Summary

Radiation Exposures from Imaging and Image-Guided Interventions

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From the Preface

"... This monograph purports to be scientific in that it seeks to answer the question, rather than to argue in support of a preconceived answer. It attempts to be practical in that it endeavors to extract meaning from a specific set of data their..."
Risks from “higher dose” radiological imaging procedures

Are they real?

... and if so, what can be done?
Session I: Sources of Exposure

Frequency of CT scans per year

[Graph showing the increase in CT scans per year in the UK and USA from 1980 to 2005.]
Taking onto account

* Machine variability,
* Usage variability,
* Age variability,
* Multiple scans (mean 2)

the relevant organ dose range for CT is

5 - 100 mSv
Mean individual total radiation dose in the US: 1980 vs. 2007

1980: 3.6 mSv
2007: 6.3 mSv
Dose rate: 20 – 40 mGy/min

Dose rate: ~250 mGy/min

From Louis Wagner’s talk
Architecture of the Radiation Dose Received from Nuclear Medicine Studies

- Cardiac imaging agent
- Increased use due to limited supply of $^{99m}\text{Tc}$
- Effective dose $\approx 15\text{mSv}$

Whole Body Distribution of $^{201}\text{Tl}$ Chloride

From Roger Howell’s talk
Mammography

- In the next few slides I will discuss mammography as a comprehensive example....
- education, a general consensus as to good practice,
- voluntary standards, and finally
- regulatory (Mandatory) Standards, with the Mammography Quality Standards Act of 1992 (MQSA).

From Orhan Suleiman’s talk
Session II: Risks
Number of solid cancers in A-bomb survivors exposed to doses from 5-100 mSv

<table>
<thead>
<tr>
<th>Study population (5-100 mSv)</th>
<th>Cancer incidence (1958-98)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solid cancers observed</td>
<td>27,789</td>
</tr>
<tr>
<td>Solid cancers expected (controls)</td>
<td>4,406</td>
</tr>
<tr>
<td>Radiation-related excess solid cancers</td>
<td>81</td>
</tr>
</tbody>
</table>

Small but statistically significant increase in risk

Preston et al 2007
The A-bomb data are for individuals of all ages.... what about just children?
Estimating cancer risks from radiological exams, such as CT

- Risk estimation based on organ doses and current "generic" risk estimates
- Direct epidemiology on people who received CT scans
Estimated percent lifetime radiation cancer mortality risk for a single CT exam

![Graph showing estimated lifetime attributable risk for abdominal and head CT scans at different ages with 200 mAs exposure.](image-url)
Epidemiological studies of cohorts of patients who had pediatric CT

- Ongoing or just starting:
  - UK ~200,000 children (Mark Pearce)
  - Ontario: ~275,000 children
  - Israel: ~80,000 children
  - Australia ~150,000 children
Session III Dose / Risk Reduction

Reduce the dose per scan

Minimize unnecessary imaging

Use other imaging modalities where possible
Reducing the dose per scan

1. Patient-size adapted mA
   - Lower mA
   - Higher mA

2. z-axis modulation
   - Lower mA
   - Higher mA

3. angular modulation
   - Higher mA
Image Gently: A Template for Change

Donald P. Frush, MD
Pediatric Radiology
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Estimated % lifetime attributable cancer mortality risk, as a function of age at exam, for a single CT exam.
Can CT usage be reduced? (or the rate of increase slowed?) without compromising patient care....
Can CT usage be reduced? 
(or the rate of increase slowed?)

without compromising patient care....

Some common potential CT scenarios where there is evidence that CT usage could potentially be reduced

- CT for renal colic
- CT for minor head trauma
- CT for abdominal pain
- CT for abdominal and chest trauma
- CT angiography for pulmonary embolus
What proportion of CT scans could potentially be avoided?

Many retrospective studies have been reported of the proportion of CT scans that could have been avoided if CT decision rules had been applied.

