CT Imaging: The Benefits are Worth the Responsibilities

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Acknowledgement

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Benefits’ of CT

- Standard Axial Imaging
  - Superb Anatomic Depiction
    - Head to toe
  - Innumerable Diagnoses
    - Confirmed
    - Excluded
Hepatoma

Invasion of Gastrohepatic Ligament, Stomach
Sigmoid Volvulus

Bird’s Beak
‘Benefits’ of MDCT

• New uses of CT imaging
  – Renal/Ureteral Stone CT
  – CT “Virtual” Colonoscopy
  – CT Angiography of Head, Pulmonary Vessels, Aorta and Extremities
  – Coronary CT Angiography
Impacted Stone
Lt. UVJ

Edema in
Lt. Trigone
9 mm Tubular Adenoma: Asc Colon
“Missed patch” tool

- Shows colonic wall not displayed with auto-centerline
- Useful in cases with limited distention

Courtesy of Perry Pickhardt, M.D.
Motorcycle Accident

? Arterial Injury
Motorcycle Accident

Occluded Left Anterior Tibial Artery
example of coronary artery with a heavy plaque burden

Courtesy of Kevin Johnson, M.D.
Diffuse Plaque in Proximal LAD

Courtesy of Kevin Johnson, M.D.
Diffuse Plaque in Proximal LAD

Courtesy of Kevin Johnson, M.D.
Triple Rule-Out:

Aortic Dissection
Pulmonary Emboli
Coronary Artery Disease
Acute Chest Pain: Gated CTA
Hybrid Imaging:

- PET/CT
- CT Colon
- CT Angio
Radiation Exposure from CT

Collective dose to population rising

• High radiation dose per examination
  – Compared to plain radiography
• Increasing number of indications
• Increasing availability
• Easier to perform
• Faster
Unnecessary CT scans exposing patients to excessive radiation

Study: Cancer cases could spike as result

By Steve Sternberg
USA TODAY

Overuse of diagnostic CT scans may cause as many as 3 million excess cancers in the USA over the next two to three decades, doctors report today.

Researchers say they're not trying to discourage all use of CT scans — CT stands for computed tomography — which superimpose multiple X-ray images to make 3-D pictures. Rather, they say, CT scanning is an invaluable tool in many cases. The problem is that doctors too often overlook its risks.

"About one-third of all CT scans that are done right now are medically unnecessary," says David Brenner of Columbia University, lead author of the study reported in today's New England Journal of Medicine.

CT scans offer an unparalleled window into the human body, and the use has grown dramatically in recent decades as doctors use them to identify ailments in the head, abdomen and heart.

Today, about 62 million CT scans are performed nationwide every year, up from 3 million in 1980, the authors say. Medical exposure to radiation, mainly through CT scans, has replaced environmental radon as the dominant source of radiation exposure for the U.S. population, the doctors say.

"On average, we now get double the radiation exposure we got in 1980 because of increased CT scans," Brenner says. "Virtually anyone who presents in the emergency room with pain in the belly or a chronic headache will automatically get a CT scan. Is that justified?"

University of New Mexico radiologist Fred Mettler, who was not part of the study, agrees that CT scans are overused. "We're always behind on CT scans because of demand from clinicians," he says.

As many as 5 million scans are now done in children, who are 10 times more sensitive to radiation than adults. The increase was driven by technical advances that allow doctors to capture images in less than a second, eliminating the need for anesthesia to keep a child from moving.

And the use of the scans continues to grow, Brenner says. Doctors are scanning smokers and ex-smokers for early-stage lung cancer, a highly controversial practice; they're using non-invasive "virtual" colonoscopies to check for colon cancer; and CT angiography is now being tested as a possible complement to ordinary angiography as a way to diagnose blockages in arteries leading to the heart.

In critiquing a study on CT angiography at an American Heart Association meeting in Orlando last month, Michael Lauer of the National Heart, Lung and Blood Institute called that practice into question. He said there is no evidence of benefit from the technology, and a real concern for harm.

New machines being developed by Philips and Toshiba for CT angiograms, however, may be safer because they emit 80% less radiation than standard CT scanners, Brenner says.

Brenner and his co-author, Eric Hall, also of Columbia, say many doctors don't realize that just a scan or two can bathe a patient in roughly the same amount of radiation as the atomic bomb delivered to the Japanese survivors of Hiroshima and Nagasaki standing a mile or two from ground zero. And many people receive multiple scans over a lifetime.

The amount of radiation delivered during a single CT scan can range from 1,000 to 10,000 millirems, depending on the machine and the protocol. Japanese survivors a mile or two from ground zero received about 3,000 millirems on average.

