Reducing Unnecessary Radiation: Patient and Clinical History Specific Protocols

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Acknowledgments

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Unnecessary Radiation

- Important to tailor the CT exam to
  - Prescribed clinical protocol
  - Specific patient
- In order to address particular clinical questions
- Focused exams help avoid unnecessary imaging
- Thereby reduce unnecessary radiation
Unnecessary Radiation

Tailoring the CT exam

• Confining scan volume to region of interest
• Eliminating unnecessary series
• Scanning less frequently and/or substituting MRI or US for CT
• Selective dose reduction
Unnecessary Radiation

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Unnecessary Radiation

• Confine scan length to proper upper and lower anatomic boundaries for the body part being examined
• Reducing extra top and bottom scanning
Extra Scanning in Chest CTs

- 148 chest CT scans
- 98% of scans had supra-apical extraneous imaging
- 98% had infrapulmonary extraneous imaging
- Mean 7 cm extra imaging per study (range 0-16)
- ~ 1.5 cm supra-apical
- ~ 5.5 cm infrapulmonary

Campbell J. AJR 2005;185:1525
Extra Scanning in Chest CTs

- Supra-apical extraneous imaging
  - 0/145 showed additional findings
- Infrapulmonary extraneous imaging
  - 45/145 showed additional findings
  - Most findings not clinically significant, especially in patients without known malignancy

Campbell J. AJR 2005;185:1525
Extra Scanning in Chest CTs

• % of total radiation due to extraneous imaging
  • Fixed tube current: 21%
  • Z-axis tube current modulation: 57%
• ATCM bumped up mAs above and below the lungs
• Thyroid gland
• Abdominal organs

Campbell J. AJR 2005;185:1525
Extra Scanning in Abdominal/Pelvic CTs

- 106 abdomen and pelvic CT scans
- 97% of scans had extraneous imaging above diaphragm
- 94% had extraneous imaging below symphysis pubis
- Mean 6 cm extra imaging per study (range 0.5-18)
- ~3 cm above diaphragm
- ~3 cm below symphysis pubis

Kalra M. Radiology 2004;232:409
Extra Scanning in Abdominal/Pelvic CTs

- Supra-diaphragmatic extraneous imaging
  - 3/103 exams showed additional findings
  - Only one was clinically significant
- Below symphysis extraneous imaging
  - 0/98 exams showed additional findings
- Overall, extra images almost never gave clinically significant information

Kalra M. Radiology 2004;232:409
Extra Scanning in Abdominal/Pelvic CTs

• % of total radiation due to extraneous imaging
  • Fixed tube current: 13%
  • Z-axis tube current modulation: 17%

• Breasts
• Testicles

Kalra M. Radiology 2004;232:409
Clinical history specific protocols Already exist with upper/lower boundaries

- Renal stone protocol: kidneys \( \rightarrow \) pubis
- Adrenal evaluation: just adrenals
Extra Scanning: Associated Factors

- >400 consecutive CT exams: chest, abdomen, pelvis, thighs
- Variety of different disease specific scanning protocols (lung nodule, aorta, appendicitis, pulmonary embolus, etc.)
- Tabulated extra length scanned above and below prescribed borders for particular protocol used

Liao E. JCAT 2011;35:50
Extra Scanning: Associated Factors

- 99% of exams showed extraneous imaging
- Mean 4.3 cm, range 0 – 18 cm
- Mean 10% of total radiation due to extraneous imaging

Liao E. JCAT 2011;35:50

Pelvis CT
13 cm extra
Included entire scrotum
Extra Scanning: Associated Factors

Type of boundary

• Osseous
  • Iliac crests, lesser trochanters
• Air / soft tissue interface
  • Lung apices, aortic arch, diaphragm
• Soft tissue or vascular
  • Adrenals, celiac axis

Liao E. JCAT 2011;35:50
Extra Scanning: Associated Factors

Amount of extra length scanned depended on boundary type (p < .05)

