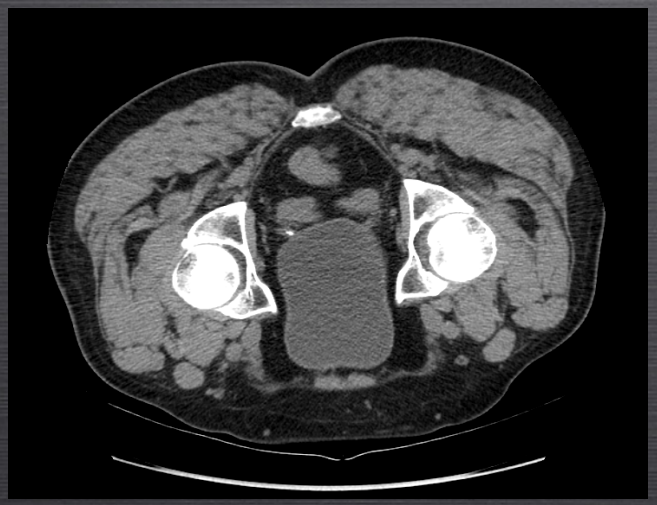
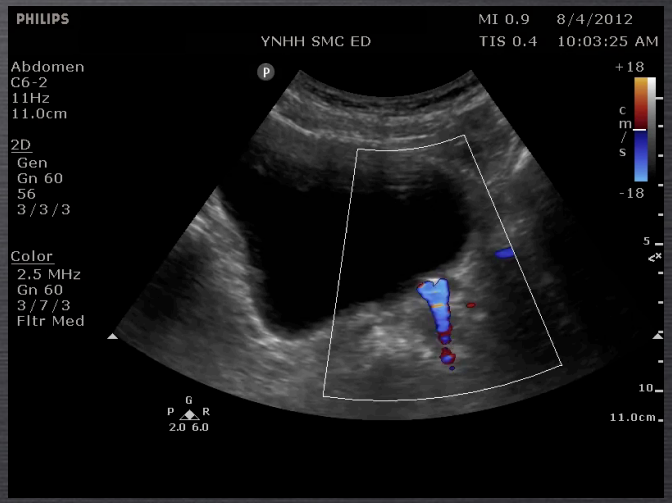
The DOSE initiative: Supporting Dissemination of Reduced-dose Renal Colic CT





October 21st 2017
Chris Moore MD
Associate Professor, Department of Emergency Medicine
Yale University School of Medicine

Disclosures

- I am currently funded by the Agency for Healthcare Research and Quality (AHRQ) under R18HS023778 "Minimizing unnecessary irradiation from renal colic CT scans in the United States"
- I am a consultant with Philips Healthcare on an image recognition research project

“You can observe a lot by just watching”

“When you come to a fork in the road, take it”

“The future ain’t what it used to be”

Yogi Berra 1925-2015

Urinary Stone Disease

- Common: 1 in 11 people, increasing in U.S. and worldwide
- Recurrent: >50% will recur within 5y
- Is an ED dx: >1M dx per year; >2M visits per year for flank pain concern for renal colic
- Painful: "worse than labor"
- Expensive: ~$10B in annual costs
- Lots of CT: 70% of USD get CT
- Controversial: dx and management

Case

- 37 y.o. white male, no past medical history, presents with acute onset of right flank pain and vomiting. Urine is clear but dip shows hematuria. He is getting fluids, toradol, morphine, and zofran.

Imaging?

CT for Kidney Stone

Diagnosis of Acute Flank Pain:
Value of Unenhanced Helical CT

Robert C. Smith[1]
Marco Verga
Shirley McCarthy
Arthur T. Rosenfield

AJR 1996;166:97–101

Received August 7, 1995; accepted after revision September 6, 1995.

Supported in part by the Society of Uroradiology.

[1]All authors: Department of Diagnostic Imaging, Yale University School of Medicine, 333 Cedar St., New Haven, CT 06510. Address correspondence to R. C. Smith.

0361–803X/96/1661–97
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CONCLUSION. Unenhanced CT is a valuable technique for examining patients with acute flank pain in whom a clinical diagnosis is uncertain. It can accurately determine the presence or absence of ureteral stones as well as extraurinary causes of acute flank pain. In most cases, other imaging studies are not required.