The cancer rates in the new study were drawn directly from a joint $1 billion study of the bomb survivors financed by the United States and Japan.
Steps to Control Radiation Exposure

Appropriate Utilization

• Tailor exam to the patient/application
  – Reduce dose as such as possible
• CT vs. other imaging tests
• Avoid un-necessary / repetitive studies
Steps to Control Radiation Exposure

Appropriate Utilization

• Tailor exam to the patient/application
  – Reduce dose as such as possible

• CT vs. other imaging tests

• Avoid un-necessary / repetitive studies
### ACR Appropriateness Criteria

<table>
<thead>
<tr>
<th>Topic</th>
<th>Variant</th>
<th>Test</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>Arteriography visceral</td>
<td>8</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>X-ray chest</td>
<td>8</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>Tc-99m labeled RBC scan liver</td>
<td>6</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>Tc-99m sulfur colloid scan liver</td>
<td>6</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>X-ray barium swallow and upper GI ser</td>
<td>4</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>US liver with Doppler</td>
<td>4</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>CT abdomen</td>
<td>4</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>CT chest</td>
<td>4</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>MRI with or without MRA/MRV abdomen</td>
<td>4</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>Wedge venography liver</td>
<td>4</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>No history of alcoholism or liver disease.</td>
<td>Slenoportography</td>
<td>2</td>
</tr>
</tbody>
</table>

- 167 Topics, > 800 Variants
- 7578 Topics / Variants / Tests:
- CT is listed as a possible test in 931 / 7578 (12%)
**ACR Appropriateness Criteria - Hematemesis**

**Variant 2:** No history of alcoholism or liver disease.

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteriography visceral</td>
<td>8</td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>X-ray chest</td>
<td></td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Tc-99m labeled RBC scan</td>
<td></td>
<td></td>
<td>Med</td>
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<tr>
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<td></td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>X-ray barium swallow</td>
<td></td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>US liver with Doppler scan</td>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>CT abdomen</td>
<td></td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>CT chest</td>
<td></td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>MRI with or without MRA abdomen</td>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Wedge venography liver</td>
<td>4</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>Splenoportography</td>
<td>2</td>
<td></td>
<td>NS</td>
</tr>
</tbody>
</table>

**Relative Radiation Level Designations**

<table>
<thead>
<tr>
<th>Relative Radiation Level*</th>
<th>Effective Dose Estimate Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Minimal</td>
<td>&lt; 0.1 mSv</td>
</tr>
<tr>
<td>Low</td>
<td>0.1-1 mSv</td>
</tr>
<tr>
<td>Medium</td>
<td>1-10 mSv</td>
</tr>
<tr>
<td>High</td>
<td>10-100 mSv</td>
</tr>
</tbody>
</table>

*Relative Radiation Level

**Rating Scale:** 1 = Least appropriate, 9 = Most appropriate
## Blunt Abdominal Trauma

### Unstable Patient

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray chest</td>
<td>8</td>
<td>To evaluate for fracture and abnormal air collection. Patient condition permitting.</td>
<td>Min</td>
</tr>
<tr>
<td>US chest abdomen and pelvis (FAST scan)</td>
<td>8</td>
<td>Rapid assessment of free fluid. Patient condition permitting.</td>
<td>None</td>
</tr>
<tr>
<td>X-ray abdomen and pelvis</td>
<td>8</td>
<td>To evaluate for fracture and abnormal air collection. Patient condition permitting.</td>
<td>Med</td>
</tr>
<tr>
<td>CT chest abdomen and pelvis with contrast</td>
<td>7</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Arteriography with possible embolization abdomen and pelvis</td>
<td>5</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>US abdomen and pelvis</td>
<td>3</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

**Rating Scale**: 1=Least appropriate, 9=Most appropriate

*Relative Radiation Level*
## Blunt Abdominal Trauma

### Stable Patient -- Hematuria

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<thead>
<tr>
<th>Radiologic Procedure</th>
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<th>Comments</th>
<th>RRL*</th>
</tr>
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<tbody>
<tr>
<td>CT chest abdomen and pelvis with contrast</td>
<td>9</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>X-ray chest</td>
<td>8</td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>X-ray abdomen and pelvis</td>
<td>7</td>
<td>To identify pelvic or spinal fracture.</td>
<td>Med</td>
</tr>
<tr>
<td>CT pelvis with bladder contrast (CT cystography)</td>
<td>6</td>
<td>Refer to text for indications.</td>
<td>High</td>
</tr>
<tr>
<td>X-ray retrograde urethrography</td>
<td>6</td>
<td>Refer to text for indications.</td>
<td>Med</td>
</tr>
<tr>
<td>Arteriography with possible embolization kidney</td>
<td>5</td>
<td>If CT identifies active site of bleed or arterial injury.</td>
<td>NS</td>
</tr>
<tr>
<td>X-ray cystography</td>
<td>4</td>
<td>CT cystography preferred.</td>
<td>Med</td>
</tr>
<tr>
<td>X-ray intravenous urography</td>
<td>3</td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>US abdomen and pelvis</td>
<td>3</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

