007; 357:2277-2284

# Population risk from CT

- Based on USA CT use in 2006[1]:
  - 1.5-2% of cancers attributable to CT
- Canadian based on 1991-1996[3]:
  - 1.1% of cancers attributable to CT
- Based on 2012 Canadian statistics:
  - Potentially 1,320 fatal malignancies induced by CT/ year
  - (5% risk/ Sv, 4.4 million CTs & 6 mSv mean dose per scan)


1. Brenner DJ, Hall EJ. Computed Tomography: An Increasing Source of Radiation Exposure. NEJM. 2007; 357:2277-2284
2. Sodickson et al. Recurrent CT, Cumulative Radiation Exposure, and Associated Radiation-Induced Cancer Risks from CT of Adults. Radiology. 2009; 251: 175-184
3. Computed Tomography Radiation Safety Issues in Ontario. Toronto, On.: University Health Network, Centre for Global eHealth Innovation, Healthcare Human Factors Group; 2006

# Difficulty With Models

- There is no transference of risk
  - If one person has 15 CT scans they will not share this risk with the rest of the population
  - CT scans in terminally ill will not increase population risk of malignancy
- Ignores benefits of CT
  - Detection and staging of malignancy to enable treatment
  - Imaging of acute injury/disease

# CT Dose Knowledge

- Is there risk of cancer from a single CT?
- What is dose of abdo-pelvis CT scan vs. chest x-ray?

# CT Dose Knowledge: Increased Risk of Malignancy?

| Year | Author | Country | % confirm Increased risk cancer |
|---|---|---|---|
| 2004 | Jacob | England | 12.5% |
| 2004 | Lee (ER only) | USA | 9%(MD) 47% (RAD) |
| 2005 | Rassin | Israel | 70% |
| 2007 | Rice | USA | 53% |
| 2008 | Gumas | Turkey | 52% |
| 2008 | Soye | England | 19% |
| 2011 | Irving | Sask | 74%MD 97%RAD |


1. Krille, Hammer, Merzenich and Zeeb. "Systematic Review of physician's knowledge about radiation doses and radiation risks from computed tomography". Eur J Radiol. 2910; 76:36-41
2. Irving LB, Leswick DA, Fladeland DA, Lim H. "Knowing the Enemy. A Survey of Healthcare Provider Knowledge of CT Radiation Dose and Associated Risks" Presented at Can Assoc Radiol Annual General Meeting. Apr 28-May 1, 2011.

# CT Dose Knowledge: Dose Levels in CXR equivalents(1)

| Year | Author | Country | % correct CXR equivalent | % underestimate CXR equivalent |
|---|---|---|---|---|
| 1996 | Renston | USA | | 93% |
| 1997 | Quinn | England | 9% | 60% |
| 2004 | Lee (ER only) | USA | 22% | 74% |
| 2004 | Jacob | England | 18% | |
| 2005 | Rassin | Israel | | 62% |
| 2006 | Heyer | Germany | 89% | 12% |
| 2006 | Thomas | Canada | 1-13% | 99-87% |
| 2007 | Aeslanoglu | Turkey | 2-8% | 83% |
| 2007 | Rice | USA | 19% | 76% |
| 2008 | Gumas | Turkey | 17% | 73% |
| 2008 | Shiralkar | England | 6% | 97% |
| 2011 | Irving | Sask | 18% | 52% |


1. Krille, Hammer, Merzenich and Zeeb. "Systematic Review of physician's knowledge about radiation doses and radiation risks from computed tomography". Eur J Radiol. 2910; 76:36-41
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# Dose Audits

# Dose Audits

- A review of current practice, not optimal practice[1,2]
- Important to let institutions know of local doses[1,2]
- Compare with reference levels helps maintain doses[1]
- Variation is both good and bad[2,3]
  - Tailor exams to patient sizes/needs
  - Variation between sites can indicate equipment/protocol problems

1. University Health Network, Centre for Global eHealth Innovation, Human Healthcare Factors Group. "Computed Tomography Radiation Safety Issues in Ontario. (2006)
2. Dumaine et al Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ (2012) 63(3) 183-91
3. Nickoloff et al. "Radiation Dose Descriptors: BERT, COD, DAD and other strange creatures" Radiographics (2008) 28(5): 1439-50

# How to Do a Dose Audit

- Standard patient vs. actual cases
- Older systems did not archive CTDI/DLP
  - Needed technologists to complete forms[1]
- If CTDI/DLP archived on PACS:
  - Manual review
  - Automated review[2]
- Third party software solutions:
  - e.g. eXposure by Radimetrics/Bayer[3]
    - Individual study and patient history dose tracking
    - Also aggregate data by physician, technologist, protocol etc

1. Leswick DA et al Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2):71-781
2. Jaron Chong
3.Radimetrics.com

# SK Dose Surveys: 2006 & 2008

- 2006:
  - 1,734 patients, 12 of the 13 provincial scanners
- 2008:
  - 3,358 patients, all 13 scanners
- No new installs/upgrades between the studies


1. Leswick DA, Syed NS, Dumaine CS, Lim H, Fladeland DA. Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2):71-78
2. Dumains CS, Leswick DA, Fladeland DA, Lim H, Toews L. Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ (2012) 63(3) 183-91

