Reducing Unnecessary Radiation: Patient and Clinical History Specific Protocols

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Acknowledgments

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Kirk Frey

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Joel Platt

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

Tailoring the CT exam

- **Confining scan volume to region of interest**
- **Eliminating unnecessary series**
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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

Extra Scanning

Clinical history specific protocols

Already exist with upper/lower boundaries

- **Renal stone protocol: kidneys → pubis**
- **Adrenal evaluation: just adrenals**

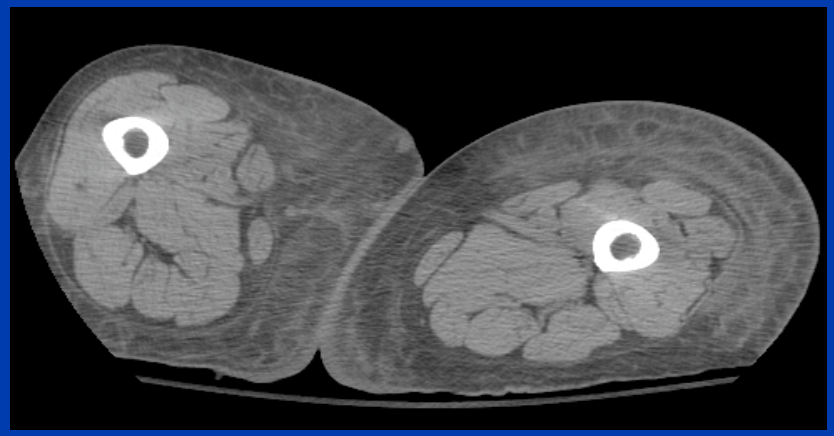
Extra Scanning: Associated Factors

- >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



Pelvis CT
13 cm extra
Included entire scrotum

Liao E. JCAT 2011;35:50

Extra Scanning: Associated Factors

Type of boundary

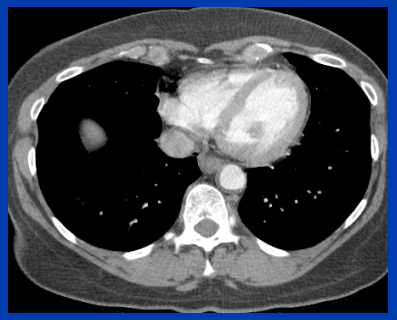
- Osseous
  - Iliac crests, lesser trochanters
- Air / soft tissue interface
  - Lung apices, aortic arch, diaphragm
- Soft tissue or vascular
  - Adrenals, celiac axis

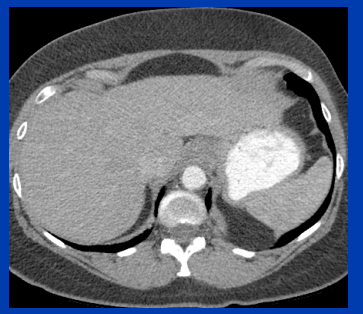
Liao E. JCAT 2011;35:50

Extra Scanning: Associated Factors

osseous | air/ soft tissue | soft tissue or vascular

least ← → most



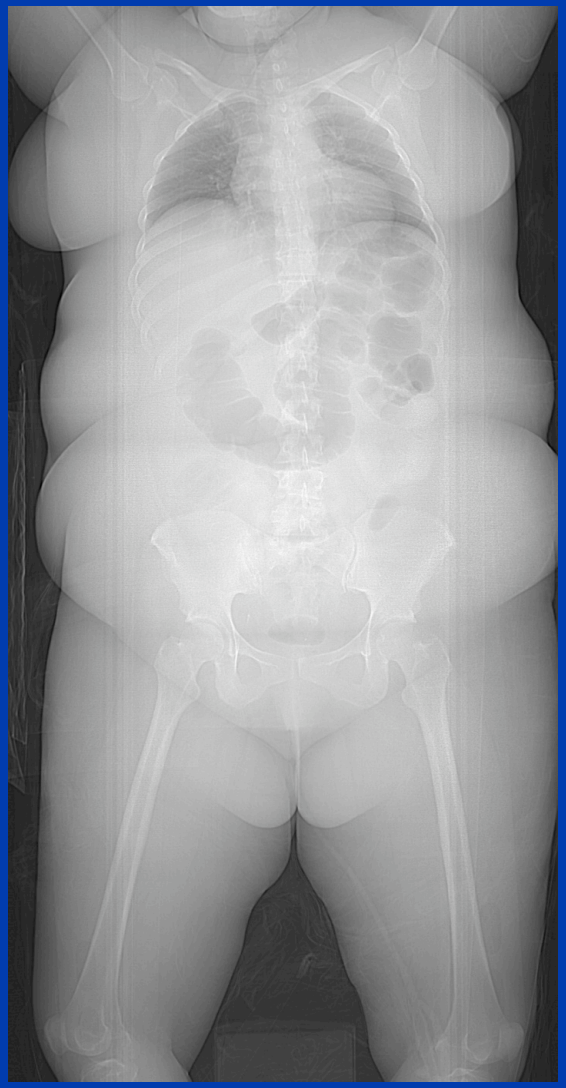


Amount of extra length scanned depended on boundary type ($p < .05$)

