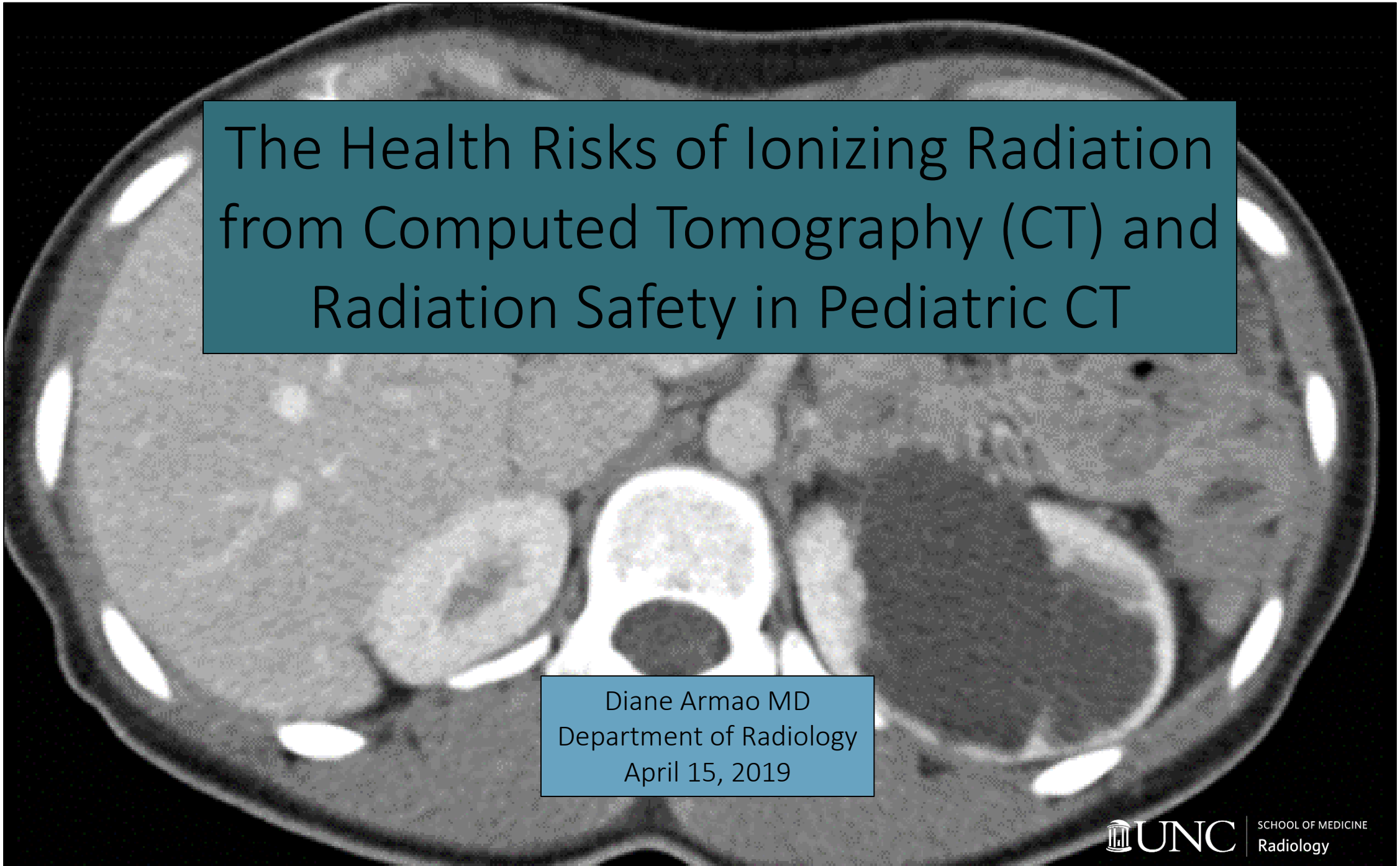

The Health Risks of Ionizing Radiation from Computed Tomography (CT) and Radiation Safety in Pediatric CT

Diane Armao MD
Department of Radiology
April 15, 2019

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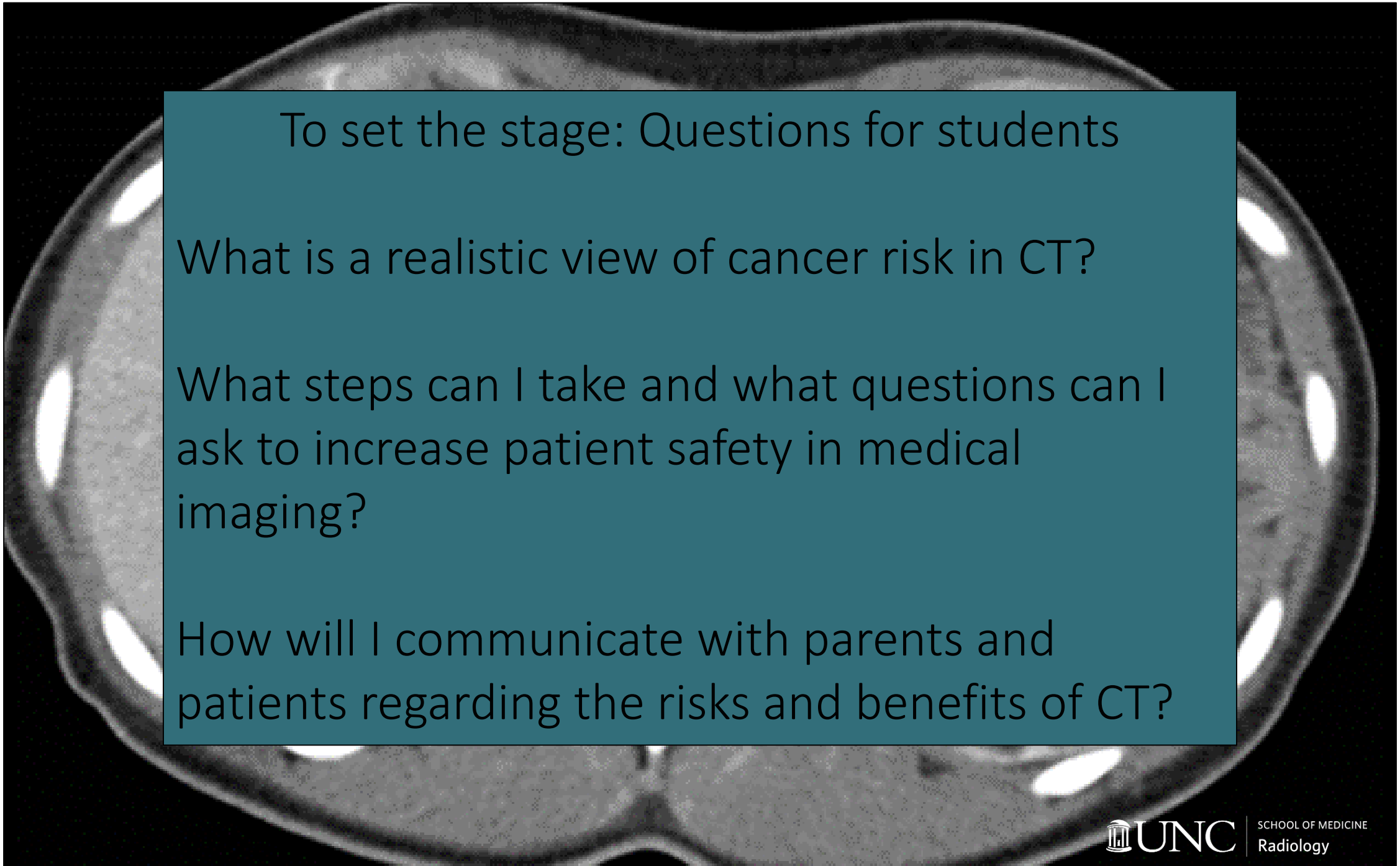
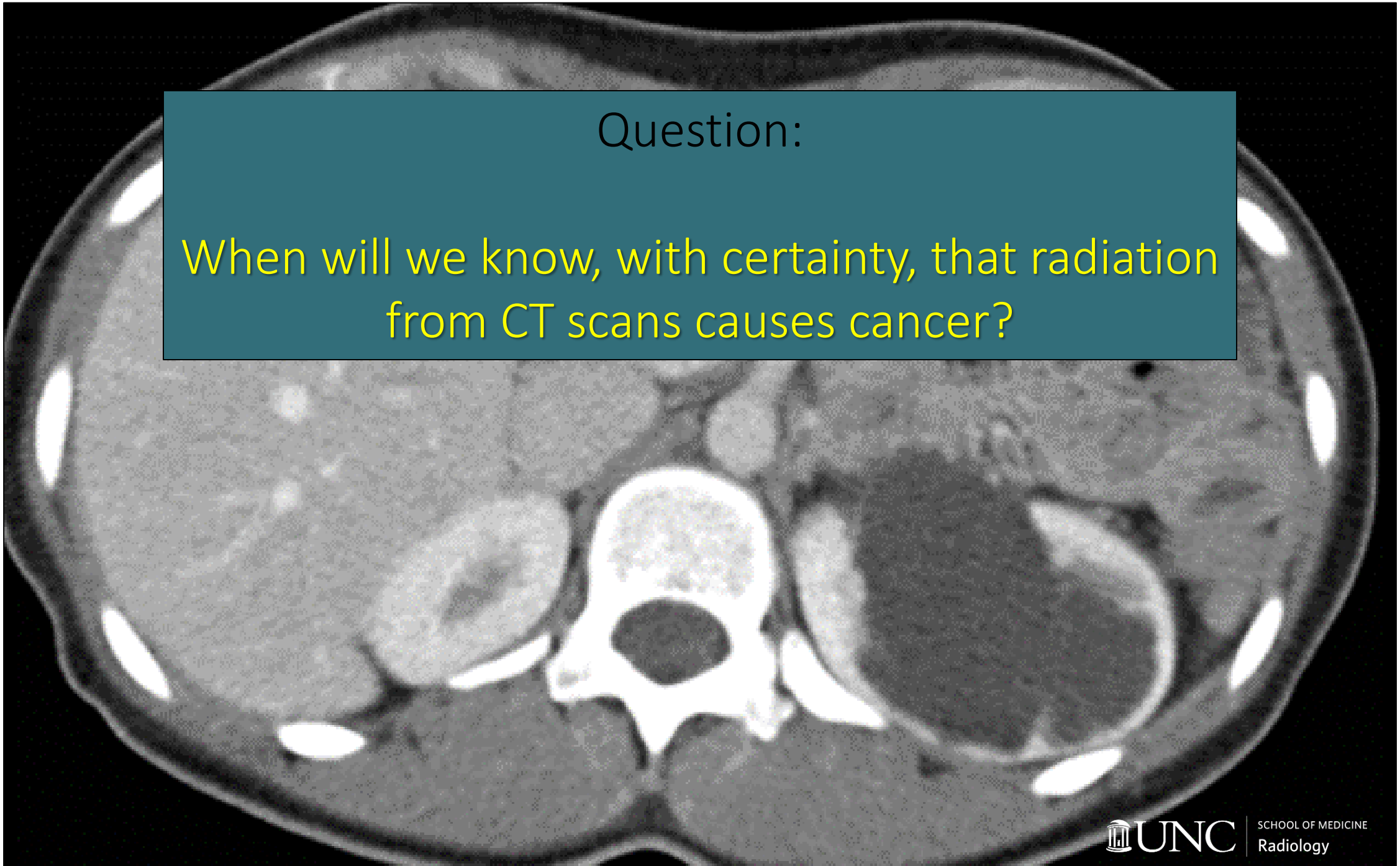


To set the stage: Questions for students

What is a realistic view of cancer risk in CT?