Liao E. JCAT 2011;35:50
Extra Scanning: Associated Factors

- Increased patient BMI
- May obscure landmarks on scout images

Liao E. JCAT 2011;35:50
Extra Scanning

Possible contributing factors

• Technologist errors
  • Lack of training regarding anatomy and protocols (prescribed boundaries)
  • Extra to assure prescribed anatomy has all been included
  • Extra to include “abnormalities” seen on top or bottom images

• Patient movement between scout and axial scanning (uncooperative patient)
• Patient breathing (diaphragmatic motion)
Extra Scanning

Take away message:

• Potential for considerable radiation reduction by eliminating extraneous imaging

• Increase awareness of problem among techs: scope, contributing factors

• Assure adequate technologist training (anatomy, protocols)

• Consider very low dose localizer images for soft tissue or vascular boundaries
Unnecessary Radiation

Tailoring the CT exam

• Confining scan volume to region of interest
Unnecessary Radiation

Tailoring the CT exam

• Confining scan volume to region of interest
  • Revisit all protocols and revise specific protocols to reduce the prescribed scan length
  • Evidence based whenever possible
Protocol: Initial Staging of NSCLC

- CT chest; ?CT abdomen
- Most common sites of mets: brain, bone, liver, adrenal
- Previously: scan through entire liver
- ISOLATED liver mets rare
- Esp if mediastinal nodes are negative
- → Dedicated liver CT not necessary

Kligerman S. AJR 2009;193:1203
Protocol: Initial Staging of NSCLC

- Chest CT for T and N staging and for determining resectability
- Most patients undergo PET for initial staging: good for M staging
- If patient will get PET, limit diagnostic CT to thorax
- No need to scan liver and adrenals
Protocol: r/o Pulmonary Embolism

- Current protocols: diaph-apices
- Older protocols extended from diaphragmatic dome to just above aortic arch (tube cooling)
- How much would we miss by excluding the costophrenic sulci & the apices?
- Other causes of chest pain
- Use limited protocol for follow-up exams

Revel MP. Radiology 2005;234:265
de Monye W. Radiology 2000;215:184
Protocol: F/U Lung Nodule

• Fleischner society guidelines suggest follow-up intervals for lung nodules
• Benign, stable nodule: ≥ 3 scans over 2 years
• Radiate entire lung over & over for 1 small lesion (albeit, low dose scan)
• New nodules and other incidental findings discovered on each f/u scan → more scans / tests

MacMahon H. Radiology 2005;237:395
Protocol: F/U Lung Nodule

- If only one small, solid nodule or small cluster of nodules
- Specify location of lesion in report → rescan only that level
- More work for radiologist, slows throughput

MacMahon H. Radiology 2005;237:395
Protocol: Aortic Aneurysm

• Initial aortic exam of chest and abdomen, without and with contrast
• If aneurysm confined to ascending aorta, arch or proximal descending aorta →
• Follow-up scans of chest only
Unnecessary Radiation

Tailoring the CT exam

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Radiation Exposure from CTU
2005 Estimates: 10 Patients*

Single Bolus / Three Phase / 16 Row

<table>
<thead>
<tr>
<th>Phase</th>
<th>Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unenhanced (5mm)</td>
<td>3.9 (1.9 – 6.8)</td>
</tr>
<tr>
<td>Nephrographic phase (5mm)</td>
<td>6.4 (4.5 – 8.4)</td>
</tr>
<tr>
<td>Excretory phase (1.25 mm)</td>
<td>16.2 (11.0 – 25.0)</td>
</tr>
<tr>
<td>Total</td>
<td>26.6 (20.6 – 40.2) mSv</td>
</tr>
</tbody>
</table>


Estimated dose to a 5’10”, 170 lb male

*Rich Cohan
Radiation Exposure from CTU 2005 Estimates: 5 Patients*

Split Bolus / 16 Row

- Unenhanced (5mm) 3.8 (1.9 – 6.8)
- Nephrographic phase (5mm) 6.4 (4.5 – 8.4)
- Excretory phase (1.25 mm) 16.2 (12.0 – 22.0)
- Total 20.0 (14.1 – 28.3) mSv