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

www.pbase.com/borderrose/image/80225151

Unnecessary Radiation

Tailoring the CT exam

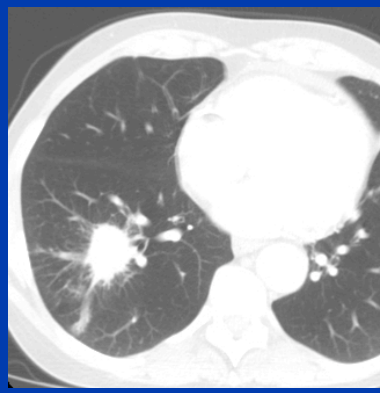
- Confining scan volume to region of interest

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

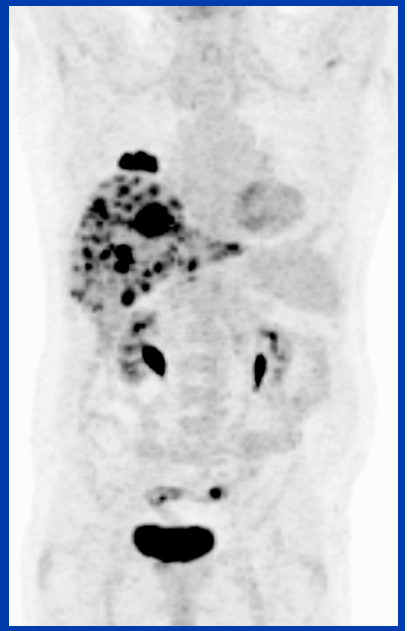


- CT chest; ?CT abdomen
- Most common sites of mets: brain, bone, liver, adrenal
- Previously: scan through entire liver
- ISOLATED liver mets rare
- Esp if mediastinal nodes are negative
- → Dedicated liver CT not necessary

Quint LE. Ann Thor Surg 1996;62:246
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

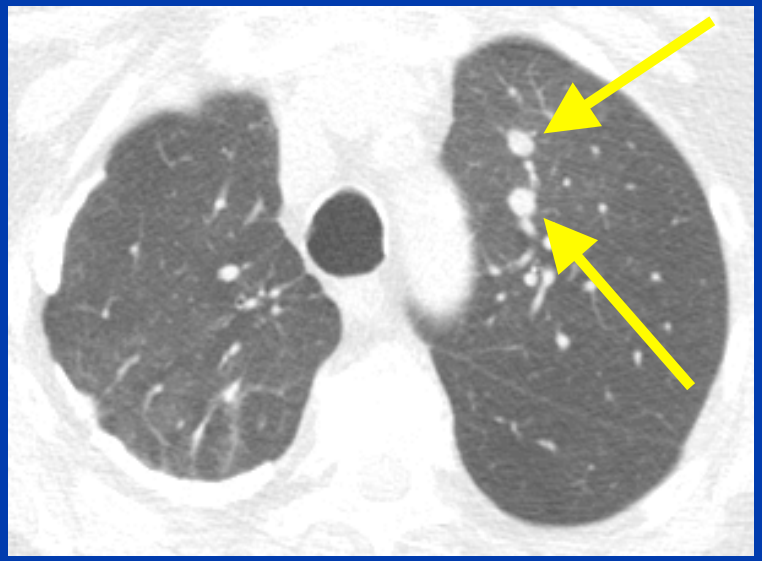
Protocol: F/U Lung Nodule

- 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

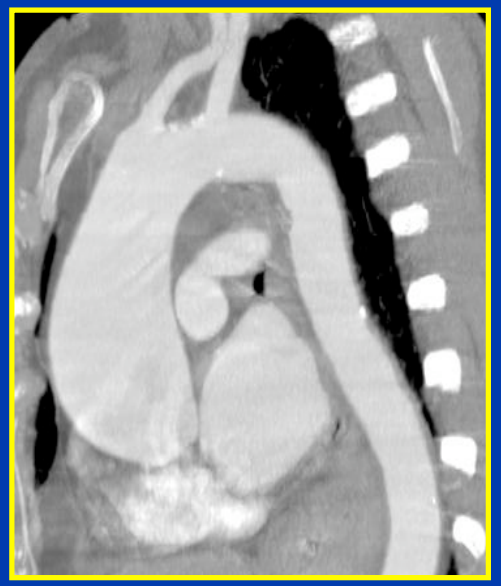
- If only one small, solid nodule or small cluster of nodules →
- Specify location of lesion in report → rescan only that level
- More work for radiologist, slows throughput