<table>
<thead>
<tr>
<th>CT Decision Rule for mild traumatic brain injury</th>
<th>Sensitivity</th>
<th>Percent of CT scans that would be avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canadian</td>
<td>0.99</td>
<td>44</td>
</tr>
<tr>
<td>NCWFNS</td>
<td>0.96</td>
<td>44</td>
</tr>
<tr>
<td>New Orleans</td>
<td>0.99</td>
<td>31</td>
</tr>
<tr>
<td>Nexus-II</td>
<td>0.97</td>
<td>44</td>
</tr>
<tr>
<td>NICE</td>
<td>0.99</td>
<td>39</td>
</tr>
<tr>
<td>Scandinavian</td>
<td>0.96</td>
<td>50</td>
</tr>
</tbody>
</table>

Stein et al 2009
Can CT usage be reduced? (or the rate of increase slowed?) without compromising patient care....

- A significant fraction of CT scans ($\frac{1}{3}$ ??) could practically be replaced by alternate approaches, or need not be performed at all
- Targeting this “one third” is more than just a challenge
- Physicians are subject to significant pressures:
  - Throughput
  - Legal
  - Economic
  - From patients

Clinical Decision Rules
200 trauma patients studied, who had some radiation imaging

- 169 had CT scans
- Total number of CTs: 660
- Cost $837,000

Had ACR Appropriateness Criteria been applied.....

- 44% of CTs would not have been carried out
- None of the major injuries would have been excluded from CT imaging
- 11 minor injuries, none of which required follow up, would have been excluded from CT imaging
- 39% decrease in cost
Clinical Decisions Rules: Awareness and Use

The Canadian CT Head Decision Rule, among US ER physicians (n=239)

Aware of the decision rule: 31%
Use the decision rule: 12%

Most significant factor for usage was “teaching vs. non teaching hospital”

Eagles et al 2008
Three potential approaches towards increased utilization of CT decision rules

1) **Promote increased awareness of radiation issues**

2) **Incorporate decision rules into a computerized radiology order entry system**

3) **Build decision rules into a managed care preauthorization program**
Three potential approaches towards increased utilization of CT decision rules

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### MGH Radiology Order-Entry and Decision-Support System

**HEAD CT**

At least one box MUST be selected from either of the following groups

**SIGNS / SYMPTOMS**

- Acromegaly
- Speech changes (or Aphasia), new or progressive
- Concussion mild or moderate acute, no neurological deficit
- Coordination changes, new or progressive
- Dementia
- Head injury mild or moderate acute, no neurological deficit
- Headache
- Hyperprolactinemia
- Pain in face
- Weakness- right side / left side / both
- Acute visual deficit (other than photophobia and aura)
- Syncope/fainting
- Signs of meningeal irritation (such as stiff neck)
- Arteriovenous malformation
- Head injury moderate or severe acute, stable
- Head injury moderate or severe acute, subacute
- Head injury moderate or severe acute, chronic
- Mental Status change (after trauma)
- Sensation loss
- TIA with transient neurological disturbance
- Mass or lump
- Vision changes
- Signs of increased intracranial pressure (such as funduscopic exam)
- Abnormal gait (Ataxia)
- Seizures new or progressive
- Cranial nerve palsy (specify): ___
MGH Radiology Order-Entry and Decision-Support System: Effect on Outpatient CT Volume

Before decision support rules

Decision support rules in effect
Three potential approaches towards increased utilization of CT decision rules

1) Promote increased awareness of radiation issues

2) Incorporate decision rules into a computerized radiology order entry system

3) **Build decision rules into a managed care preauthorization program**
At the Beth Israel Deaconess ER, a CT preauthorization program did not change CT usage patterns

Smulowitz et al. 2009
Conclusions

I: Are CT / nuclear medicine risks real?

- The suggestion is that organ doses (5-100 mSv) will produce a small increase in individual cancer risk..... Is this
  a) Based fairly directly on epidemiological evidence?
  b) “Extrapolated from high radiation dose exposures studied in the Atomic Bomb experience”?

- 5 to 100 mSv is the same dose range for which there is a statistically significant increase in risk in A-bomb survivors

- That being said, we await the results of the epidemiological studies over the next few years....
Conclusions

II. Even if the risks from CT / nuclear medicine are real, the individual risks are small

- The concern is really about the population exposure from 70 million CT scans (+ other higher dose imaging scans) per year
Conclusions

III. The CT-related population exposure can be reduced

- Reduce the dose per scan
  - (feasible and getting done)

- Reduce the number of clinically unwarranted imaging procedures
  - (very hard, but possible)