What steps can I take and what questions can I ask to increase patient safety in medical imaging?

How will I communicate with parents and patients regarding the risks and benefits of CT?


Question:
When will we know, with certainty, that radiation from CT scans causes cancer?
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Answer:
Never
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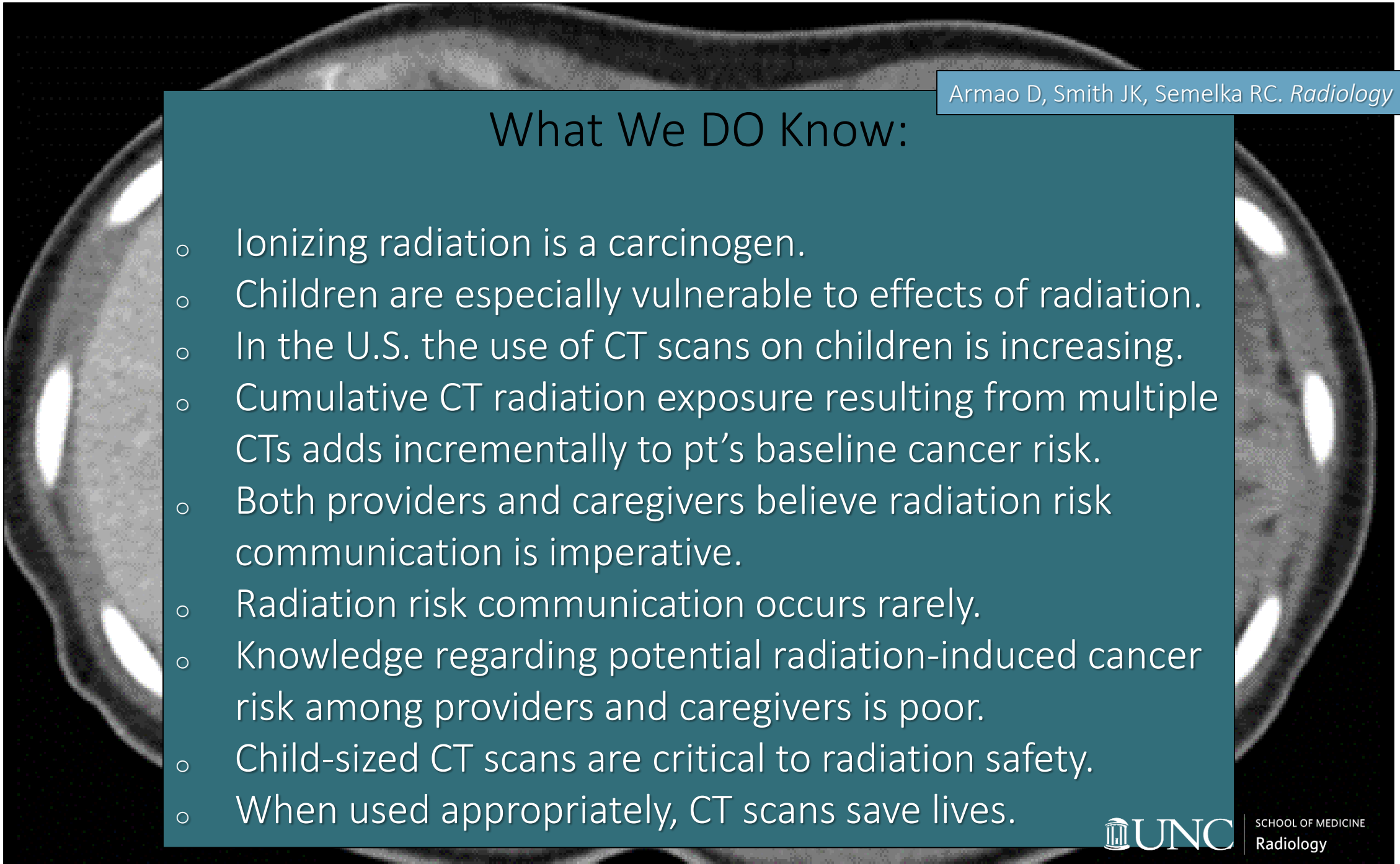

Armao D, Smith JK, Semelka RC. *Radiology* 2015

What We DO Know:

- Ionizing radiation is a carcinogen.
- Children are especially vulnerable to effects of radiation.
- In the U.S. the use of CT scans on children is increasing.
- Cumulative CT radiation exposure resulting from multiple CTs adds incrementally to pt's baseline cancer risk.
- Both providers and caregivers believe radiation risk communication is imperative.
- Radiation risk communication occurs rarely.
- Knowledge regarding potential radiation-induced cancer risk among providers and caregivers is poor.
- Child-sized CT scans are critical to radiation safety.
- When used appropriately, CT scans save lives.

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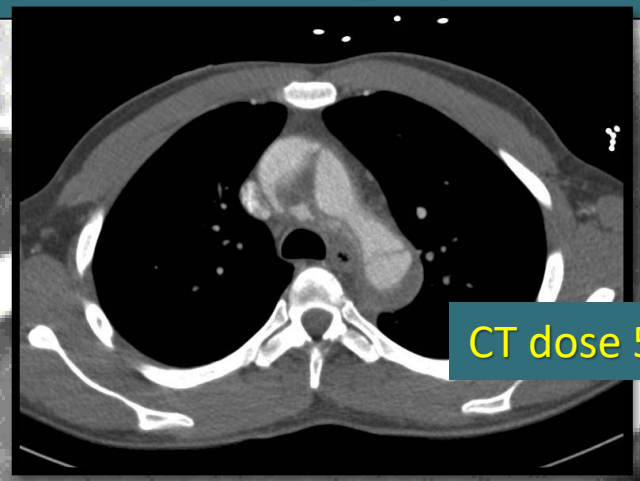
Radiation Risks of Medical Imaging

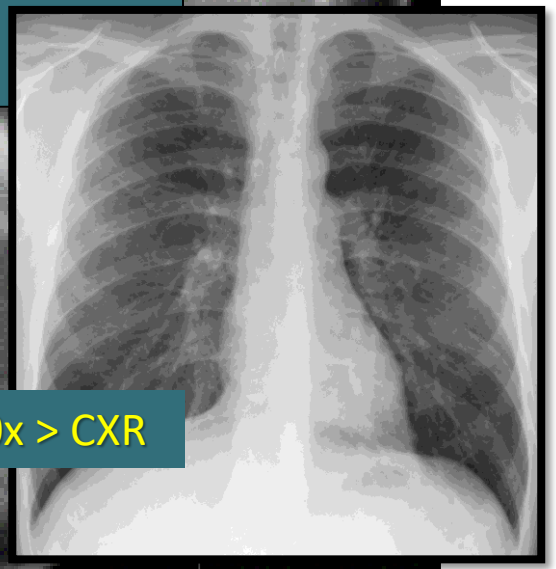
- BEIR VII: an effective dose of 10 mSv is associated with an increased chance of developing cancer for 1 patient in 1,000
- Approximately 29,000 future cancers (approximately 2% of the cancers diagnosed annually) could be related to CT scan use in the U.S. in 2007
- For an abdominal or pelvic CT scan, the lifetime risks for children, irrespective of age at exposure, are 1 cancer per 500 scans

Biological Effects of Ionizing Radiation VII Phase 2. *National Academies Press* 2006. Smith-Bindman R. *Arch Int Med* 2009

Not All X-Rays Are Created Equal

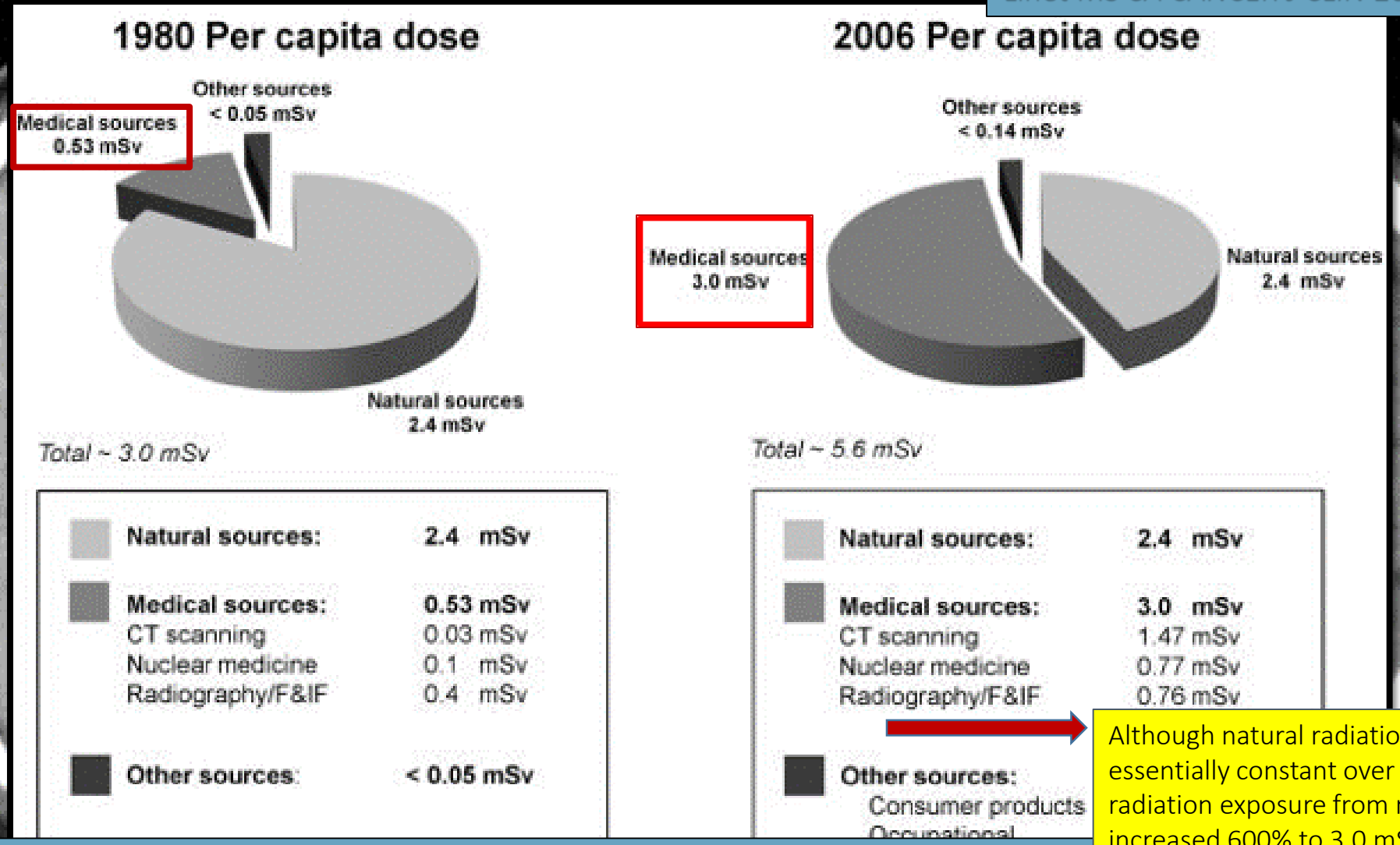
- The radiation doses delivered by CT scans are much higher than those of conventional radiography.
- For instance, a single CT scan of the chest delivers an effective dose that is approximately 500 times greater than that received during a chest radiograph.