# 2006 SK Dose Survey(1)

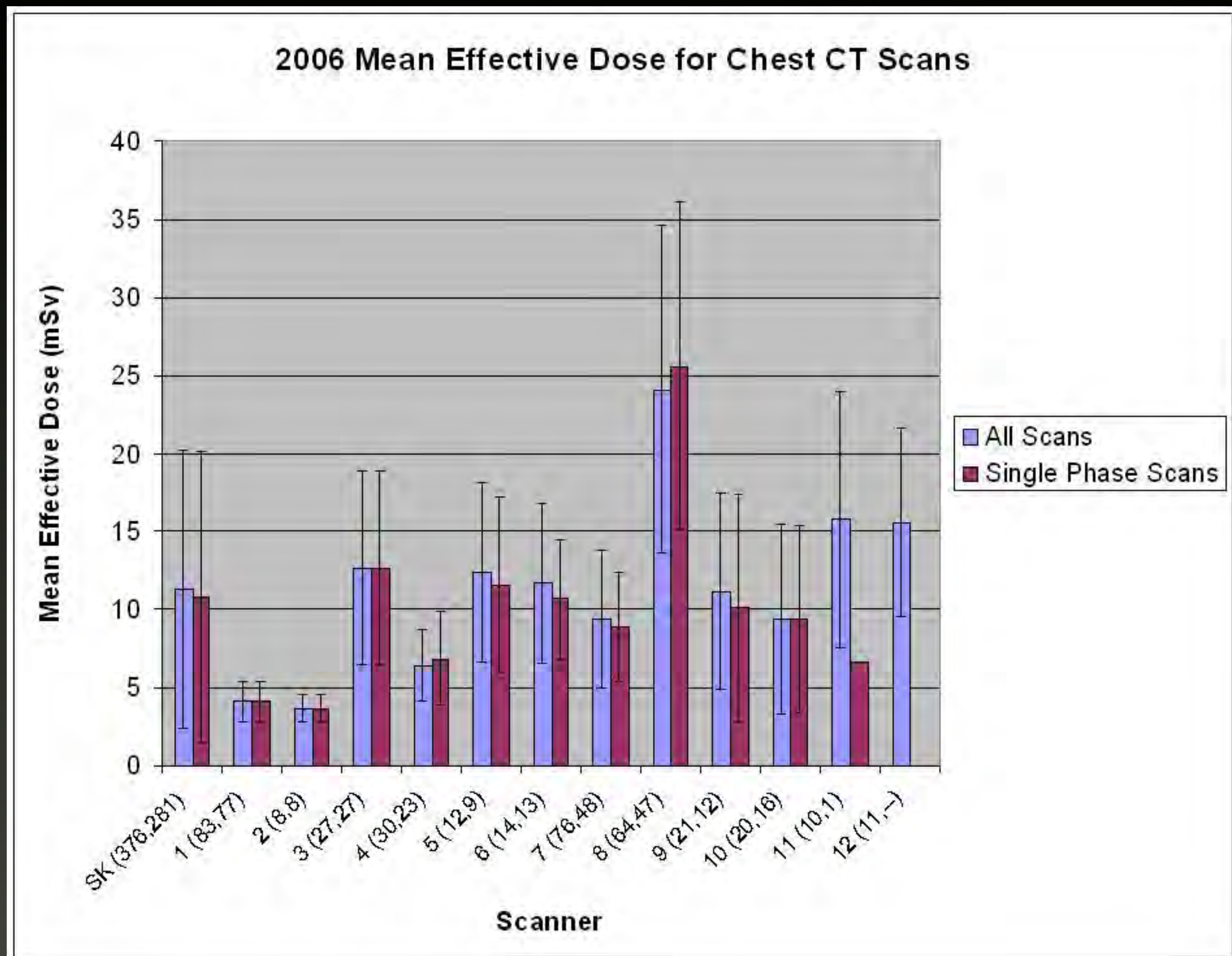
| | Avg. SK Dose mSv |
|---|---|
| Head | 2.7 ± 1.6 |
| Chest | 11.3 ± 8.9 |
| Abdomen & Pelvis | 15.5 ± 10.0 |
| Theoretical Trauma Patient: Total for head, chest, abdomen & pelvis | 29.5 |

- Significant variability between sites
- Wide variability in individual patient doses

1. Leswick DA, Syed NS, Dumaine CS, Lim H, Fladeland DA. Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2):71-78*

3. 0.05 mSv PA CXR ED in Mayo et al. Radiation exposure at chest ct: A statement of the Fleishner Society. Radiology. 2003; 228: 15-21 & our RUH review

# 2006 Variability Between Sites
## CT Chest Doses by Scanner





1. Leswick DA, Syed NS, Dumaine CS, Lim H, Fladeland DA. Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2): 71-78

# 2006 vs. 2008

- Did mean doses change?
- Did variability of doses change
  - Between sites
  - Between patients


1. Dumaine CS, Leswick DA, Fladeland DA, Lim H, Toews L. Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ 63:183-91
2. Leswick DA, Syed NS, Dumaine CS, Lim H, Fladeland DA. Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2):71-78

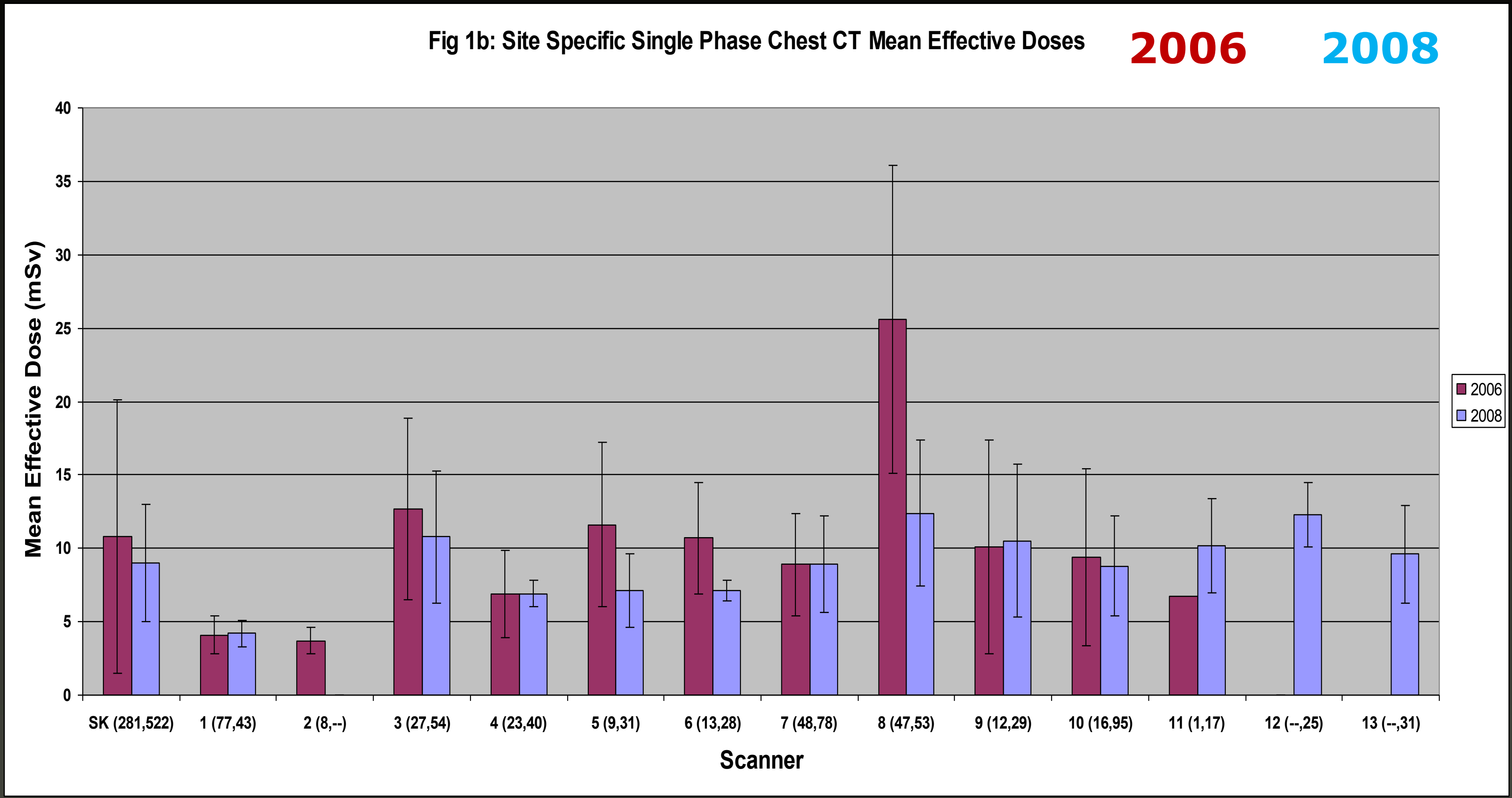
# Dose (mSv) 2008 vs. 2006 Overall MDR Single Phase Only