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

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Radiation Exposure from CTU 2005 Estimates: 10 Patients*

Single Bolus / Three Phase / 16 Row

• Unenhanced *(5mm)*	3.9 (1.9 – 6.8)
• Nephrographic phase *(5mm)*	6.4 (4.5 – 8.4)
• Excretory phase *(1.25 mm)*	16.2 (11.0 – 25.0)
• Total	26.6 (20.6 – 40.2) mSv

120 Kv (all) UE: 80 – 200, NP: 230 – 410 EP: 390 – 640 mA

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

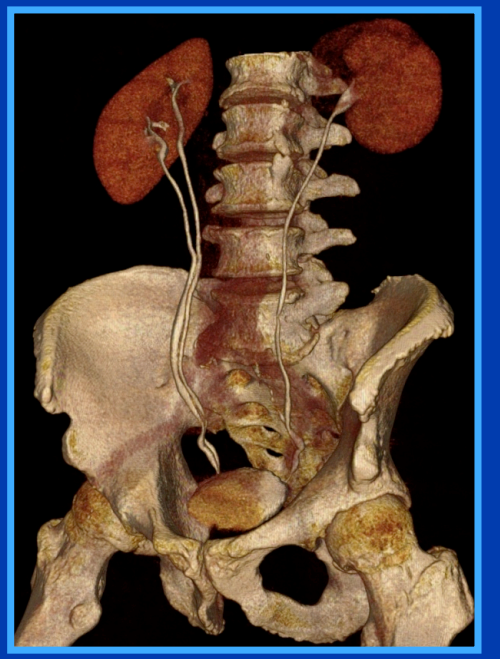
120 Kv (all) UE: 80 – 200, NP: 230 – 410 EP: 400 – 480 mA

Same dose range for 64 row scanners

*Rich Cohan

Protocol: Split Bolus CTU

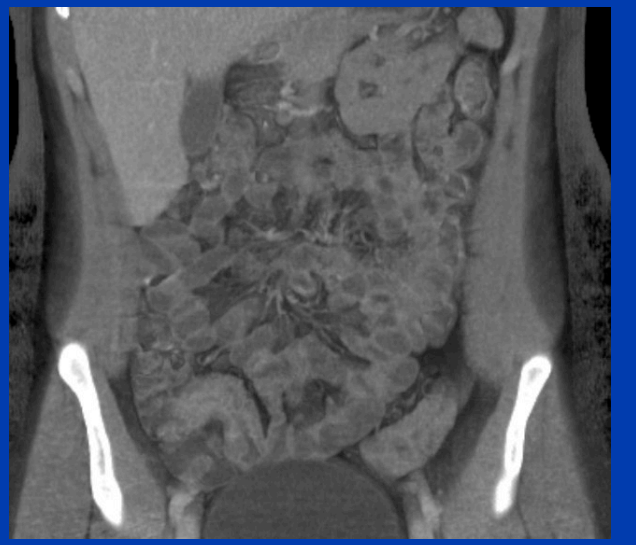
- Elimination of nephrographic phase series reduces radiation dose by ~25%
- Theoretical disadvantage: poorer opacification/distention of urinary tract
- Technique maintains high sensitivity and specificity for detection of urothelial tumors in collecting systems and pelvises



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

Protocol: CT Enterography

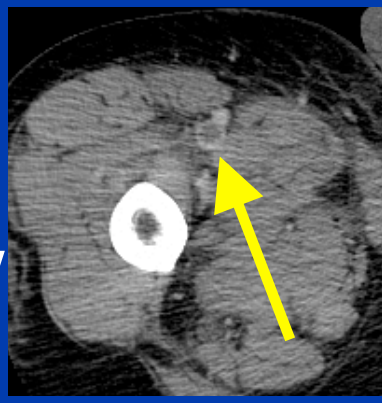
- Small bowel Crohn's disease
- Arterial phase 40 s
- Venous phase 70 s
- No difference between two phases for detection of active disease
- At Univ Michigan we now do only venous phase imaging