CT dose 500x > CXR

Linet MS *CA CANCER J CLIN* 2012;62:75-100



Although natural radiation exposure remained essentially constant over the 25-year period, radiation exposure from medical sources increased 600% to 3.0 mSv per capita per year.

US Annual Per Capita Effective Radiation Dose in Millisieverts (mSv) From Various Sources for 1980 and 2006

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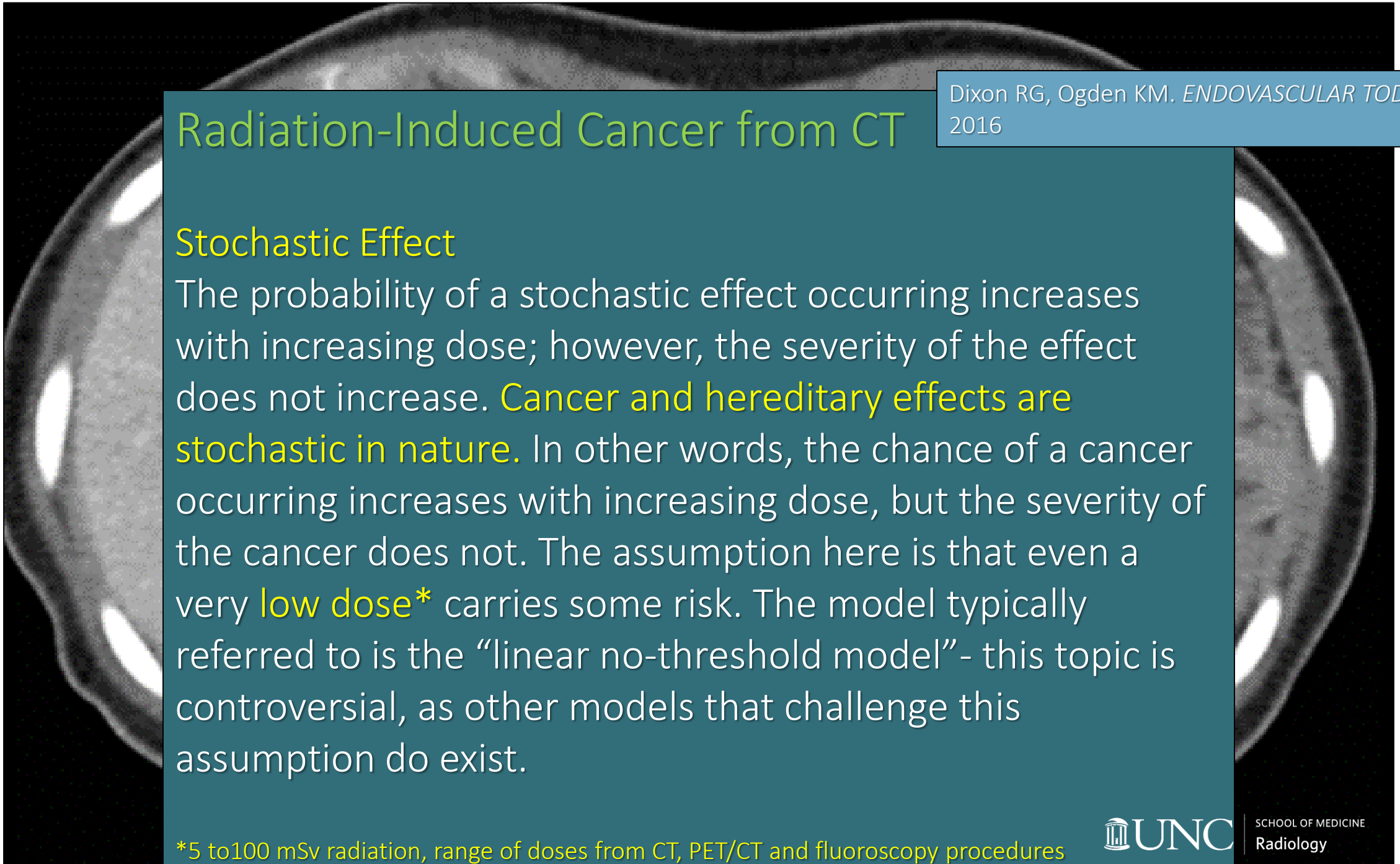

Radiation-Induced Cancer from CT

Dixon RG, Ogden KM. *ENDOVASCULAR TODAY* 2016

Stochastic Effect

The probability of a stochastic effect occurring increases with increasing dose; however, the severity of the effect does not increase. Cancer and hereditary effects are stochastic in nature. In other words, the chance of a cancer occurring increases with increasing dose, but the severity of the cancer does not. The assumption here is that even a very low dose* carries some risk. The model typically referred to is the "linear no-threshold model"- this topic is controversial, as other models that challenge this assumption do exist.

*5 to100 mSv radiation, range of doses from CT, PET/CT and fluoroscopy procedures

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Redberg RF, Smith-Bindman R. The New York Times 2014

The New York Times http://nyti.ms/1hUyUlq

THE OPINION PAGES | OP-ED CONTRIBUTORS

We Are Giving Ourselves Cancer

By RITA F. REDBERG and REBECCA SMITH-BINDMAN JAN. 30, 2014

Authors: Rita F. Redberg MD, cardiologist at UCSF, Editor in Chief JAMA Internal Medicine Rebecca Smith-Bindman MD, radiologist at UCSF

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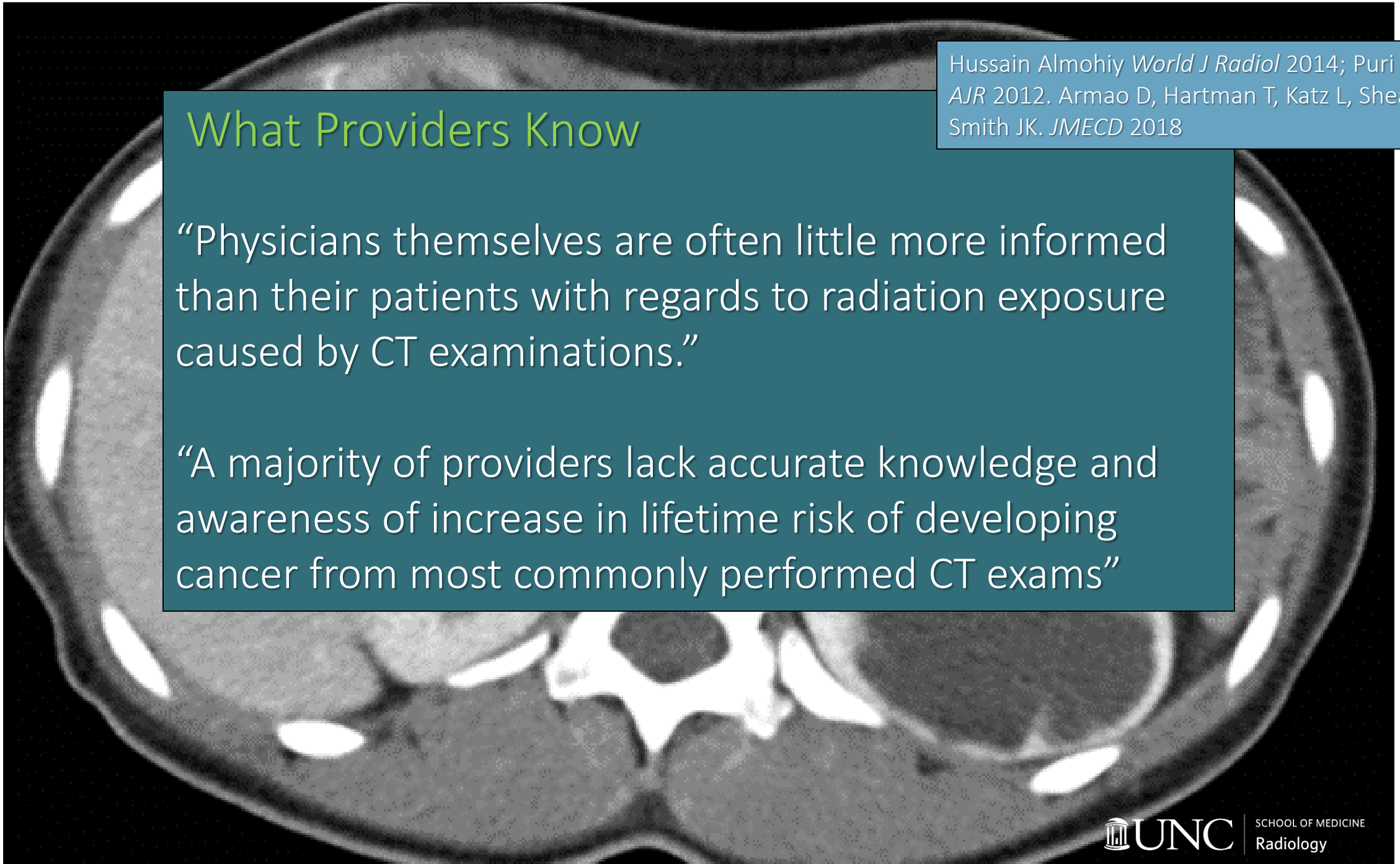
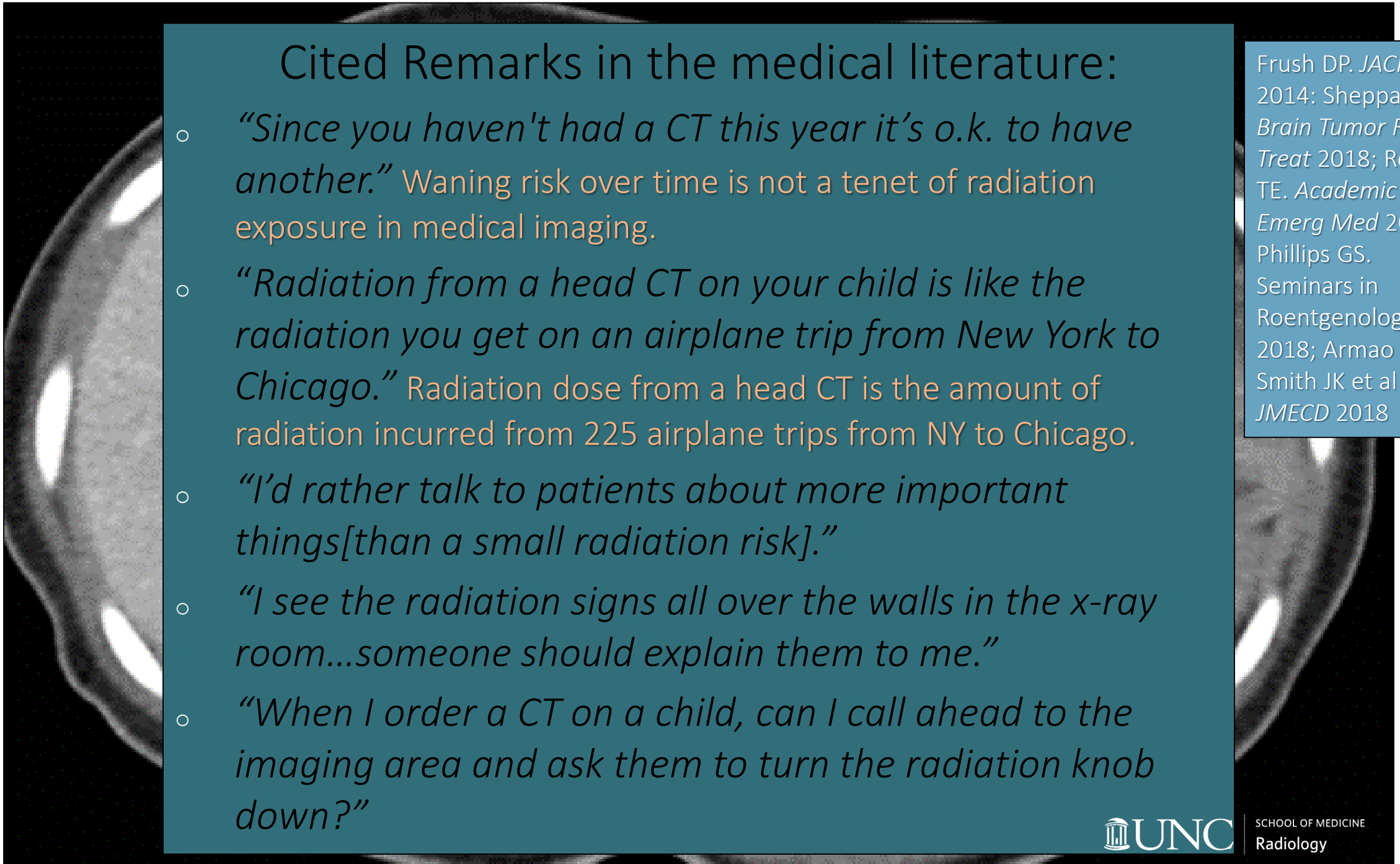


What Providers Know

"Physicians themselves are often little more informed than their patients with regards to radiation exposure caused by CT examinations."