| | 2008[1] | 2006[2] | Difference |
|---|---|---|---|
| Head | 3.2 ± 1.2 | 2.7 ± 1.5 | +19% ($p<0.001$) |
| Chest | 9.5 ± 3.9 | 13.7 ± 9.7 | -31% ($p<0.001$) |
| Abdo & Pelvis | 13.9 ± 6.0 | 16.8 ± 10.6 | -17% ($p<.001$) |

| Significantly lower | No difference | Significantly Higher |
|---|---|---|


1. Dumaine CS, Leswick DA, Fladeland DA, Lim H, Toews L. Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ 63:183-91
2. Leswick DA, Syed NS, Dumaine CS, Lim H, Fladeland DA. Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2):71-78

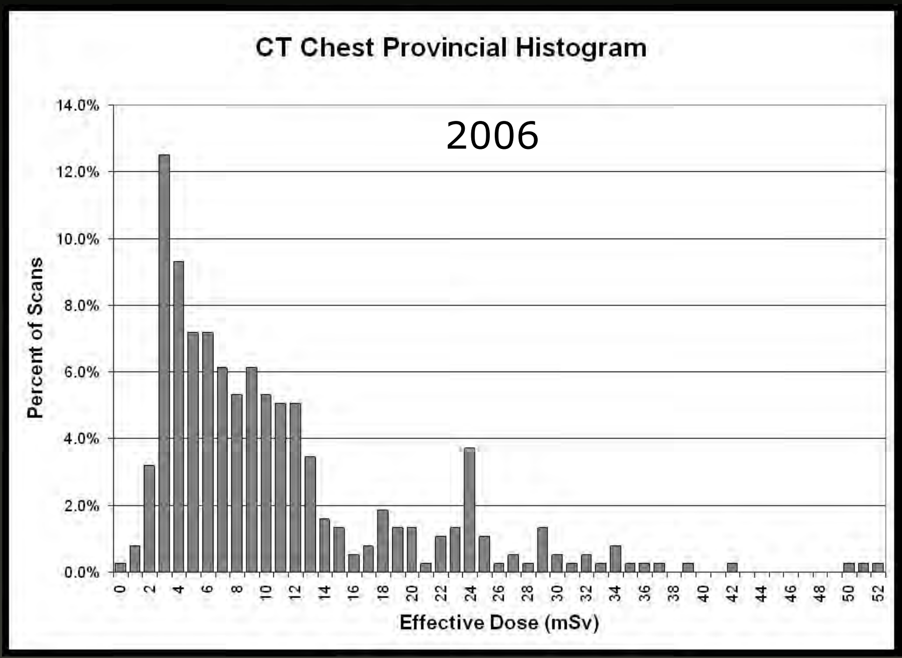
# Change in Variability Mean Doses for Chest CT – 2008 vs. 2006

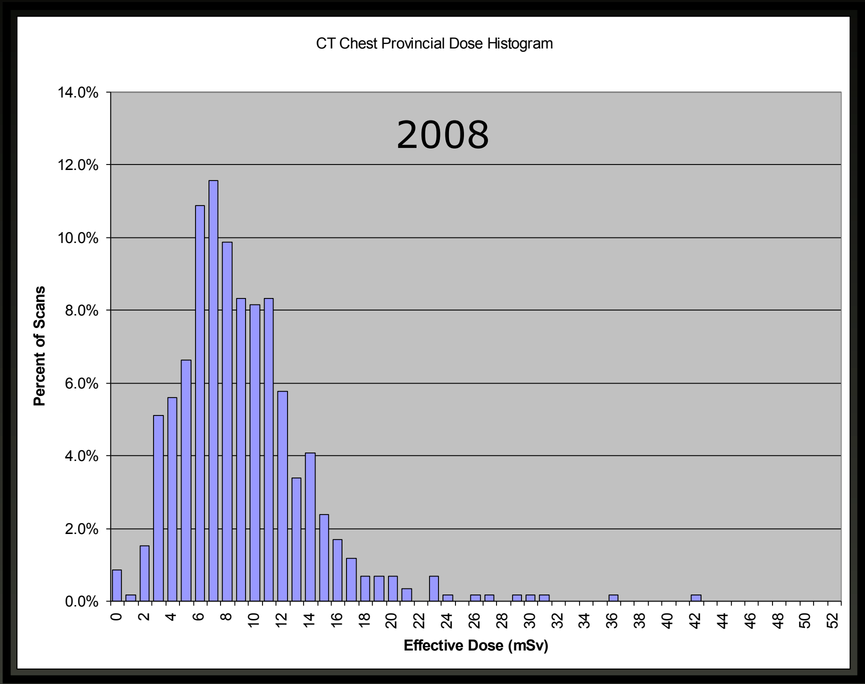




1. Dumaine CS, Leswick DA, Fladeland DA, Lim H, Toews L. Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ 63:183-91

# 2006 vs. 2008 Chest Doses Histograms

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2. Dumaine CS, Leswick DA, Fladeland DA, Lim H, Toews L. Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ 2012. 63:183-91