**Rating Scale:** 1=Least appropriate, 9=Most appropriate  
**RRL*:** Relative Radiation Level
### Blunt Abdominal Trauma

#### Stable Patient – No Hematuria

<table>
<thead>
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<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT chest abdomen and pelvis with contrast</td>
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<td></td>
<td>High</td>
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<tr>
<td>X-ray chest</td>
<td>8</td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Arteriography with possible embolization abdomen and pelvis</td>
<td>5</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>US chest abdomen and pelvis (FAST scan)</td>
<td>5</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>X-ray abdomen and pelvis</td>
<td>4</td>
<td>Information provided by CT.</td>
<td>Med</td>
</tr>
<tr>
<td>US abdomen and pelvis</td>
<td>3</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**Rating Scale:** 1=Least appropriate, 9=Most appropriate  
**RRL*:** Relative Radiation Level

- CT is listed as “7, 8, or 9” in 285 / 931 (31%)
- CT is listed as “9” in 115 / 931 (12%)
“In high risk patients, CT should be avoided when an ultrasound or MRI is of comparable diagnostic utility”
RLQ Pain: Pregnant (26 wks)

Appendicoliths
RLQ Pain: Pregnant (32 wks)

Ureteral Calculus
### RLQ Pain in Pregnancy (w/ Fever, WBCs)

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
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<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>US abdomen RLQ</td>
<td>8</td>
<td>With graded compression. Better in first and early second trimester.</td>
<td>None</td>
</tr>
<tr>
<td>MRI abdomen and pelvis without contrast</td>
<td>7</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>US pelvis</td>
<td>6</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>CT abdomen and pelvis with contrast</td>
<td>6</td>
<td>Use of oral or rectal contrast depends on institutional preference.</td>
<td>High</td>
</tr>
<tr>
<td>CT abdomen and pelvis without contrast</td>
<td>5</td>
<td>Use of oral or rectal contrast depends on institutional preference.</td>
<td>High</td>
</tr>
<tr>
<td>X-ray abdomen</td>
<td>2</td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>X-ray contrast enema</td>
<td>2</td>
<td></td>
<td>Med</td>
</tr>
<tr>
<td>Tc-99m WBC scan abdomen and pelvis</td>
<td>2</td>
<td></td>
<td>Med</td>
</tr>
</tbody>
</table>

*Relative Radiation Level

**Rating Scale:** 1=Least appropriate, 9=Most appropriate

- US and MR are more appropriate than CT for RLQ pain in pregnant woman
Asymptomatic Patients

• CT Colonography
  – American Cancer Society endorsed CTC as screening test for colorectal cancer in 2008
  – Anticipated life-time risk of colorectal cancer = 5 – 6%
  – Potential risk of radiation-induced cancer from CTC*
    50 years      0.14%
    70 years      0.07%

(Benefit >> Risk)

*Brenner DJ, Georgsson MA. Mass screening with CT colonography: should the radiation exposure be of concern? Gastroenterology 2005:129;328-337
Steps to Control Radiation Exposure

Appropriate Utilization

• Tailor exam to the patient/application
  – Reduce dose as such as possible
• CT vs. other imaging tests
• Avoid un-necessary / repetitive studies
“I am an adult and a physician! I don’t need your approval for CT scans that are necessary for my patients”

Anon – ER Physician
Computed Tomography in Emergency Medicine – Ensuring Appropriate Use

September 23-24, 2009
Bethesda-Chevy Chase Rescue Squad Building
Anastasi Conference Room
Bethesda, Maryland
Physician Education

- Adult CT patients for abdominal pain
- Questioned about consent, radiation risk and CXR equivalents
- Same questions asked of ED physicians and radiologists

Physician Education

- 9% of referring physicians believed that there was an increased cancer risk from CT
- CXR Equivalents (%):

<table>
<thead>
<tr>
<th></th>
<th>&lt;1</th>
<th>1-10</th>
<th>10-100</th>
<th>100-250</th>
<th>&gt;500</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDs</td>
<td>7</td>
<td>44</td>
<td>22</td>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>Rads</td>
<td>5</td>
<td>56</td>
<td>15</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Pts</td>
<td>28</td>
<td>64</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- Medical Exposures Directive of Council of the European Union**
  - Strict referral criteria
  - Strict justification criteria
  - Dose optimization requirement
  - Dose exposure reference levels

*Ionizing Radiation (Medical Exposures) Regulations
**Council Directive 97/43 Euratom
Appropriate Utilization

“CT should be avoided when the benefit is marginal”
Repetitive CT for Renal Colic

- 6 year period
- 4562 patients
- 5564 CT examinations
- Mean age: 45 years
  - 4% of exams were in children