"A majority of providers lack accurate knowledge and awareness of increase in lifetime risk of developing cancer from most commonly performed CT exams"

Hussain Almohiy *World J Radiol* 2014; Puri S. *AJR* 2012. Armao D, Hartman T, Katz L, Shea C, Smith JK. *JMECD* 2018



Cited Remarks in the medical literature:

- *"Since you haven't had a CT this year it's o.k. to have another."* Waning risk over time is not a tenet of radiation exposure in medical imaging.
- *"Radiation from a head CT on your child is like the radiation you get on an airplane trip from New York to Chicago."* Radiation dose from a head CT is the amount of radiation incurred from 225 airplane trips from NY to Chicago.
- *"I'd rather talk to patients about more important things[than a small radiation risk]."*
- *"I see the radiation signs all over the walls in the x-ray room…someone should explain them to me."*
- *"When I order a CT on a child, can I call ahead to the imaging area and ask them to turn the radiation knob down?"*

Frush DP. *JACR* 2014: Sheppard JP. *Brain Tumor Res Treat* 2018; Robey TE. *Academic Emerg Med* 2014; Phillips GS. Seminars in Roentgenology 2018; Armao D, Smith JK et al *JMECD* 2018

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Are We Protecting Our Children?

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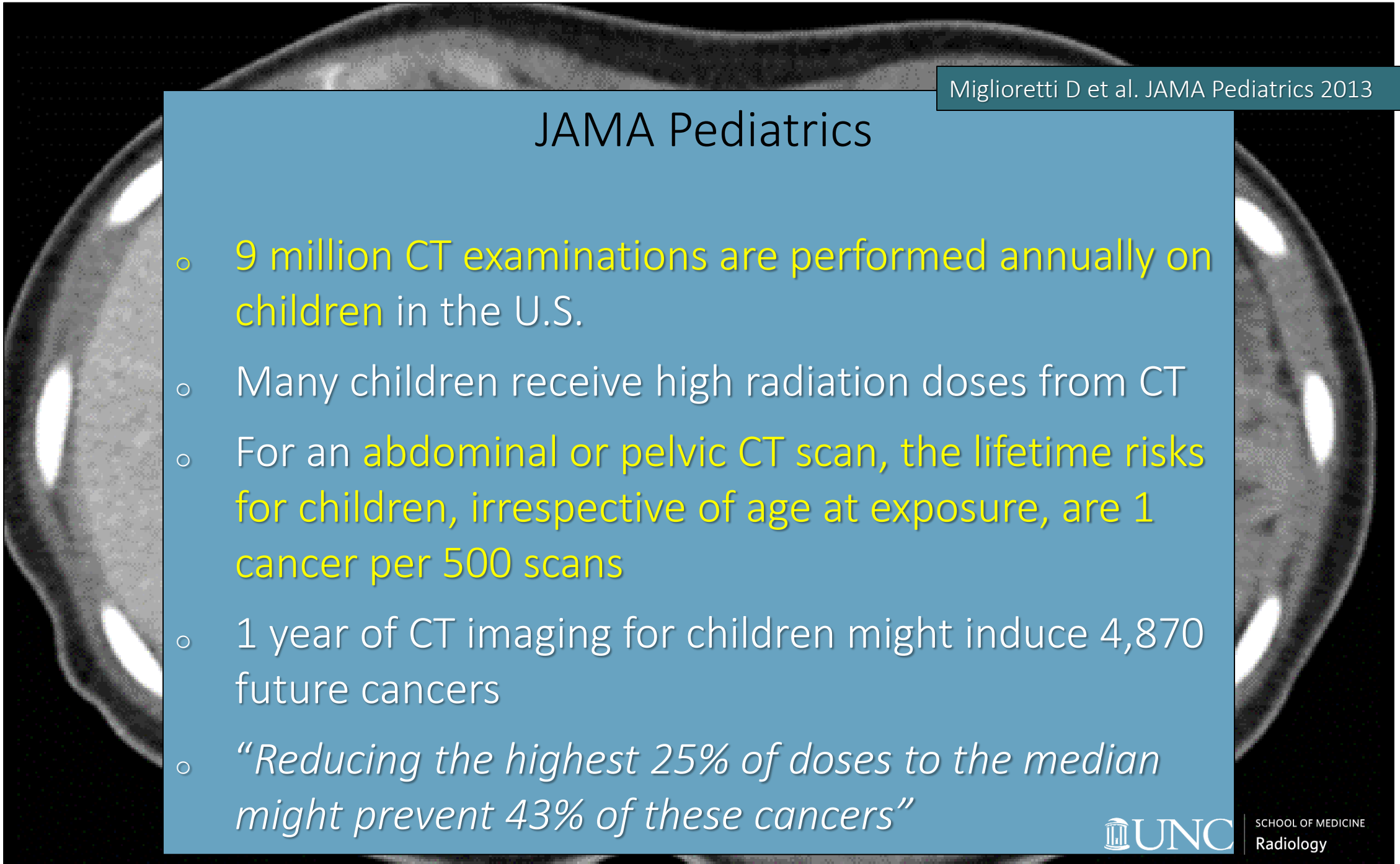

Miglioretti D et al. JAMA Pediatrics 2013

JAMA Pediatrics

- 9 million CT examinations are performed annually on children in the U.S.
- Many children receive high radiation doses from CT
- For an abdominal or pelvic CT scan, the lifetime risks for children, irrespective of age at exposure, are 1 cancer per 500 scans
- 1 year of CT imaging for children might induce 4,870 future cancers
- *"Reducing the highest 25% of doses to the median might prevent 43% of these cancers"*

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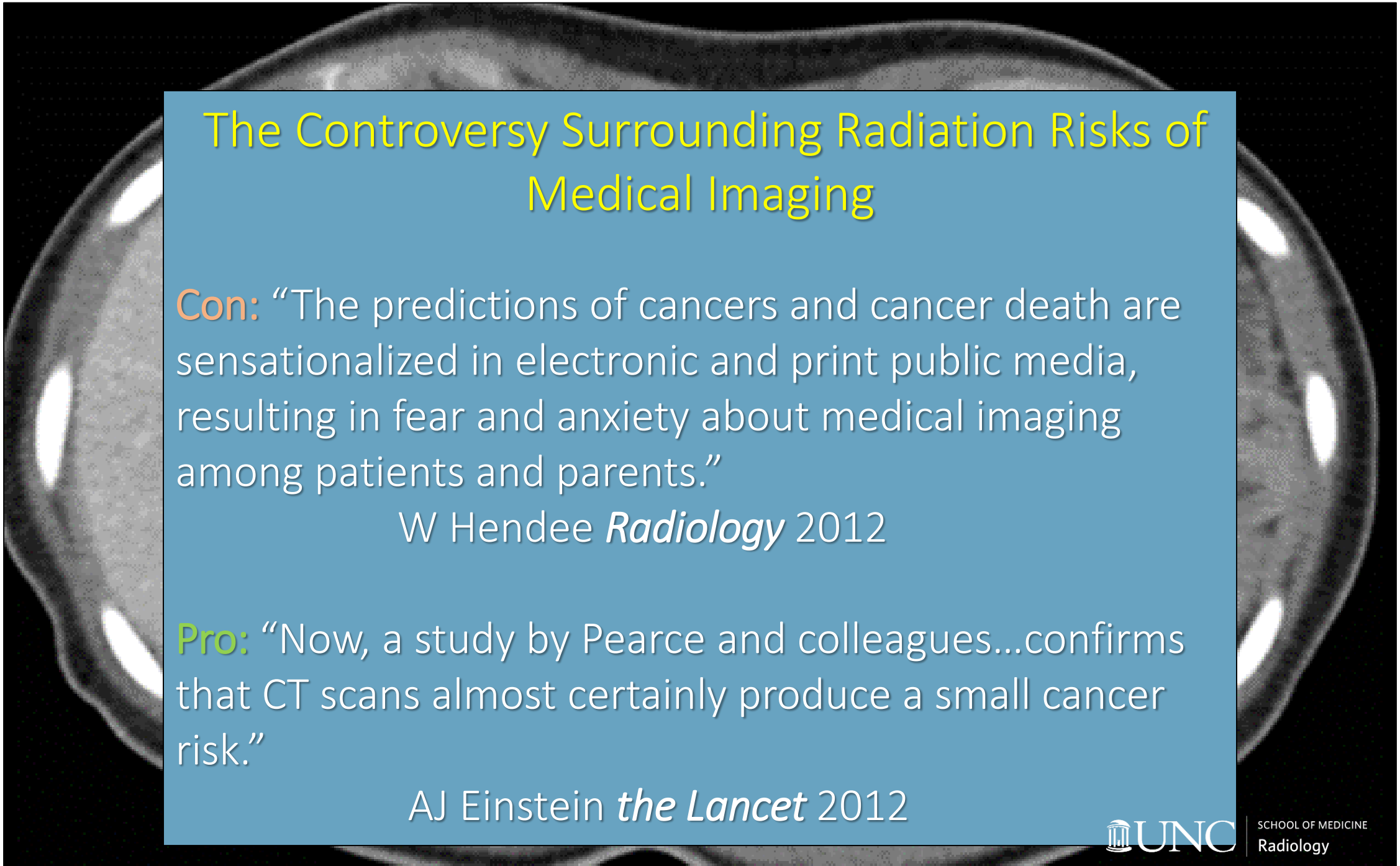