# SK Dose Surveys: comparisons

| | Manitoba 2010[4] | SK 2008[3] | SK 2006[2] | BC 2004[1] |
|---|---|---|---|---|
| Head | 3.0 ± 1.0 | 3.4 ± 1.6 | 2.7 ± 1.6 | 2.8 |
| Chest | 13.2 ± 6.4 | 9.6 ± 4.8 | 11.3 ± 8.9 | 9.0 |
| Abdo-pelvis | 18 ± 8.6 | 16.1 ± 9.9 | 15.5 ± 10.0 | 16.5 |


1. Aldrich JE, Bilawich AM, Mayo JR. Radiation doses to patients receiving computed tomography examinations in British Columbia. Can Assoc Radiol J. 2006; 57(2): 79-85.
2. Leswick DA, Syed NS, Dumaine CS, Lim H, Fladeland DA. Radiation Dose from Diagnostic CT in Saskatchewan. CARJ. 2009; 60(2):71-78
3. Dumains CS, Leswick DA, Fladeland DA, Lim H, Toews L. Changing Radiation Dose from Diagnostic CT in Saskatchewan. CARJ (2012) 63(3) 183-91
4. Elbakri & Kirkpatrick. Survey of Clinical Doses from Computed Tomography Examinations in Manitoba. June 27, 2011

# CTDI, DLP, ED, and SSDE

- $CTDI_{(vol)}$: CT Dose Index
  - Measurement of radiation exposure in a cylindrical phantom
- DLP: Dose Length Product
  - $CTDI_{(vol)}$ adjusted for scan length
- ED: Effective Dose
  - Conversion factor accounts for tissue radiosensitivity
  - Developed in an idealized phntom
  - Best used for dose to a population of patients

Measures of radiation output, not patient dose

1. Brink et al. "Size Specific Dose Estimation for CT: How should it be Used and What Does it Mean?" Radiology (2013) 265:666-668

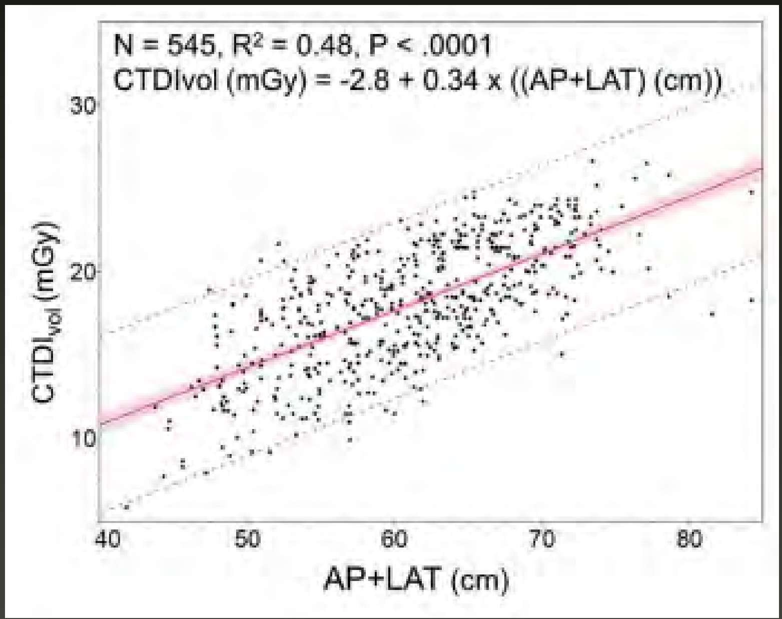
# Size Specific Dose Estimate (SSDE)

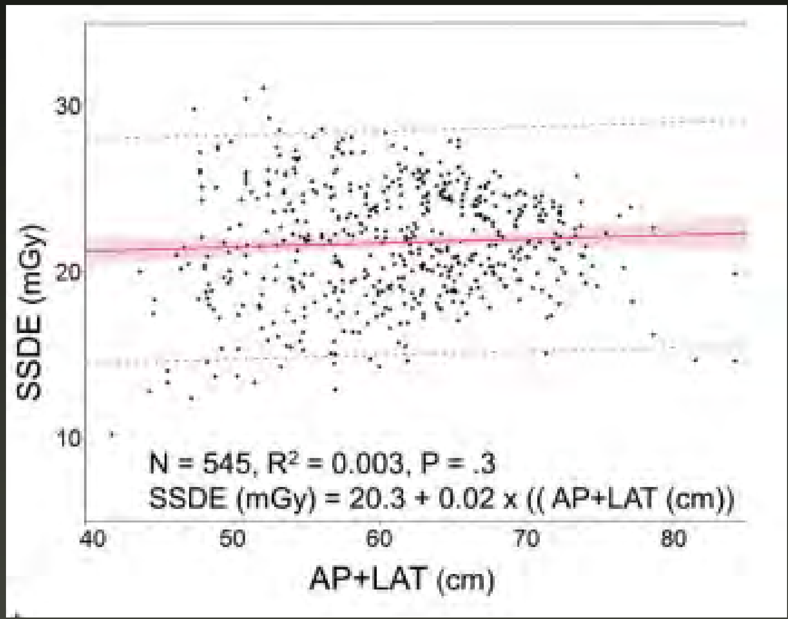
- Accounts for different patient geometry to give more accurate estimate of dose at the centre of a phantom & patient
- Cannot estimate effective dose because does not account for organ dose
- Apply conversion factor based on patient geometry to CTDI to produce SSDE (mGy)

1. American Association of Physicists in Medicine. "Size-specific Dose estimates in pediatric and adult body CT examinations of AAPM Task Group 204" College Park, Md. American Association of Physicists in Medicine, 2011
2. www.imagewisely.

