Cumulative Radiation Dose Recording and Monitoring: Are We Ready?

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No Disclosures
National Medical Radiation Tracking: Regulatory Requirements

There are none.....
Recurrent CT, Cumulative Radiation Exposure, and Associated Radiation-induced Cancer Risks from CT of Adults

Purpose:
To estimate cumulative radiation exposure and lifetime attributable risk (LAR) of radiation-induced cancer from computed tomography (CT) scanning of adult patients at a tertiary care academic medical center.

Materials and Methods:
This HIPAA-compliant study was approved by the Institutional Review Board with waiver of informed consent. The cohort comprised 31,482 patients who underwent diagnostic CT in 2007 and had undergone 392,712 CT examinations over the prior 26 years. Each patient's cumulative CT radiation exposure was estimated by summing typical CT effective doses, and the Biological Effects of Ionizing Radiation (BEIR) VII methodology was used to estimate LAR on the basis of sex and age at each exposure. BEIR VII C250 codes and electronic order entry information were used to identify patients with LAR greater than 1%.

Results:
Thirty-three percent of patients underwent five or more lifetime CT examinations, and 2% underwent between 25 and 132 examinations. Fifteen percent received estimated cumulative effective doses of more than 100 mSv, and 4% received between 250 and 1320 mSv. Associated LAR had mean and maximum values of 0.3% and 12% for cancer incidence and 0.2% and 6.2% for cancer mortality, respectively. CT exposures were estimated to produce 0.2% of total expected lifetime cancer incidence and 1% of total cancer mortality. Seventeen percent of the cohort had estimated LAR greater than 1%, of which 40% had either no malignant history or a cancer history without evidence of residual disease.

Conclusion:
Cumulative CT radiation exposures added incrementally to baseline cancer risk in the cohort. While most patients acquire low radiation-induced cancer risks, a subgroup is potentially at higher risk due to recurrent CT imaging.

Sodickson et al Radiology 2009; 251
Retrospective: CT Examinations

- 33% > 5 CTs
- 5% 22-132
- 15% ED > 100 mSv
- 4% 250 -1375 mSv
- 1% >399 mSv
Imaging Examination Radiation

- **0.2% of enrollees >20 mSv**
  - ✔ Fazel 2009 NEJM 361

- **SAH: mean dose 12.8 Gy (max 36.1 Gy)**
  - ✔ Moskowitz 2010 Am J Neuroradiol 31

- **Other investigations:**
  - ✔ Chronic illness (Stein 2010 JACR 7)
  - ✔ Emergency setting (Griffey and Sodickson 2009 AJR 192)
  - ✔ Pediatric cardiology (Ait-Ali 2010 Heart 96)
  - ✔ Oncology: max 642 mSv (Ahmed 2010 Pediatrics 126)
...13 fold variation in CT dose

(although...a far greater evil is having no variation).
“I am contacting you to ask about the radiation exposure my son has had when having a CT angiogram ... Can I make the radiation exposure request or does his physician need to? Here is my son’s information and the date of his CT angiogram. I am wanting to get his radiation exposure in a file for his health history. Thank you for your time.”
But we really don’t know if there is a risk with low level exposures...

....true, bit doesn’t matter.
If we don’t control this, someone will for us.

We have a responsibility to know individual and cumulative (CT) dose, and what this does or doesn’t signify.

- Patients
- Colleagues
- Regulatory organizations
X-rays, CAT scans, fluoroscopy (including angiography/angioplasty), and nuclear medicine exams all cause ionizing radiation to be delivered to the body, which can cause cancer. Over the last 15 years, the use of medical imaging has been rapidly increasing. There have been recent estimates that up to 7.2% of all cancers within the US are caused by radiation from CAT (CT) scans.

The purpose of Radiation Passport is to educate about the radiation and cancer risks associated with medical imaging exams and procedures that physicians (and dentists) want you to undergo, to keep track of radiology and imaging-related exams and procedures, and to provide an estimate of risk of developing cancer because of this radiation.

The radiation exposure and associated risk numbers are based on published scientific journal papers, however, are in each case an estimate. There are different methods by which to estimate the associated risk.
This bill would, commencing July 1, 2012, require hospitals and clinics, as specified, that use computed tomography (CT) X-ray systems for human use to record, if the CT systems are capable, the dose of radiation on every CT study produced during the administration of a CT examination, as specified. The bill would require the dose to be verified annually by a medical physicist, as specified, unless the facility is accredited.

SB 1237, Padilla. Radiation control: health facilities and clinics: records.

Under existing law, the State Department of Public Health licenses and regulates health facilities and clinics, as defined.

Under existing law, the Radiation Control Law, the department licenses and regulates persons that use devices or equipment utilizing radioactive materials. Under existing law the department may also require registration and inspection of sources of ionizing radiation, as defined. Violation of these provisions is a crime.