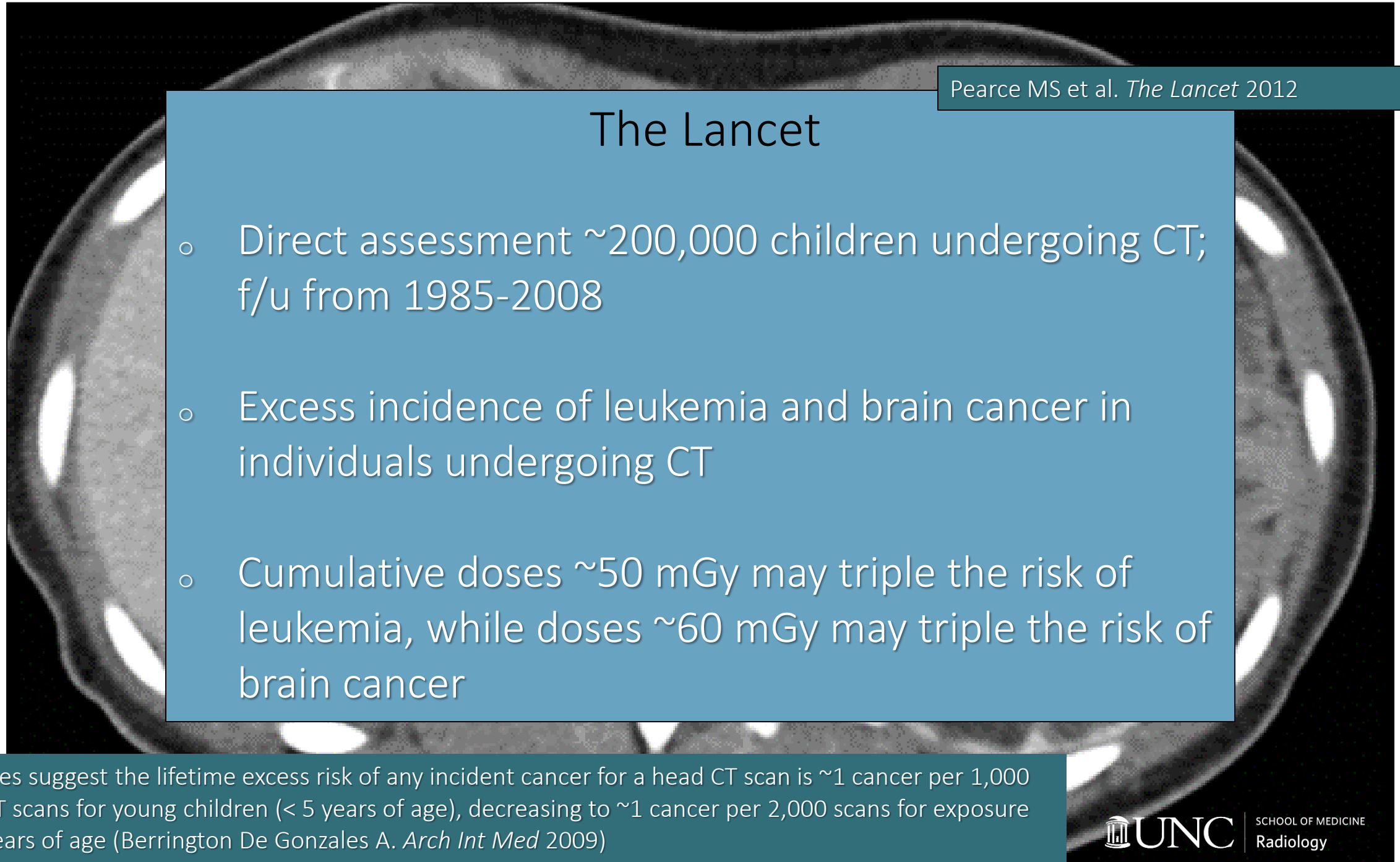
The Controversy Surrounding Radiation Risks of Medical Imaging

Con: "The predictions of cancers and cancer death are sensationalized in electronic and print public media, resulting in fear and anxiety about medical imaging among patients and parents."

W Hendee ***Radiology*** 2012

Pro: "Now, a study by Pearce and colleagues…confirms that CT scans almost certainly produce a small cancer risk."

AJ Einstein ***the Lancet*** 2012

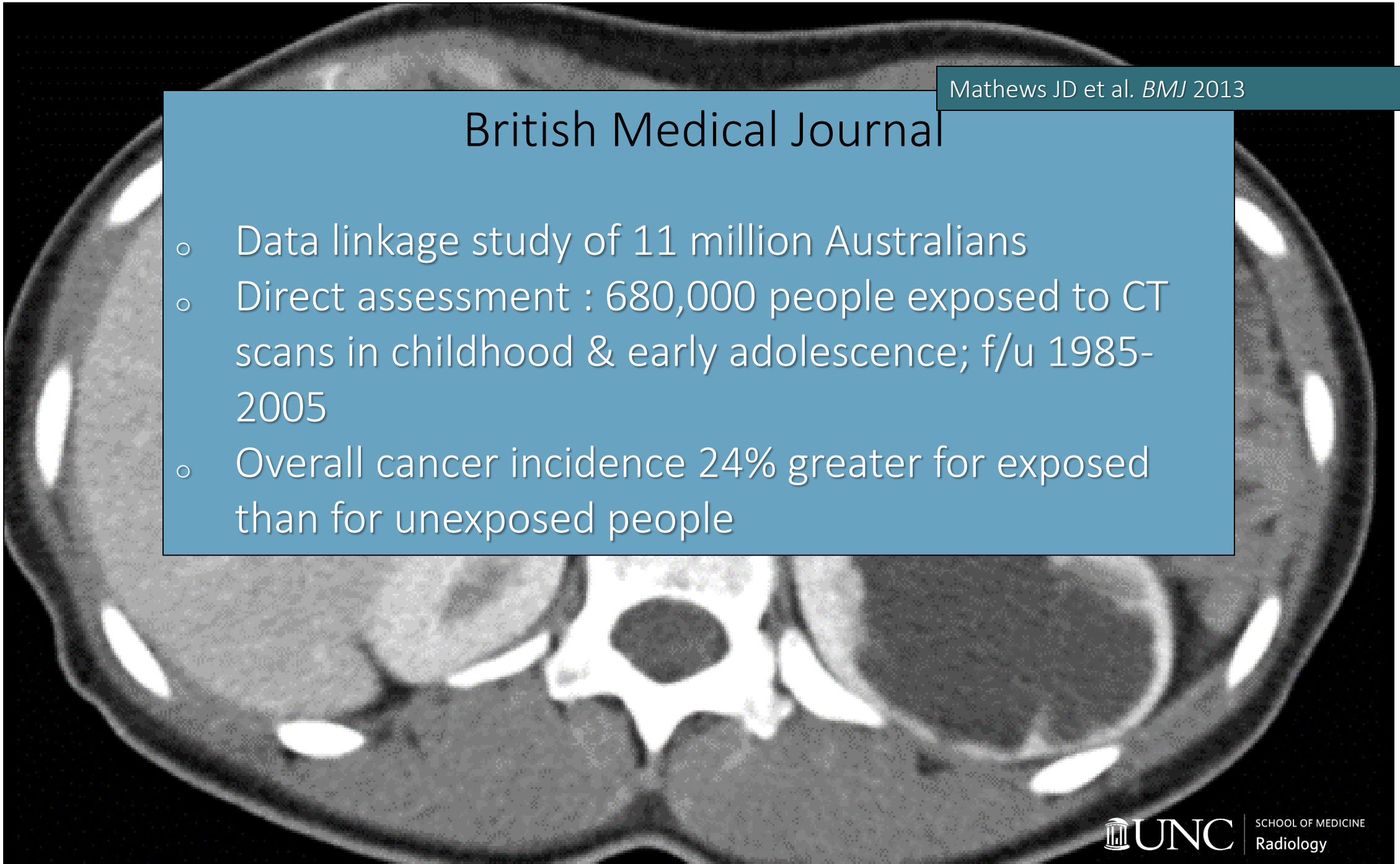


Pearce MS et al. *The Lancet* 2012

The Lancet

- Direct assessment ~200,000 children undergoing CT; f/u from 1985-2008
- Excess incidence of leukemia and brain cancer in individuals undergoing CT
- Cumulative doses ~50 mGy may triple the risk of leukemia, while doses ~60 mGy may triple the risk of brain cancer

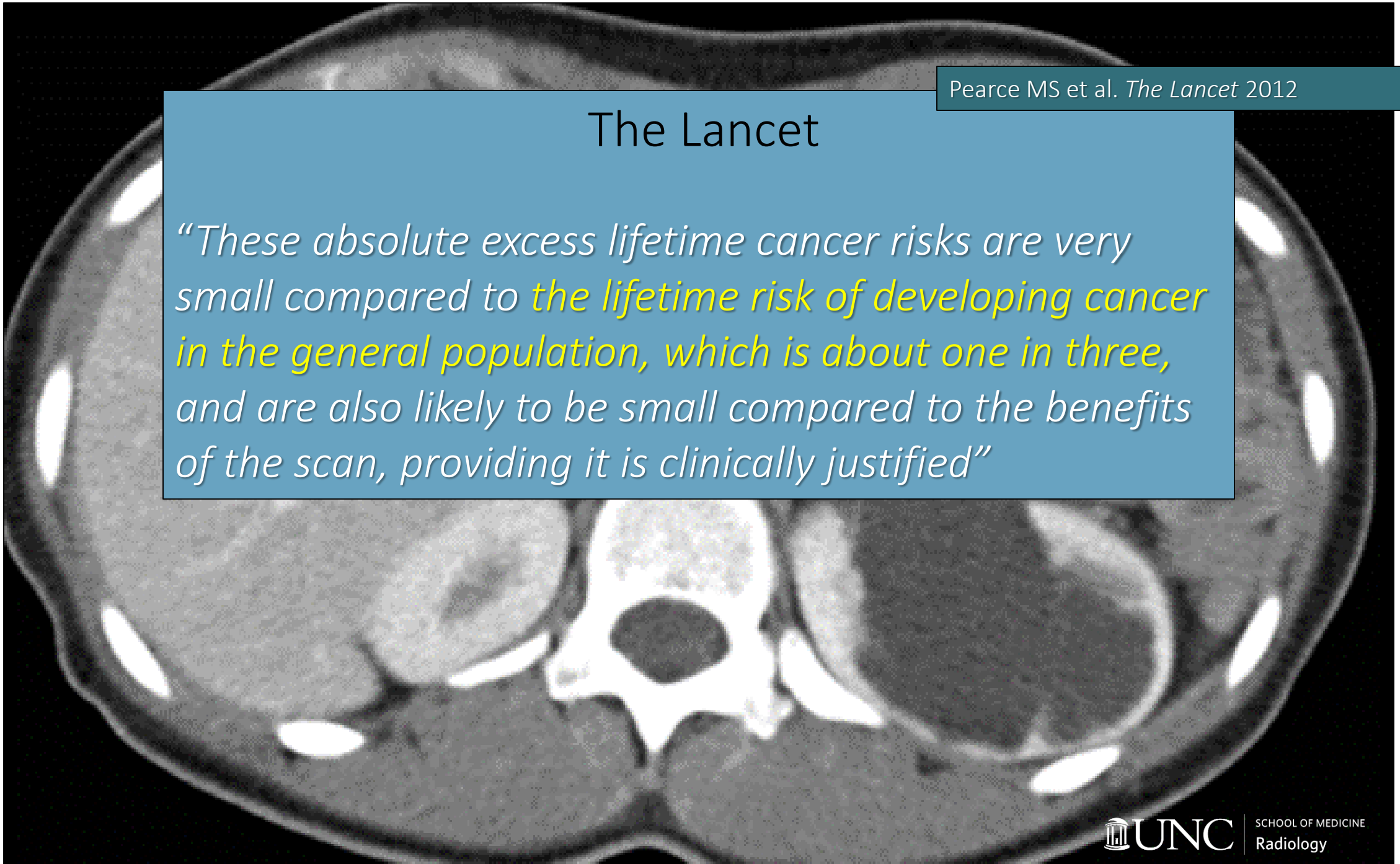
Estimates suggest the lifetime excess risk of any incident cancer for a head CT scan is ~1 cancer per 1,000 head CT scans for young children (< 5 years of age), decreasing to ~1 cancer per 2,000 scans for exposure at 15 years of age (Berrington De Gonzales A. *Arch Int Med* 2009)