# SSDE

- Patient size strong correlation with $CTDI_{vol}$
- SSDE eliminated size correlation
- Variation seen because of different patient density & protocols



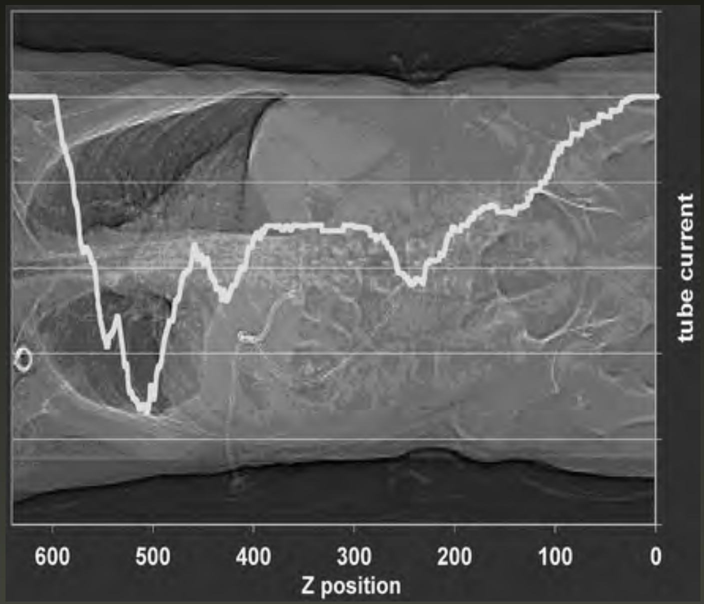

1. Christner et al. “Size-specific Dose Estimates for Adult Patients at CT of the Torso” Radiology. (2013) 265: 841-846

# Dose Reduction Techniques

- ATCM
- ASIR
- Minimizing Overlapping Coverage
- Shielding

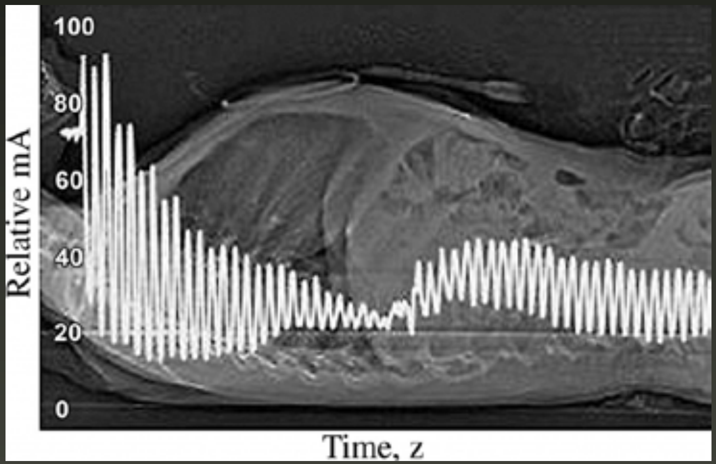
# ATCM

- Automatic Tube Current Modulation
- Adjust mA to size, geometry and density of the body part being scanned to provide diagnostic images with lower dose[1]




z-axis

Combined




1. McCollough CH, Bruesewitz MR, Kofler JM, Jr. CT dose reduction and dose management tools: overview of available options. Radiographics 2006; 26:503-512

# ATCM potential

- Evaluating the effectiveness of ATCM systems is difficult:
  - performance varies significantly with radiologist and technologist technique choice
- Previous study showed dose reduction ranges for ATCM systems as follows:[1]
  - chest 14-20%
  - abdomen 18-38%
  - abdomen-pelvis 26-32%

1. Mulkens TH, Bellineck P, Baeyaert M. Use of an automatic exposure control mechanism for dose optimization in multi-detector row CT examinations: clinical evaluation. Radiology. 2005; 237(1): 213-223.

# ASIR

## Adaptive Statistical Iterative Reconstruction

- Modified method for reconstructing data from traditional filtered back projection[(1)]
- Lower image noise, so equivalent IQ obtained with lower dose[(1)]
- Same spatial and low contrast resolution
  - Slightly 'waxy' look may take time getting used to[(1)]
- How much ASIR to use:
  - 30-50% at many centers[(1)]

1. http://www.imagewisely.org/Imaging-Professionals/Imaging-Physicians/Articles/Adaptive-Iterative-Reconstruction-in-CT Accessed April 24, 2013

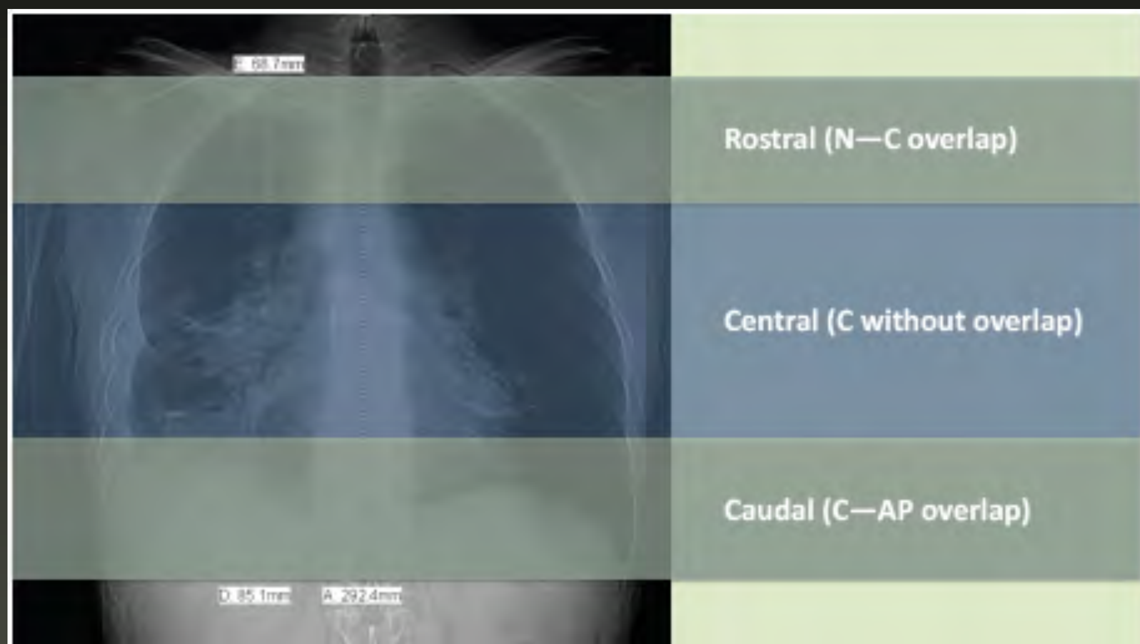
# ASIR - Effect on Dose

- Chest CT study – 30% ASIR[1]
  - Lower objective image noise than FBP
  - 28% decrease ED
- Abdo CT Study – 40% ASIR[2]
  - Lower objective image noise than FPB
  - 25% lower dose
- Trauma Pan Scans[3]
  - ASIR: 20-40% Ch-AP     30% Brain/C-Sp
  - ↓ dose:    14% Ch-AP     20% Brain/C-Sp
  - No difference in objective IQ