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What is a Botswanan pula? 1,218,060 pulas?
= $180,000 US

= 1,218,060 P
(Botswana)

http://www.netcarshow.com/ferrari/2003-360_chALLENGE_STRADALE/800x600/wallpaper_01.htm
June 30, 2011

To: Jane Doe
555 Main Street
Anywhere, NC 12345

Dear Ms. Doe,

This letter is to inform you that you had 10 or more CT scans in 2010. This is more than most people get in a year. Medicaid records show that you went through a CT scanner ## times in 2010.

CT scans, sometimes called CAT scans, expose you to radiation while taking a picture of what is inside your body. Too much radiation can be bad for your health. It can increase your chances of getting some kinds of cancer.

Sometimes CT scans are important for doctors to see what is going on when you are sick or hurt. But sometimes there may be other ways to figure out what is wrong.

If a doctor treating you does not know you well or have your medical records, that doctor will not know how many CT scans you have had. It is important for you to remind them of this information. Showing your doctors this letter will help them treat you as safely as possible. Please take this letter with you when you go to the emergency department or doctor’s office.

Call 1-800-662-7030 if you have any questions.

Please call [enrollment office number] for help finding a primary care doctor in your town.

Wishing you the best of health,
Right dose

3. Adhere to ALARA guidelines as required by the Nuclear Regulatory Commission. The ALARA acronym stands for “as low as reasonably achievable” – making sure doses are as low as possible while achieving the purposes of the study.16

4. Adhere to the Society for Pediatric Radiology’s Image Gently guidelines when providing imaging radiation (or fluoroscopy) to children.17,18,20,21 and, for adults, adhere to the Image Wisely guidelines (developed by the American College of Radiology and the Radiological Society of North America in collaboration with the American Association of Physicists in Medicine and the American Society of Radiologic Technologists).22

5. Provide physicians and technologists with reference doses based on anatomy, purpose of the study, and patient size. Establish appropriate dose ranges for high-volume and high-dose diagnostic imaging studies.

6. Radiologists should assure that the proper dosing protocol is in place for the patient being treated.

7. Institute a process for the review of all dosing protocols either annually or every two years to ensure that protocols adhere to the latest evidence.

8. Investigate patterns outside the range of appropriate doses. Track radiation doses from exams repeated due to insufficient image quality or lack of availability of previous studies to identify the causes. Address and resolve these problems through education and other measures.23

9. Record the dosage or exposure as part of the study’s summary report of findings.

See relevant Joint Commission requirements:
LD 04.04.07 (hospital and critical access hospital);
LD 04.04.09 (ambulatory)
Cumulative Dose

Cumulative radiation record, ... but also more accurate dose estimations and significance of these estimations:

- Reference levels
- Age/gender appropriate risks
Pediatric CT Dose Estimation

AAPM TG 204 report
April 2011

http://www.aapm.org/pubs/reports/RPT_204.pdf
Cumulative Dose

- Consensus development
- Simple
- Meaningful
- Consistent
  - across specialties
  - across geographies
- Commutable
- Protected
- Electronic medical record
Must become automated...

• Track individual patient doses, and
• Track institutional dose profile
Computed Tomography

Criteria:
- Age: [min] [max]
- Gender: [ALL]
- Institution: 
- Protocol: 
- Description: 
- Body Part: [ALL]
- Dose (mSv): [min] [max]
- Include Cumulative Dose

Courtesy Olav Christianson, RAIL
Duke Rad Tracker

Patient Name: 
Accession Number: 
Patient ID: 
Exam Description: PET SKULLBASEMIDTHIGH

<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>
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<tr>
<td>200</td>
<td>Axial</td>
<td>1373.250-1373.250</td>
<td>14.58</td>
<td>14.56</td>
<td>Body 32</td>
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<tr>
<td>2</td>
<td>Helical</td>
<td>59,000-1919,680</td>
<td>12.48</td>
<td>1198.50</td>
<td>Body 32</td>
</tr>
</tbody>
</table>

Total Exam DLP: 1213.06

1/1

Optical Character Recognition

Courtesy Olav Christianson, RAIL
Dose and Risk Calculations

**Effective Dose**

\[ E = \sum_T w_T H_T \]  
(ICRP 103)

average over gender and age groups

**Risk Index**

\[ R = \sum_T r_T H_T \]  
(BEIR VII)