Vandenbroucke F. Acta Radiol. 2007;23:1

Protocol: r/o PE and DVT

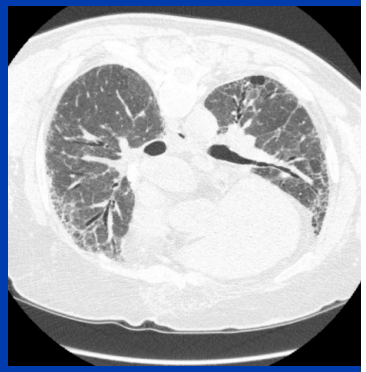
- Default: CTV of pelvis & lower extremities
- Pioped II:
  - Incidence of positive studies in pts without signs, sx, or hx of DVT is low
  - CT venography and Doppler showed similar results in dx or excluding DVT
- Some pts have already had Doppler
- Many pts are young, mult ED visits, CTs
- Consider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



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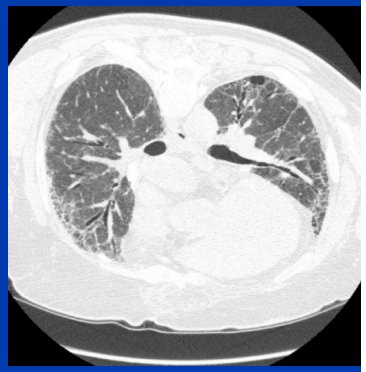
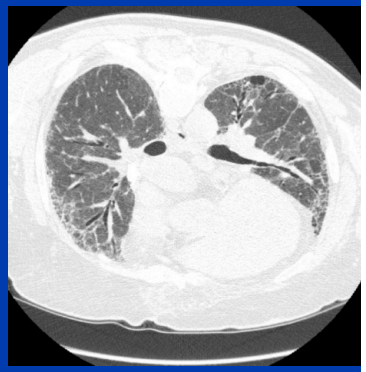