1. Prakash et al. "Radiation Doe Reduction with Chest CT Using ASIR: Initial Experience" JCAT 2010. 34: 40-45
2. Prakash et al. "Reducing Abdominal CT Radiation Dose with ASIR" Investigative Radiology. 2010. 45:202-210
3. Maxfield et al. "Impact of ASIR on radiation dose in evaluation of trauma patients" J Trauma Acute Care Surg. 2012:1406-1411

# Overlapping Dose

- When doing combined neck, chest, abdo-pelvis scans often have regions of overlap




1. Zheng J, Leswick DA, Fladeland DA. CT Dose to Patients Receiving Scans of Multiple Body Sites at a Single Visit In Saskatoon. Presented at Canadian Association of Radiologists Annual General Meering. April, 2011. Montreal

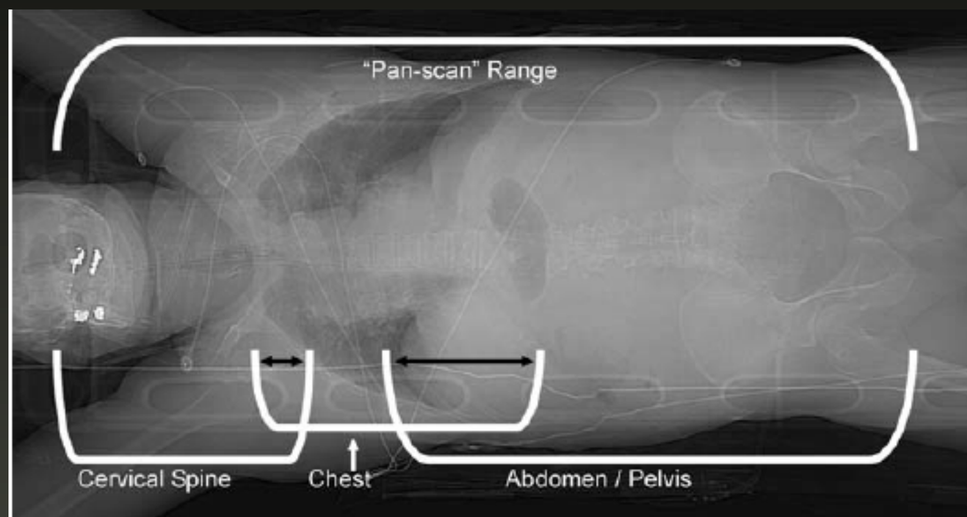
# Overlapping Dose

- 2010 QA project on Pan-scans[1]
- Neck-Chest Overlap
  - 25% of chest coverage 1.8 ± 0.8 mSv
- Chest-Abdo Pelvis Overlap
  - 41% of chest coverage 2.6 ± 1.3 mSv
- Overall
  - 66% of chest coverage
  - 4.4 mSv (20% of total dose received)

1. Zheng J, Leswick DA, Fladeland DA. CT Dose to Patients Receiving Scans of Multiple Body Sites at a Single Visit In Saskatoon. Presented at Canadian Association of Radiologists Annual General Meering. April, 2011. Montreal

# Overlapping Dose

- 20% of radiation given was to overlapping areas[1]
- Compares with 17% in literature[2,3]





1. Zheng J, Leswick DA, Fladeland DA. CT Dose to Patients Receiving Scans of Multiple Body Sites at a Single Visit In Saskatoon. Presented at Canadian Association of Radiologists Annual General Meering. April, 2011. Montreal
2. Gunn & Kohr. State of the Art: Technologies for computed tomography dose reduction. Emergency Radiology 2010. 17: 209-218
3. Ptak et al. Radiation dose is reduced with a single-pass whole body MDR CT trauma protocol compared with a conventional segmental method: initial experience. *Radiology* 2003;229(902-905)

# Shields

- 2 main types of shielding for CT:
  - 'In-Plane'
    - Superficial shields that partly attenuate the CT beam placed over radiosensitive tissues
    - Eg. Bismuth breast shields during chest CT
  - 'Out-of-Plane'/scatter shielding
    - Shield body parts not exposed to the primary beam
    - Eg. Shielding abdo/pelvis during chest CT

# In-Plane shields

- In-plane bismuth shields can:
  - Reduce dose to eyes: 49%[1]
  - Reduce dose to thyroid: 42% to 74%[1-3]
  - Reduce dose to breast: 26% to 52%[1,2,4-6]
- When combined with ATCM:
  - Must place after scout scan[3,6]
- Never use with AEC
- Minimize local image noise using a spacer[2]


1. Hopper KD. Orbital, thyroid, and breast superficial radiation shielding for patients undergoing diagnostic CT. Seminars in ultrasound, CT, and MR 2002;23(5):423-7.
2. Hohl C, Wildberger JE, Suss C, et al. Radiation dose reduction to breast and thyroid during MDCT: effectiveness of an in-plane bismuth shield. Acta Radiol 2006;47(6):562-7.
3. Leswick DA, Hunt MM, Webster ST, Fladeland DA. Thyroid shields versus z-axis automatic tube current modulation for dose reduction at neck CT. Radiology 2008;249(2):572-80.
4. Coursey CA, Frush DP. CT and Radiation: What radiologists should know. Applied Radiology 2008;13(3):22-9.
5. Hopper KD, King SH, Lobell ME, TenHave TR, Weaver JS. The breast: in-plane x-ray protection during diagnostic thoracic CT--shielding with bismuth radioprotective garments. Radiology 1997;205(3):853-8.
6. Coursey C, Frush DP, Yoshizumi T, Toncheva G, Nguyen G, Greenberg SB. Pediatric chest MDCT using tube current modulation: effect on radiation dose with breast shielding. Ajr 2008;190(1):W54-61.