tissue-, gender-, and age-specific


Courtesy Ehsan Samei, PhD
### Duke Rad Tracker: 20 Yr Old

<table>
<thead>
<tr>
<th>Organ</th>
<th>k (mSv/mGy-cm)</th>
<th>q (cases/10,000 exposed/mGy-cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gender averaged*</td>
<td>male</td>
</tr>
<tr>
<td>chest-abdomen-pelvis</td>
<td>0.018</td>
<td>0.016</td>
</tr>
<tr>
<td>chest</td>
<td>0.025</td>
<td>0.018</td>
</tr>
<tr>
<td>abdomen-pelvis</td>
<td>0.018</td>
<td>0.017</td>
</tr>
<tr>
<td>abdomen</td>
<td>0.023</td>
<td>0.018</td>
</tr>
<tr>
<td>pelvis</td>
<td>0.011</td>
<td>0.016</td>
</tr>
<tr>
<td>adrenals</td>
<td>0.026</td>
<td>0.021</td>
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<tr>
<td>liver</td>
<td>0.026</td>
<td>0.019</td>
</tr>
<tr>
<td>kidneys</td>
<td>0.020</td>
<td>0.017</td>
</tr>
<tr>
<td>liver to kidneys</td>
<td>0.024</td>
<td>0.018</td>
</tr>
<tr>
<td>kidneys to bladder</td>
<td>0.015</td>
<td>0.017</td>
</tr>
<tr>
<td>head</td>
<td>0.0014</td>
<td>0.0013</td>
</tr>
<tr>
<td>neck</td>
<td>0.0051</td>
<td>0.0043</td>
</tr>
<tr>
<td>head and neck</td>
<td>0.0034</td>
<td>0.0030</td>
</tr>
</tbody>
</table>

* Per its definition, effective dose was calculated using gender-averaged organ dose values.

*q in units of cases /10,000 exposed /mGy-cm*
Duke Rad Tracker: QA/QI

Courtesy Olav Christianson, RAIL
Challenges: denham article

• Types of procedures
  – diagnostic
  – interventional

• All ages?

• What should be recorded?
  – procedure?
  – units: ED? Organ dose? CTDI/DLP?
  – risk indices?

• How archived?
  – in report?

• Who is responsible?
Cumulative Dose

- Responsibility for monitoring?
- Will it change practice?
- Will it change quality of care?
Cumulative Dose

Will it Change Practice?

We don’t order studies…
change must involve referring healthcare providers
Available at Point of Care??

CT dose 10 mSv
Risk est. = xx
Prior CTs = yy

Sistrom et al. Radiology 2009; 251: 147
Cumulative Radiation Exposure and Cancer Risk Estimates in Emergency Department Patients Undergoing Repeat or Multiple CT

OBJECTIVE: The purpose of our study was to define a comprehensive estimate of the number of patients undergoing repeat or multiple emergency department CT studies and to quantify their cumulative CT radiation doses and lifetime attributable risk of developing cancer.

MATERIALS AND METHODS: We identified all patients at a tertiary care adult academic medical center with at least one emergency department visit within a 1-year period that included CT of the head, chest, abdomen, or pelvis. For this cohort, we identified all diagnostic CT studies over the previous 7 years. We calculated cumulative radiation doses by summing total effective doses of the anatomic regions scanned, and we calculated lifetime attributable risk using the populations-averaged dose-to-effect conversion factors of one cancer per 1,000 patients receiving a 10-mSv dose in accordance with the seventh Biologic Effects of Ionizing Radiation (BEIR VII) report.

RESULTS: One hundred thirty-three emergency department patients met the inclusion criteria. Over the 7-year period, median, mean, and maximum values for the study group were 10, 13, and 70 with cumulative CT doses of 31, 132, and 570 mSv and lifetime attributable risk of one in 100, one in 20, and one in 15, respectively. Emergency department studies comprised 54% of these patients. Repeat imaging of the same study type represented at least half of the imaging for 75% of the cohort and all of the imaging for 25%.

CONCLUSION: A small proportion (18%) of emergency department patients undergoing CT of the head, chest, abdomen, or pelvis have high cumulative rates of multiple or repeat imaging. Collectively, this patient subgroup may have a lifetime risk of developing cancer from cumulative CT radiation exposure.

In many ways, CT has transformed care for emergency department patients and is to the techniques of choice for a wide range of indications because of its timely and reliable diagnostic information it provides. The use of CT, particularly in the emergency department, has grown dramatically in the past decade [1-3], spurred by rapid technological advances, imaging speed, and widespread access to CT. This has heightened concerns about appropriateness, cost control, and resource utilization in both emergent and non-emergent settings. In addition, risks from cumulative radiation exposure have recently received more widespread attention [1, 2, 4-7]. Awareness of radiation risk is making its way into clinical medical practice and may play a larger role in future validation reviews and prospective regulations [1].

Increased CT use has resulted in growing rates of repeat or multiple imaging in various patient populations. In 2005, West et al. [1] found that 10% of all patients undergoing CT in their institution had more than one CT study in the same year, even if no previous CT studies had been performed. They noted that CT examinations in the emergency department were rarely performed to rule out disease, and they suggested that the use of CT in the emergency department was often inappropriate [1].

Conclusion

A small cohort of emergency department patients undergoing CT accreates cumulative radiation doses from frequent or recurrent CT both in the emergency department setting and overall, which may place them at higher risk for subsequent radiation-induced carcinogenesis. Individualized radiation risk assessment to identify and risk stratify such groups on the basis of cumulative dose estimates is one way of informing clinicians at the point of ordering how further imaging impacts the risk-to-benefit equation. At that point, recommendations for imaging with or without the establishment of institutional protocols for addressing such scenarios may offer options to the clinician faced with the decision of whether to image again.
Recording Radiation Dose: Cumulative CT Radiation Record

Will it change quality of care? ...

- if accountability is a component of quality,
- if we are a major stakeholder,
- if information is meaningful and available,
  .... then yes