Mathews JD et al. *BMJ* 2013

British Medical Journal

- Data linkage study of 11 million Australians
- Direct assessment : 680,000 people exposed to CT scans in childhood & early adolescence; f/u 1985-2005
- Overall cancer incidence 24% greater for exposed than for unexposed people



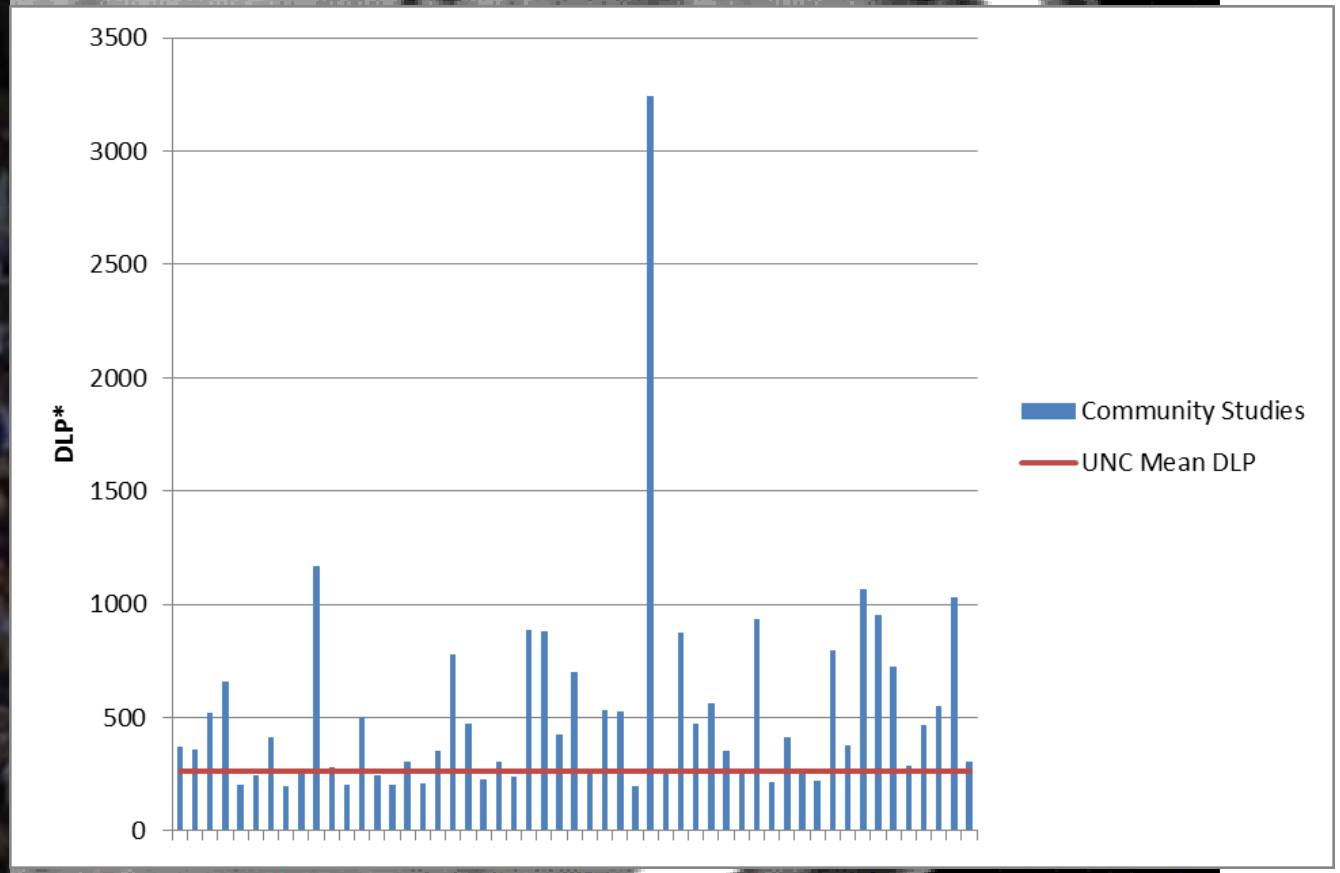
Pearce MS et al. *The Lancet* 2012

The Lancet

"These absolute excess lifetime cancer risks are very small compared to the lifetime risk of developing cancer in the general population, which is about one in three, and are also likely to be small compared to the benefits of the scan, providing it is clinically justified"

One Size Does Not Fit All !!

Armao, Hartman, Fordham, Smith. *JACR* 2016



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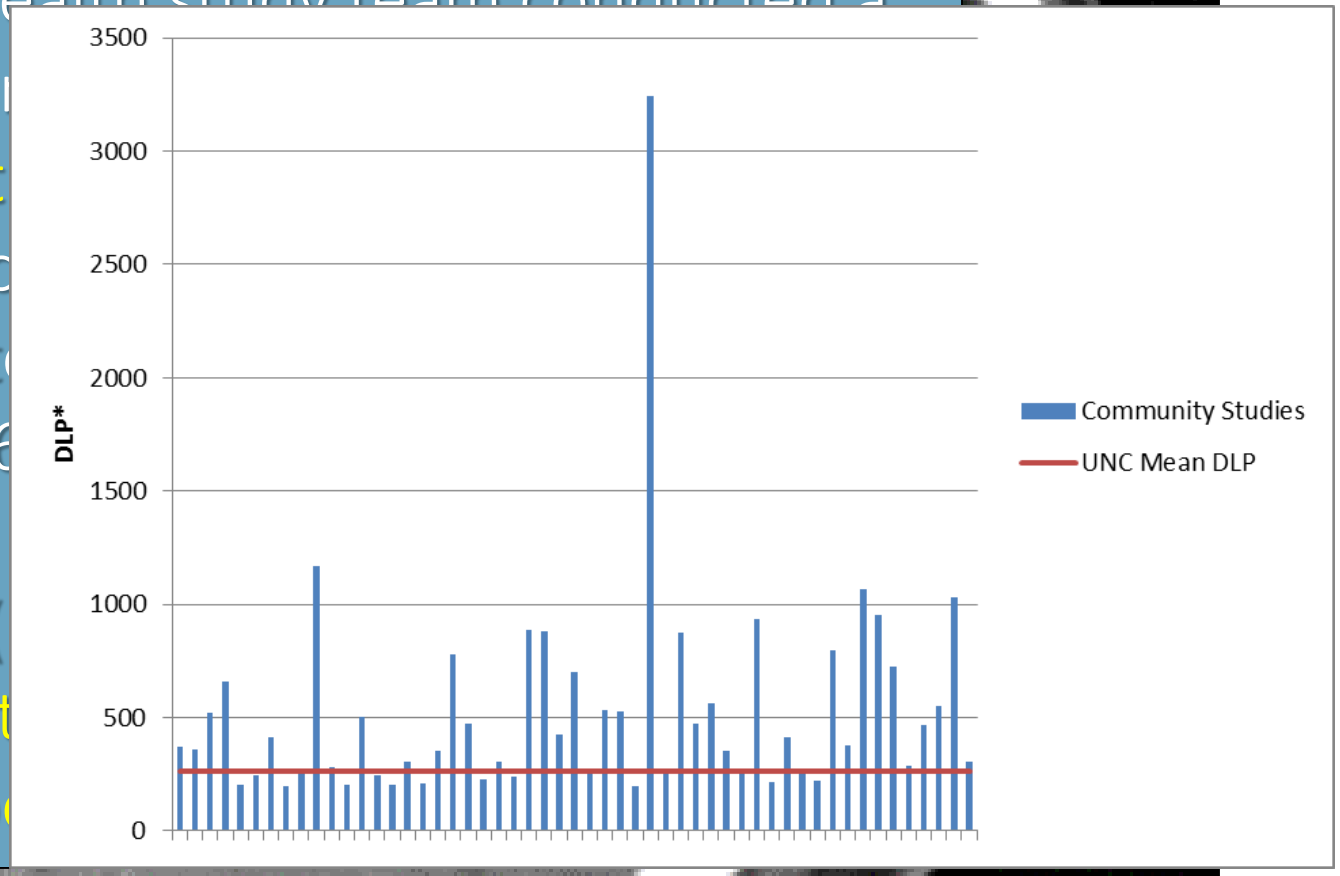
Armao, Hartman, Fordham, Smith. *JACR* 2016

To establish baseline data, our UNC Radiology/Gillings School of Global Public He… study team conducted a retrospective analysis usi… (DLP) contained in pediat… reports from 20 outside c… radiology practices sent t… transfer of care during a 6… survey identified 12 sites … and pediatric exposures (… our usual adult doses, wit… higher dose than corresp…



Note: Each blue bar represents one Head CT study. The highest peak represents a child that had 3 CT scans using adult protocols during 1 visit in order to obtain quality images.

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The ABCs of Childcare in CT:

Awareness

Belief

Change

Picasso

Cover from the UNC Radiology-developed comprehensive electronic toolkit booklet entitled "The ABCs of Childcare in CT: Awareness, Belief, Change."

Armao D, Hartman T, Fordham LA, Smith JK: NC TraCS DIR11402 supported by the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health, through Grant Award Number UL1TR001111

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The ABCs of Childcare in CT:

Awareness

Belief

Change

Picasso

RATIONALE:

Given the uncertainty surrounding cancer risk from medical radiation, any decision that is made may eventually turn out to be erroneous.

If we assume there are radiation risks when there are none, we will be expending effort and resources to minimize (non-existent) risks; however, if there truly were radiation risks that we chose to ignore, we would have subjected our children to long-term detrimental consequences.