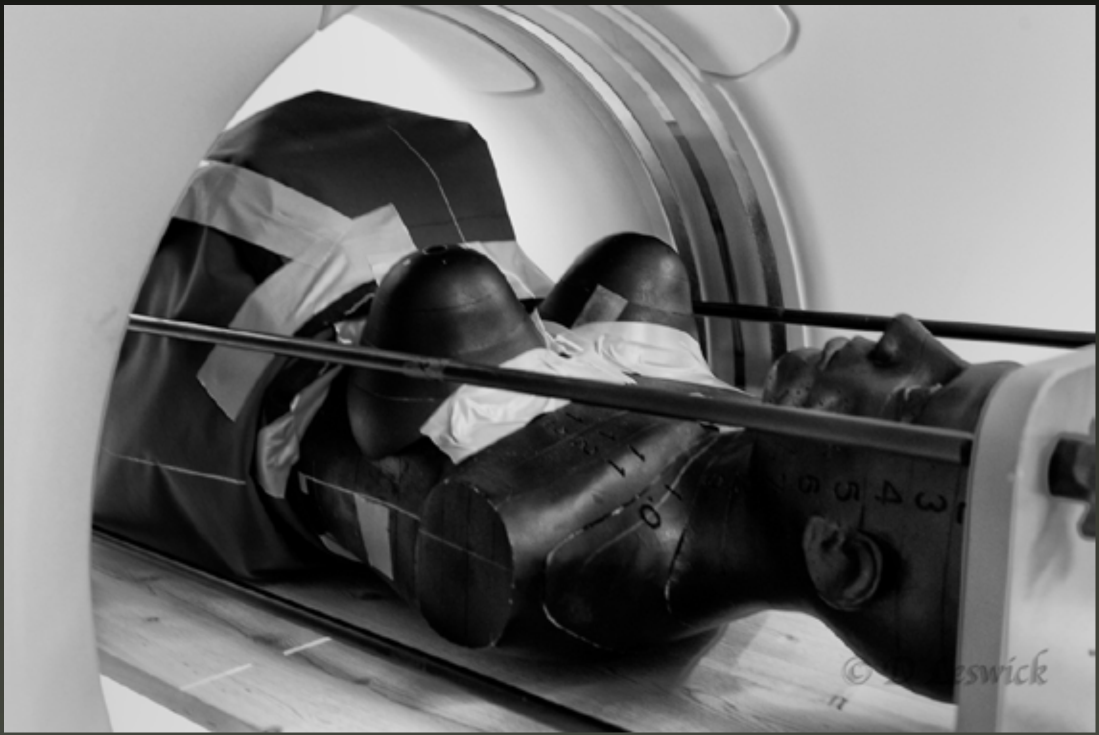
# In-Plane Shields
## Controversy

- Wasting photons(1-3)
  - Attenuates some photons already passed through the patient
- Image noise
  - If willing to tolerate noise from shields, adjust noise for whole image
  - Image noise reduces reliability of HU(2)
- Can't use with AEC systems(2-3)


1. Geleijns et al "Quantitative assessment of selective in-plane shielding of tissues in CT through evaluation of absorbed dose and image quality " Eur Radiol. 2006 16:2334-2340
2. McCollough et al "Point/counterpoint. The use of bismuth breast shields for CT should be discouraged" Med Phys 2012. 39(5) 2321-2324
3. Geleijns et al. "The use of breast shielding for dose reduction in pediatric CT: Arguments against the proposition" Pediat Radiol. 2010. 40:1744-1747