"First Time" renal colic

IMPACT OF CT SCAN IN PATIENTS WITH FIRST EPISODE OF SUSPECTED NEPHROLITHIASIS

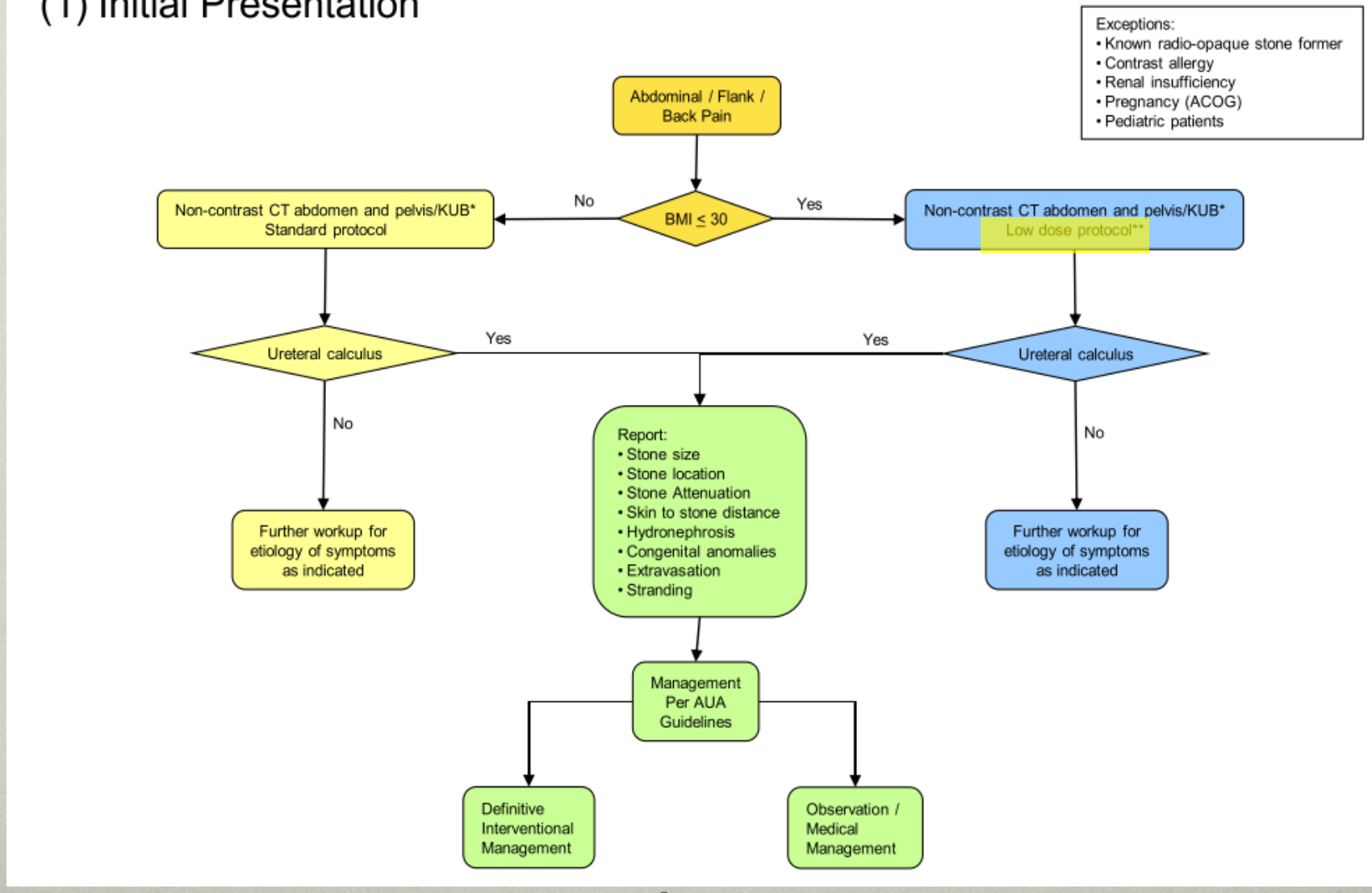
Michael Ha, MD* and Russell D. MacDonald, MD, MPH, CCFP, FRCPC†‡

The Journal of Emergency Medicine, Vol. 27, No. 3, pp. 225–231, 2004

Patients presenting with a first episode of clinically suspected nephrolithiasis should undergo CT scanning because it enhances diagnostic certainty by identifying alternate diagnoses not suspected on clinical grounds alone.

AUA

(1) Initial Presentation



ACR

ACR Appropriateness Criteria® Acute Onset Flank Pain–Suspicion of Stone Disease

TABLE 1. Clinical Condition: Acute Onset Flank Pain — Suspicion of Stone Disease

Variant 1: Suspicion of Stone Disease.