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The ABCs of Childcare in CT:

Awareness

Belief

Change

ALARA

As Low As Reasonably Achievable

= making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical

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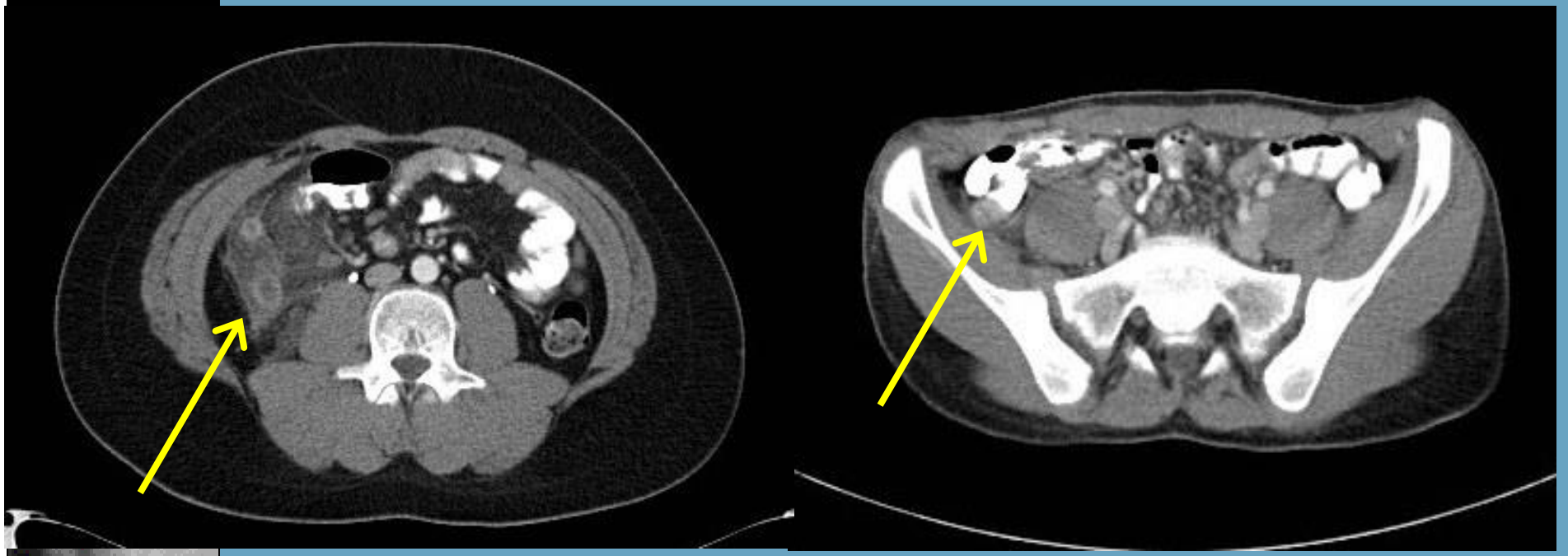
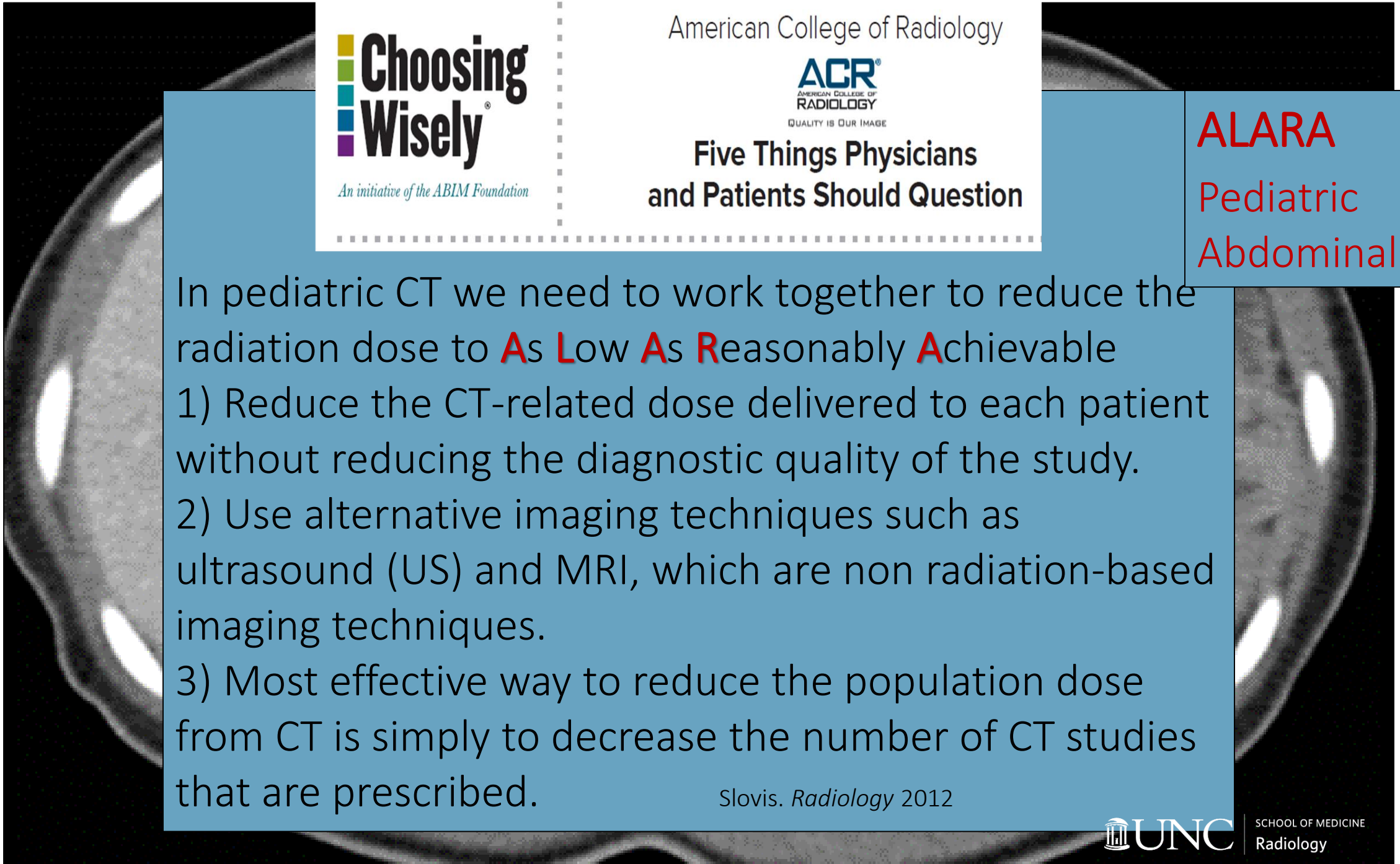
ALARA

Pediatric Abdominal CT



A. Axial contrast enhanced CT image obtained with a reference mAs of 120 beautifully shows the enlarged, hyperemic appendix with marked surrounding inflammatory stranding.

B. Axial contrast enhanced CT image obtained with a reference mAs of 30, although noisier, clearly demonstrates a less florid example of appendicitis with an enlarged appendix and more mild surrounding inflammatory stranding. This image is of diagnostic quality despite the relative paucity of intraabdominal fat as well as its location within the pelvis, where streak artifact can sometimes make evaluation more difficult.



Choosing Wisely®
An initiative of the ABIM Foundation

American College of Radiology
ACR® American College of Radiology
Quality is Our Image

Five Things Physicians and Patients Should Question

ALARA

Pediatric Abdominal CT

In pediatric CT we need to work together to reduce the radiation dose to **A**s **L**ow **A**s **R**easonably **A**chievable

1) Reduce the CT-related dose delivered to each patient without reducing the diagnostic quality of the study.

2) Use alternative imaging techniques such as ultrasound (US) and MRI, which are non radiation-based imaging techniques.

3) Most effective way to reduce the population dose from CT is simply to decrease the number of CT studies that are prescribed.

Slovis. *Radiology* 2012

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In a number of medical scenarios, the strengths of CT are unmatched, so *"Don't throw the baby out with the bathwater"*

Leonardo da Vinci *c.1497-1499*

Two excellent websites/links to help you with professional interactions and conversations with patients and parents involving the potential health risks of radiation from CT scans:

1) **Image Gently Alliance website**

http://www.imagegently.org/

2) **World Health Organization** Communicating radiation risks in paediatric imaging:

Information to support healthcare discussions about benefit and risk

http://www.who.int/ionizing_radiation/pub_meet/radiation-risks-paediatric-imaging/en/

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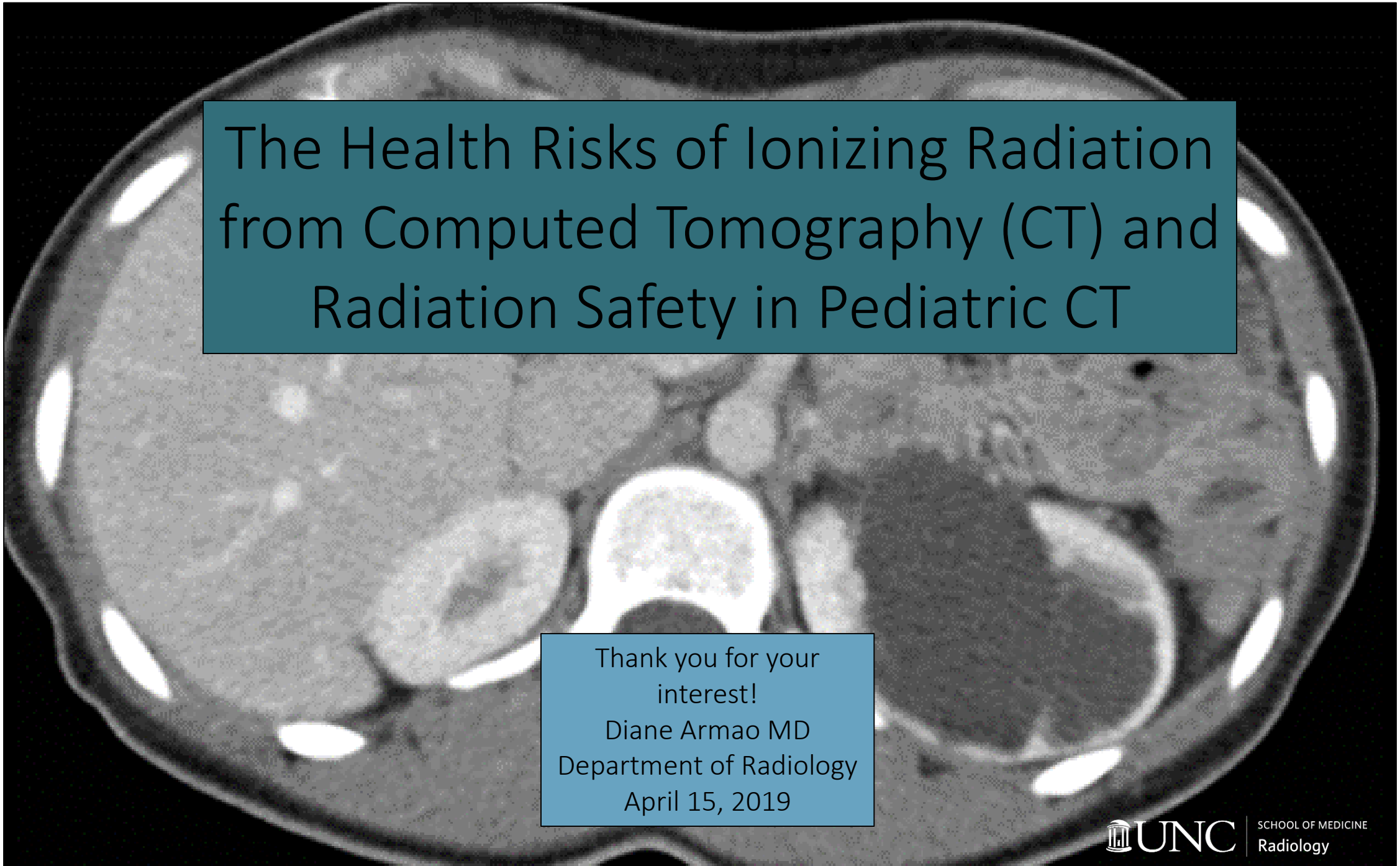

The Health Risks of Ionizing Radiation from Computed Tomography (CT) and Radiation Safety in Pediatric CT

Thank you for your interest!