120 Kv (all) UE: 80 – 200, NP: 230 – 410 EP: 400 – 480 mA

Same dose range for 64 row scanners

*Rich Cohan
Protocol: Split Bolus CTU

- Elimination of nephrographic phase series reduces radiation dose by ~25%
- Theoretical disadvantage: poorer opacification/distention of urinary tract
- Technique maintains high sensitivity and specificity for detection of urothelial tumors in collecting systems and pelvises

Chow LC. AJR 2007;189:314
Dillman JR. JCAT 2007;31:750
Kekelidze M. Radiology 2010;255:508
Protocol: CT Enterography

- Small bowel Crohn’s disease
- Arterial phase 40 s
- Venous phase 70 s
- No difference between two phases for detection of active disease
- At Univ Michigan we now do only venous phase imaging

Vandenbroucke F. Acta Radiol. 2007;23:1
**Protocol: r/o PE and DVT**

- Default: CTV of pelvis & lower extremities
- Pioped II:
  - Incidence of positive studies in pts without signs, sx, or hx of DVT is low
  - CT venography and Doppler showed similar results in dx or excluding DVT
- Some pts have already had Doppler
- Many pts are young, mult ED visits, CTs
- Consider eliminating CTV on case by case basis

Goodman LR. AJR. 2007;189:1071
Protocol: HRCT for ILD

- Routine HRCT (three series):
  - Supine helical insp (apices – bases)
  - Supine incremental exp (gaps)
    - Eval for air trapping
  - Prone incremental insp (gaps, mid and lower lungs)
    - Differentiate between dependent atelectasis and mild ILD
- All series not necessary for all pts
Protocol: HRCT for ILD

• Routine HRCT (three series):
  • Supine helical insp (apices – bases)
  • Supine incremental exp (gaps)
    • Eval for air trapping
  • Prone incremental insp (gaps, mid and lower lungs)
**Protocol: HRCT for ILD**

- Routine HRCT (three series):
  - Supine helical insp (apices – bases)
  - Supine incremental exp (gaps)
    - Eval for air trapping
  - Prone incremental insp (gaps, mid and lower lungs)
    - If no dependent disease, then prone not necessary!
    - ~13% of dose
Protocol: HRCT for ILD

- Radiologist needs to check ➔ advise tech
Protocol: HRCT for ILD

- ICU patient with presumed infection
  - Eliminate prone & exp images
Protocol: HRCT for ILD

- ICU patient with presumed infection
  - Eliminate prone & exp images
- F/u connective tissue disease
  - Prone only, apices to bases
  - Disease tends to be posterobasilar– suited to prone imaging
- Young women, many f/u scans
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Scanning Less Frequently

Aortic disease

• Annual follow-up CT for aortic aneurysms
• Change to biennial follow-up for aneurysms that are not large and have been shown to be stable
Substituting MR for CT

MR enterography for small bowel disease

- MR and CT fairly equivalent in assessing for involvement in Crohn’s disease
- MR may be superior in detecting intestinal strictures and ileal wall enhancement

Fiorino. Inflamm Bowel Dis. 2010 Nov 8
Jensen. Inflamm Bowel Dis. 2010 Nov 1
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Selective Dose Reduction

Nodule protocol chest CT

- Used in screening for occult lung cancer

- Also for f/u in cancers that tend to spread only to lungs (not mediastinum / hila), e.g. extrathoracic sarcomas

- Acceptable image quality in lungs with significant dose reduction (e.g. 60 mA)

Diederich S. Radiology 1999;213;289
Kalra MK. Radiology 2004;230:619
Selection Dose Reduction

CT enterography:
- Dose reduction techniques in patients with Crohn's disease
- Multiple follow-up exams

from Mahmoud Al-Hawary

Leng S. AJR 2010;195:76
Unnecessary Radiation

• Various ways to tailor the CT exam to
  • Prescribed clinical protocol
  • Specific patient
• Thereby reduce unnecessary radiation
• May require creative thinking, open mind, revisiting of standard protocols