176 Pts (4%) had 3 or more Flank Pain CTs
Estimated Effective Dose

EFFECTIVE DOSE (mSv)

NUMBER OF FLANK PAIN CT EXAMS
Diagnostic Algorithm for Suspected PE

Suspect PE
Non Pregnant

- Use CCSS D-dimer/thrombosis screen to calculate pre-test probability
  - Kline neg and Wells ≤ 2
  - Kline pos or Wells > 2
    - D-dimer
      - CXR Optional
        - Contraindication* to contrast
          - Less than 280 lbs
            - VQ Scan
              - Normal or Low and Wells ≤ 2
                - STOP
              - High
                - Indeterminate or Low Wells > 2
                  - Doppler US Legs +/- consider treatment/admission
                    - STOP
                  - Indeterminate
                    - VQ Scan
                      - Normal or Low and Wells ≤ 2
                        - Indeterminate or Low Wells > 2
                          - Doppler US Legs +/- consider treatment/admission
                            - STOP
                          - Indeterminate
                            - Consult chest radiologist attending
                              - Interpretation
                                - Consult chest radiologist attending

PREGNANT PATIENT

- Doppler US Legs inform OB at discretion of ED Physician ED consent
  - Unstable
    - Clinical Assessment
      - > 380 lbs
        - Unstable
          - Consider Bedside ECHO
            - Consider: Heparin + TPA 100 mg/2hrs iv filters, CT Surgical consult
  - TREAT
    - Stabilize

CTPA

- Technical
  - Other tests
    - Repeat, if no contraindication at discretion of Radiologists
      - Severe allergic reaction
      - Renal Failure
        - Creatinine > 1.6
      - Inadequate IV smaller than 20g

*Contraindications
# Decision Support

**Effect of Computerized Order Entry with Integrated Decision Support on the Growth of Outpatient Procedure Volumes:**

**Seven-year Time Series Analysis**

<table>
<thead>
<tr>
<th>Radiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christopher L. Sistrom, MD, MPH</td>
</tr>
<tr>
<td>Pragya A. Dang, MD</td>
</tr>
<tr>
<td>Jeffrey B. Weilburg, MD</td>
</tr>
<tr>
<td>Keith J. Dreyer, DO, PhD</td>
</tr>
<tr>
<td>Daniel I. Rosenthal, MD</td>
</tr>
<tr>
<td>James H. Thrall, MD</td>
</tr>
</tbody>
</table>

**Purpose:**

To determine the effect of a computerized radiology order entry (ROE) and decision support (DS) system on growth rate of outpatient computed tomography (CT), magnetic resonance (MR) imaging, and ultrasonography (US) procedure volumes over time at a large metropolitan academic medical center.

*Radiology 2009; 251: 147-155*
## Decision Support

| Results: | There was a significant decrease in CT volume growth (274 per quarter) and growth rate (2.75% per quarter) after ROE and DS system implementation ($P < .001$). For MR imaging, growth rate decreased significantly (1.2%, $P = .016$) after ROE and DS system implementation; however, there was no significant change in quarterly volume growth. With US, quarterly volume growth ($n = 98$, $P = .014$) and growth rate (1.3%, $P = .001$) decreased significantly after ROE implementation. These changes occurred during a steady growth in clinic visit volumes in the associated referral practices. |
| Conclusion: | Substantial decreases in the growth of outpatient CT and US procedure volume coincident with ROE implementation (supplemented by DS for CT) were observed. The utilization of outpatient MR imaging decreased less impressively, with only the rate of growth being significantly lower after interventions were in effect. |

*Radiology 2009; 251: 147-155*
CT Utilization at MGH

# of CT scans ordered with CPOE/DS

Radiology 2009; 251: 147-155
PCP Practice Pattern Variation
MRI L Spine for low back pain

PCP MRI L-Spine Orders Per 1000 LBP Office Visits (Oct 07 - Jun 08)

Courtesy of
Ramin Khorasani, MD, MPH 2009
PCP use of MRI in patients with low back pain

Retrospective implicit and explicit chart review of random 50 of 927 patients over 17 months  
*RSNA 2005*
Appropriateness of L-Spine MRI for evaluation of low back pain by PCPs

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention</th>
<th>Post Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric: Adherence to evidence-based guidelines</td>
<td>42%</td>
<td><strong>&gt;90%</strong></td>
</tr>
</tbody>
</table>

*P* = <0.001
Decision Support

- Opportunity to guide the ordering physicians to the appropriate imaging test at the time of order entry
  - Widespread use when linked to CPOE

- Physicians -- incentivized to participate:
  - Avoiding need for pre-authorization from 3rd party payers

- Payers -- not incentivized to participate:
  - RBMs fulfill designated utilization management function
  - RBMs’ revenue is tied to dollars saved for 3rd party payer
  - Limited confidence that rules will mirror those of RBM
That’s all…