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis without contrast	8	Reduced-dose techniques preferred.	☢☢☢☢
CT abdomen and pelvis without and with contrast	6	If CT without contrast does not explain pain or if without has abnormality that should be further assessed with contrast (ex. stone versus phleboliths).	☢☢☢☢
US kidneys and bladder retroperitoneal with Doppler and KUB	6	Preferred examination in pregnancy, in patients who are allergic to iodinated contrast, and if NCCT is not available.	☢☢
X-ray intravenous urography	4		☢☢☢
MRI abdomen and pelvis without contrast (MR urography)	4		O
MRI abdomen and pelvis without and with contrast (MR urography)	4	See statement regarding contrast in text under "Anticipated Exceptions."	O
CT abdomen and pelvis with contrast	2		☢☢☢☢
X-ray abdomen and pelvis (KUB)	1	Most useful in patients with known stone disease.	☢☢

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate.
*Relative Radiation Level.

ACEP and ACR

Table 2. ACEP and American College of Radiology approaches to acute onset of flank pain.

Acute Onset Flank Pain—Suspicion of Stone Disease

Imaging section

Radiologic procedures ranked ≥5	Rating	Comments	Relative radiation level
CT abdomen/pelvis wo contrast	8	Use reduced dose	☢☢☢☢
CT abdomen/pelvis w/wo contrast	6	Contrast helps assess cause of pain if noncontrast CT does not show stone	☢☢☢☢
US kidneys/bladder and KUB	6	Good combination for pts with known stone disease	☢☢

Clinical section

Clinical presentation	Imaging recommended	Comments
First stone passage (suspected)	NCCT	Benefit in establishing diagnosis exceeds radiation risk
Recurrent stone passage (similar clinical presentation to initial)	US kidneys/bladder plus/minus KUB Complicated clinical cases (consider NCCT)	KUB may show size and location of stone; US will typically show degree of hydronephrosis and can confirm ureteral urine flow into bladder; radiation exposure eliminated or reduced

KUB, kidneys, ureters, and bladder; *NCCT*, non-contrast CT.

National Trends in Use of Computed Tomography in the Emergency Department

Keith E. Kocher, MD, MPH, William J. Meurer, MD, MS, Reza Fazel, MD, MSc, Phillip A. Scott, MD, Harlan M. Krumholz, MD, SM, Brahmajee K. Nallamothu, MD, MPH

Smith article, 1996

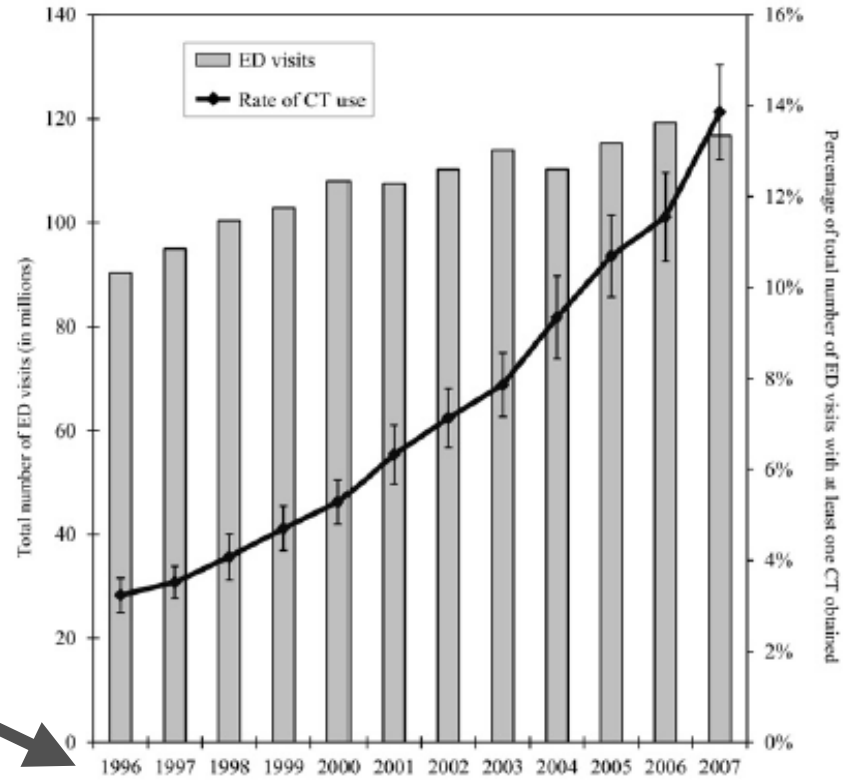


Figure 1. Number of ED visits and CT use by year, with 95% CI.