Diane Armao MD
Department of Radiology

April 15, 2019

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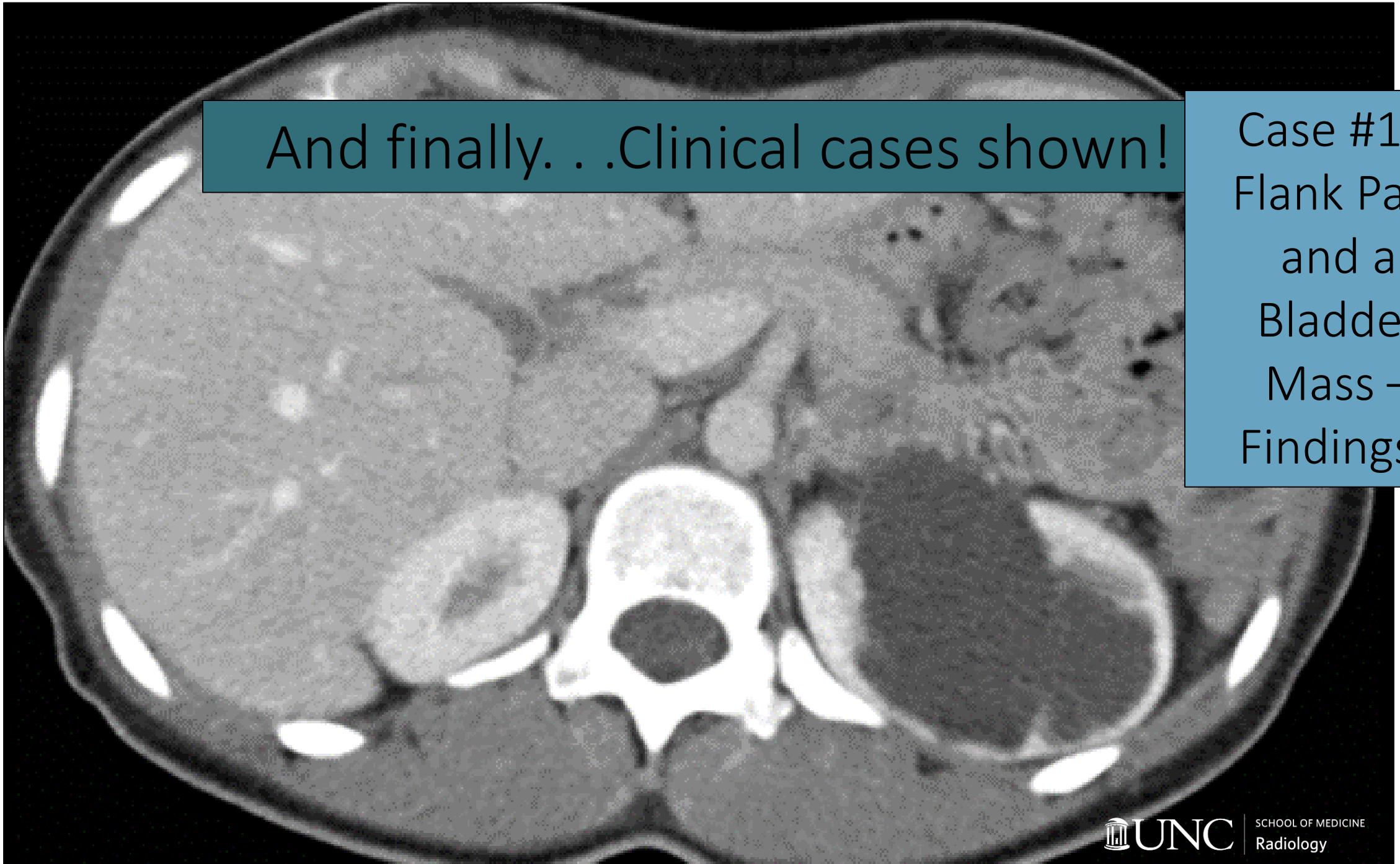
And finally. . .Clinical cases shown!
Case #1 – Flank Pain and a Bladder Mass – Findings?
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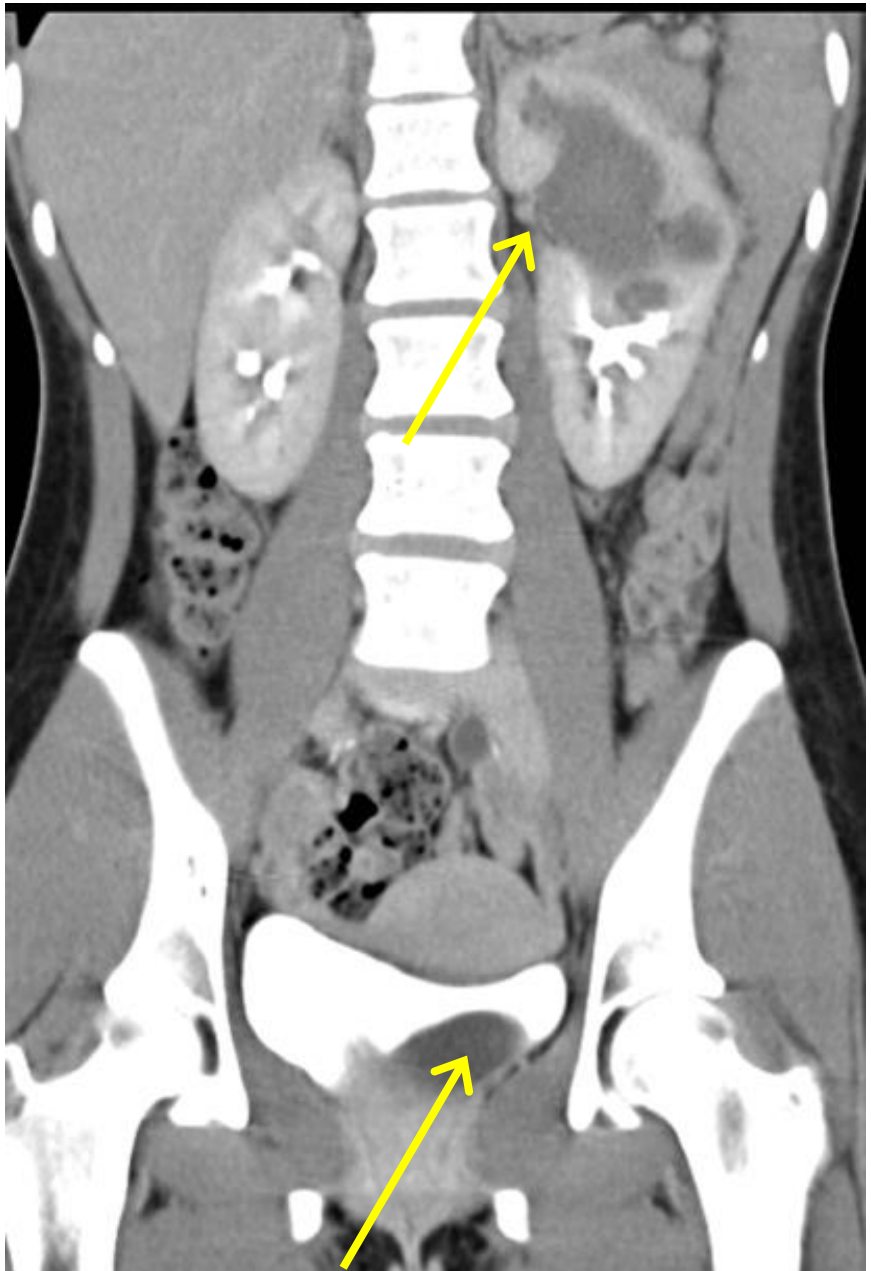
Case #1 Flank pain and bladder mass



Coronal CT, delayed phase. Duplicated collecting systems, dilated left upper pole moiety. Left ureterocele.

<u>Weigert Meyer Rule:</u>

- For duplex kidneys with complete ureteral duplication, the upper renal ureter will have an ectopic insertion that is located medially and inferiorly to the lower pole ureter.
- The upper renal ureter will often form a ureterocele
- The lower renal ureter will have an insertion located laterally and superiorly, and will often be subject to reflux.

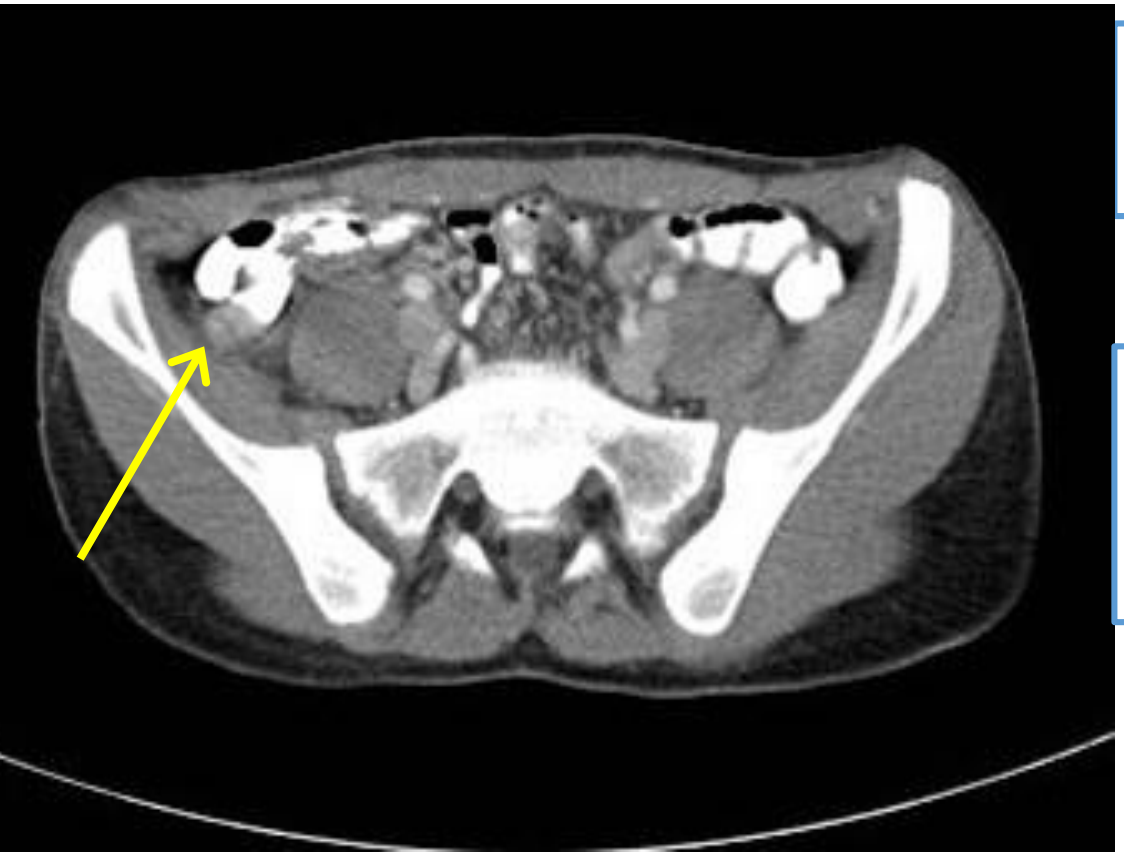
Case #2 RLQ pain

Axial CT, enhanced phase. RLQ inflammatory change and visualized tubular structure consistent with appendicitis.

<u>Acute appendicitis:</u>

- Clinical presentation: RLQ pain, guarding
- CT: Findings of dilated appendix, appendicolith(s), inflammatory stranding RLQ mesenteric fat

Case #3 RLQ pain



Axial CT, enhanced phase. RLQ visualized tubular structure without contrast arising from tip of cecum, consistent with appendicitis.

<u>Acute appendicitis:</u>

- Clinical presentation: RLQ pain, guarding
- CT: Findings of dilated appendix, minimal inflammatory stranding RLQ mesenteric fat

Case #4 Crampy lower abdominal pain

Axial CT, enhanced phase. Hyperdense fluid-filled structure in RLQ paramidline bowel loop

Case #4 Crampy lower abdominal pain

Axial CT, enhanced phase. Hyperdense fluid-filled structure in RLQ paramidline bowel loop

Ingested Foreign Body!