Protocol: HRCT for ILD

- 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

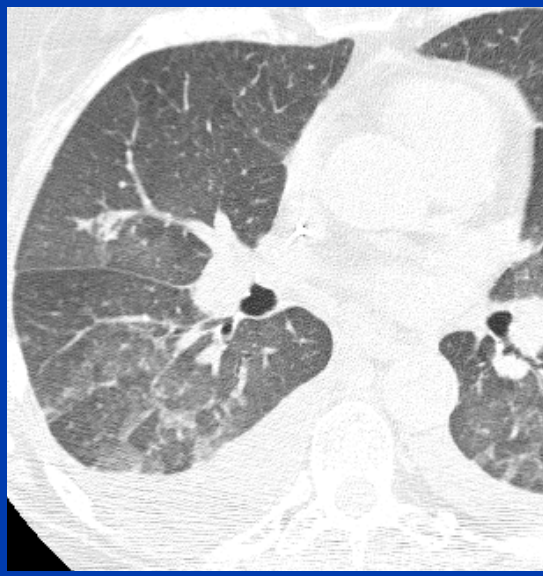


Protocol: HRCT for ILD

- Radiologist needs to check → advise tech

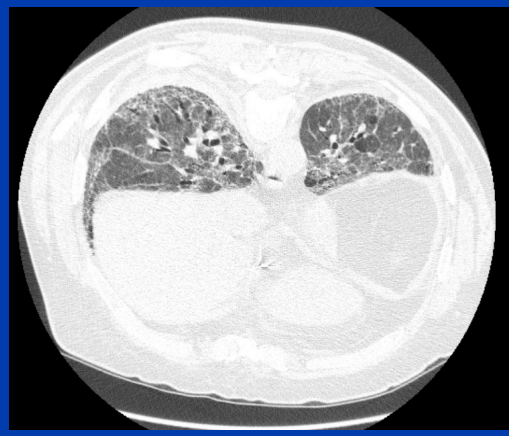
Protocol: HRCT for ILD

- 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



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

Scanning Less Frequently

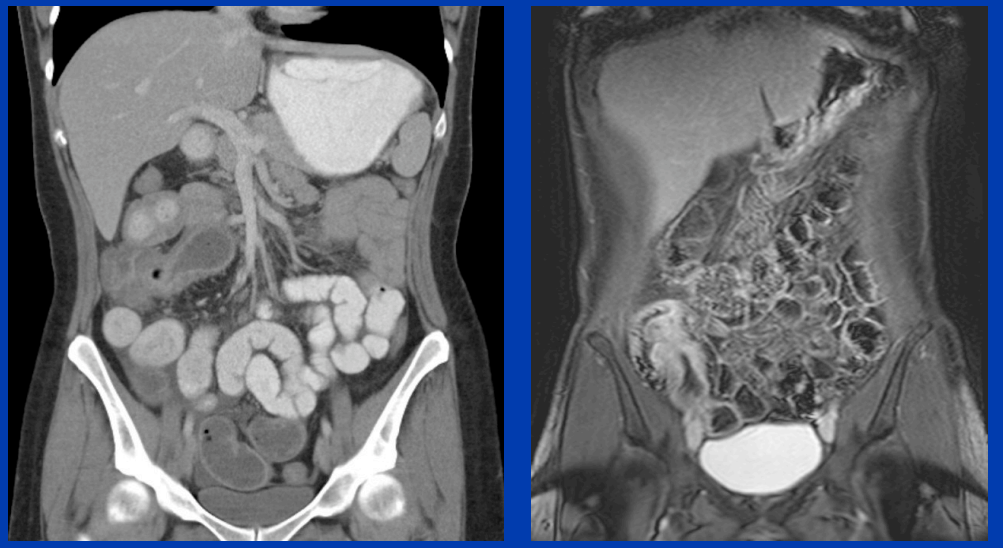
Aortic disease

- 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

Unnecessary Radiation

Tailoring the CT exam

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- Eliminating unnecessary series
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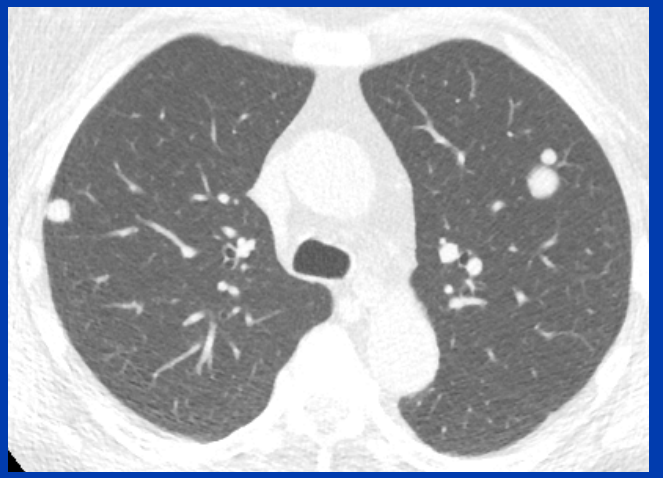
- **Selective dose reduction**

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)

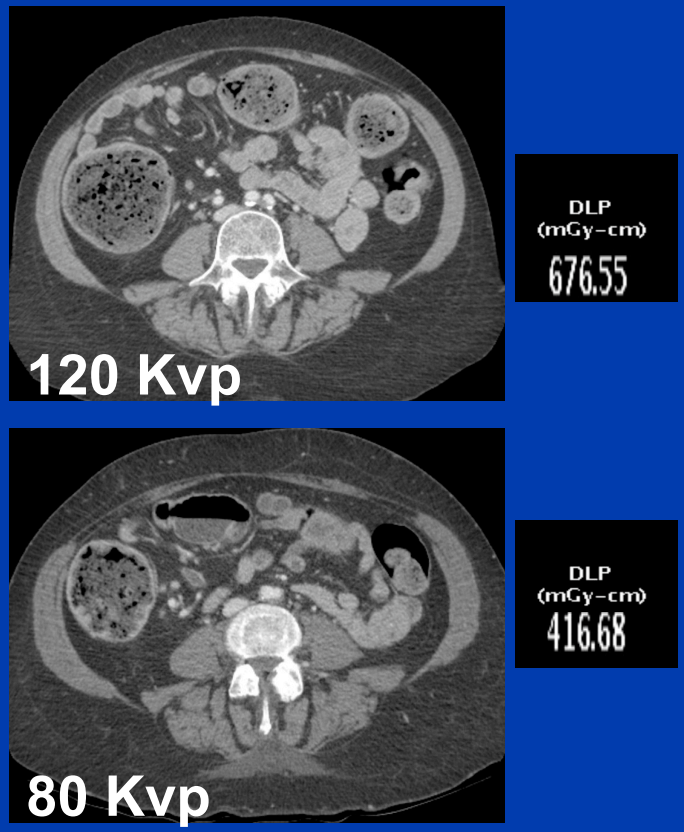


Diederich S. Radiology 1999;213;289
Kalra MK. Radiology 2004;230:619

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