# Out of Plane (Scatter) Shielding

- Shields outside scan range to absorb scatter radiation

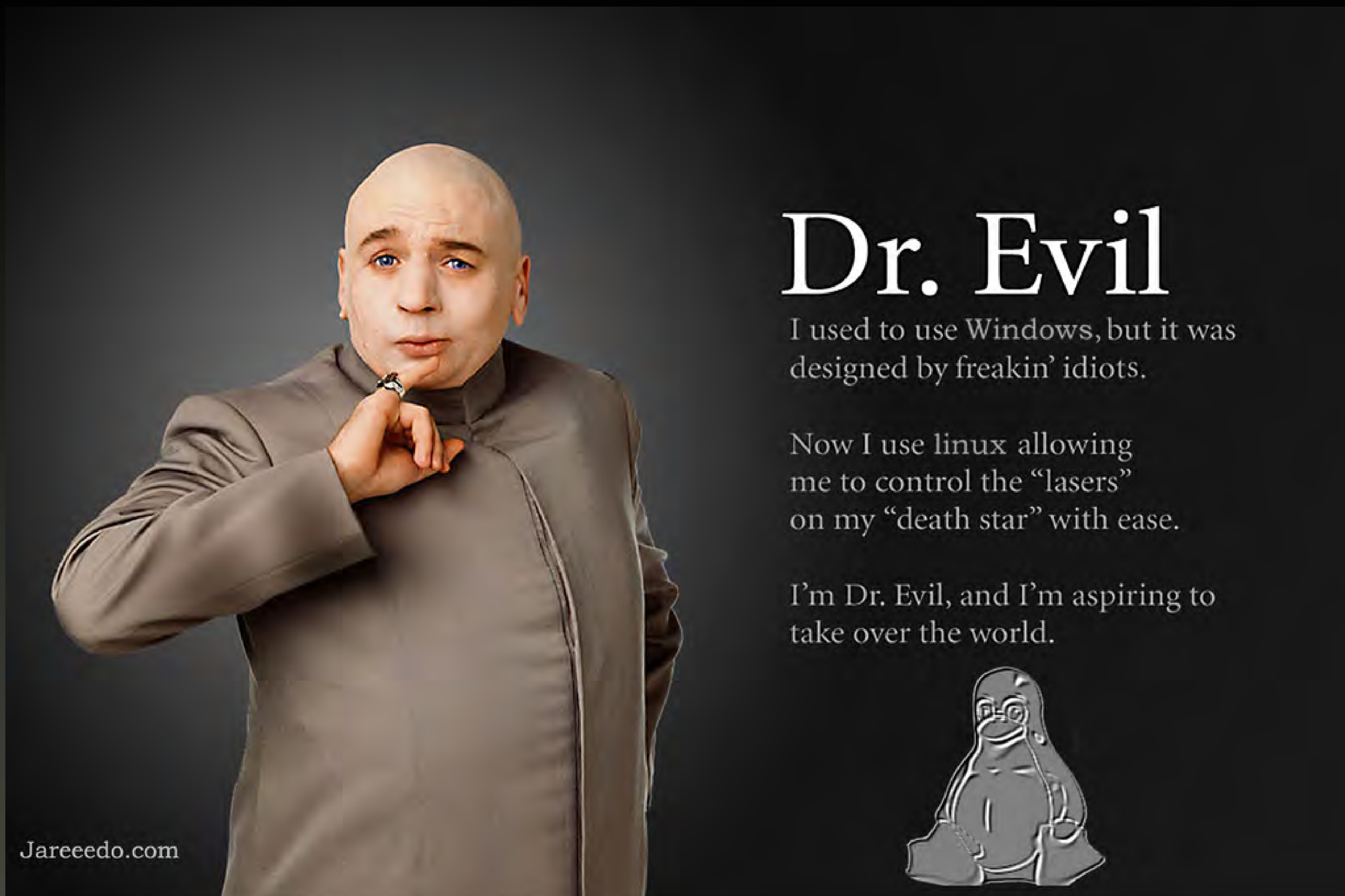


# Scatter Shielding
## Pregnant CTPE exams

- 8DR scanner (100 kVp to diaphragm)[1]
  - Shields ↓ fetal dose by 50%[1]
    - (0.17 to 0.08 mGy)
- 64DR scanner (100 kVp, 30% ASIR, ATCM, ASC)[2]
  - Shields ↓ fetal dose by 69%[2]
    - (0.13 to 0.004 mGy)


1. Chatterson, Leswick, Fladeland, Hunt, Webster. Lead versus Bismuth-Antimony Shield for Fetal Dose Reduction at Different Gestational Ages at CT Pulmonary Angiography. *Radiology. 2011: 260: 560-567*
2. *Chatterson et al. "Shields Up! Fetal Shielding combined with state of the art CT dose erduction strategies during maternal chest CT" CAR Annual Meeting 2012*

# Is CT Evil?


Dr. Evil
I used to use Windows, but it was designed by freakin' idiots.
Now I use linux allowing me to control the "lasers" on my "death star" with ease.
I'm Dr. Evil, and I'm aspiring to take over the world.
Jareeedo.com

# Striking a Balance

- Although there is risk this must be balanced against potential clinical value
- "Risk of not performing the examination (e.g. delayed or inaccurate diagnosis or treatment) must exceed the potential risk associated with the examination"(1)

1. McCollough et al. In Defense of Body CT. *AJR* 2009; 193:28-39

# Justification of Scans

- For symptomatic patients, the risk of disease is variable based on symptoms.
  - Guidelines (e.g. ACR Appropriateness Criteria & CAR imaging guidelines) can help direct to best exam type[1]
- For asymptomatic patients the risk of disease is lower
  - Justification can be based on potential morbidity of a disease, a pre-clinical phase where screening can help and morbidity from other potential screening tests[1]

1. McCollough et al. In Defense of Body CT. *AJR* 2009; 193:28-39

# What Do We Do Now?

- Monitor Dose
  - Perform dose audits
  - If site is above average, revisit equipment or protocols[1]
- Education
  - Educate patients, ordering MDs & radiologists about CT's dark side[2]
  - Radiologists *must* act as consultants
- Decrease # of CT scans[3,4]
  - Decrease unnecessary scans
  - Use US and MRI
- Minimize dose from each scan performed


1. Nickoloff EL, Lu ZF, Dutta AK, So JC. Radiation dose descriptors: BERT, COD, DAP, and other strange creatures. Radiographics 2008; 28:1439-1450
2. Lee CI, Haims AH, Monico EP et al. Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. Radiology. 2004; 231(2):393-8.
3. Brenner DJ, Hall EJ. Computed Tomography: An Increasing Source of Radiation Exposure. NEJM. 2007; 357:2277-2284
4. McCollough et al. In Defense of Body CT. *AJR* 2009; 193:28-39

# Summary

- CT use increasing, and doses can result in harm
- Knowledge limited, so radiologists should act as consultants
- www.ImageWisely.org has resources that can help
- Benefit to knowing local doses
- Optimizing protocols helps control dose

# Thank you for your time

David.Leswick@saskatoonhealthregion.ca

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CANCER

# CT Scans in Childhood Can Triple the Risk of Cancer

By Alice Park | June 07, 2012 | Add a Comment

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Having multiple CT scans in childhood may triple the risk of certain cancers, according to a new study.

MICHELLE DEL GUERCIO / GETTY IMAGES

In the first study of its kind, researchers from the U.S., U.K. and Canada worked for nearly 20 years, tracking cancer rates among children who had had CT scans during their first 15 years of life and comparing them to children who did not have the same exposure to radiation from the scans. Researchers found that children who had had two to three CT scans in childhood had triple the risk of later developing brain tumors, and children who had had five to 10 scans also had three times the risk of

- References study by showing that children with 2-3 CT scans had 3x risk brain cancer and 5-10 CT scans had 10x risk leukemia(2). Scans between 1985-2002
- Pearce "We need to make sure that everyone knows that yes, we've shown a significant increased risk of cancer, but the absolute risk is small"


1. http://healthland.time.com/2012/06/07/ct-scans-in-childhood-can-triple-the-risk-of-cancer/ June 7, 2012. Access April 23, 2013
2. Pearce et al. "Radiation exposure from CT scans in childhood and subsequent risk of leukemia and brain tumors: a retrospective cohort study. Lancet. (2012) 380(940): 499-505

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MICHELLE DEL GUERCIO / GETTY IMAGES

- Parents should ask:
  - “is there an alternative to CT scans that can answer the medical question?”
  - “does the facility adjusts doses of radiation for children?”

1. http://healthland.time.com/2012/06/07/ct-scans-in-childhood-can-triple-the-risk-of-cancer/ June 7, 2012. Access April 23, 2013
2. Pearce et al. “Radiation exposure from CT scans in childhood and subsequent risk of leukemia and brain tumors: a retrospective cohort study. Lancet. (2012) 380(940): 499-505

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- Frush "doses today are lower, approximately 50% lower than at time of study"
- Balance risk with potential benefit as the scans are done for clinical reasons


1. http://healthland.time.com/2012/06/07/ct-scans-in-childhood-can-triple-the-risk-of-cancer/ June 7, 2012. Access April 23, 2013
2. Pearce et al. "Radiation exposure from CT scans in childhood and subsequent risk of leukemia and brain tumors: a retrospective cohort study. Lancet. (2012) 380(940): 499-505