Ann Emerg Med. 2011;58:452-462

Is CT helping?

Radiological Imaging of Patients With Suspected Urinary Tract Stones: National Trends, Diagnoses, and Predictors

ACADEMIC EMERGENCY MEDICINE 2011; 18:700–707

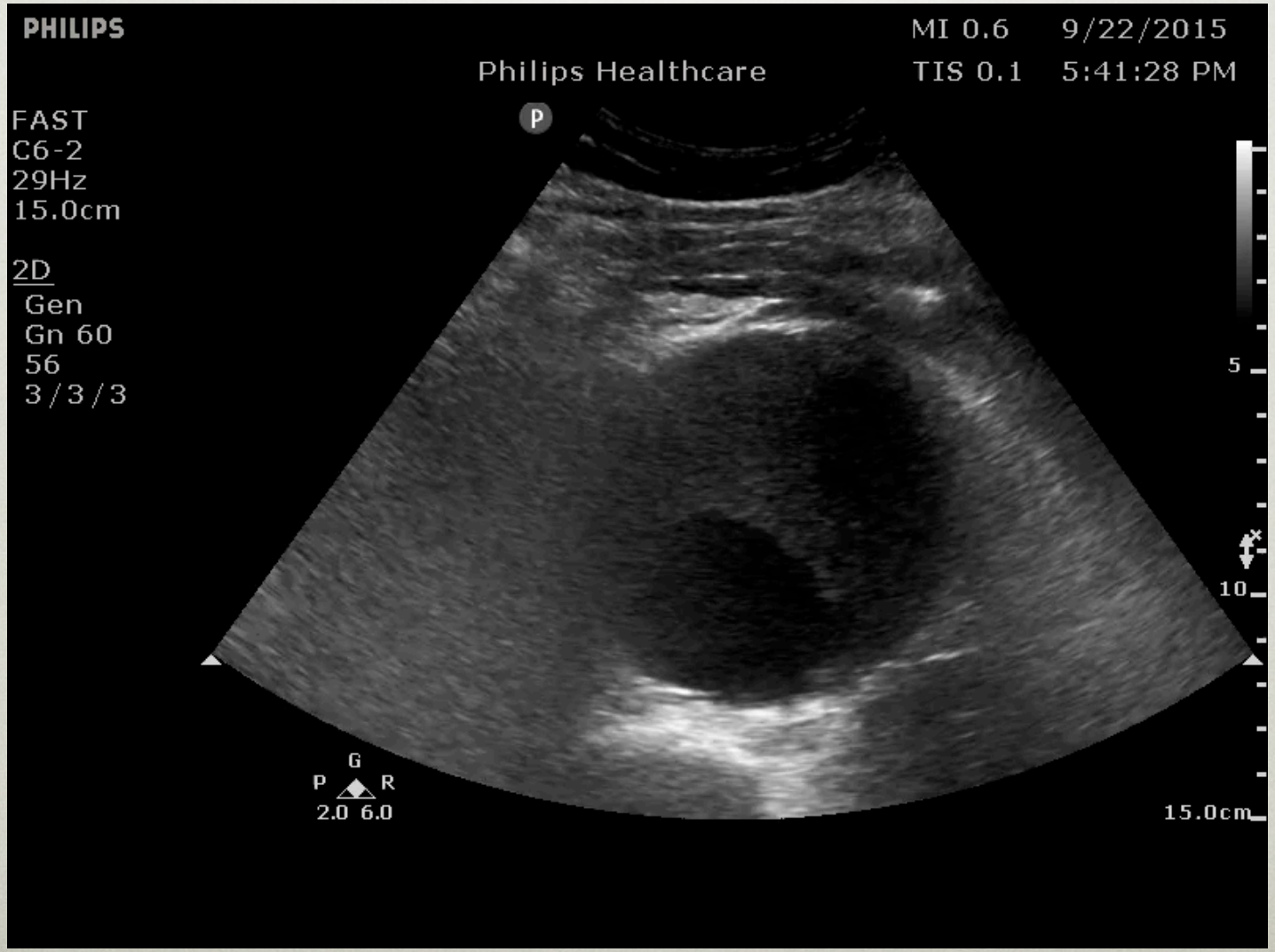
Conclusions: From 1996 to 2007, there was a 10-fold increase in the utilization of CT scan for patients with suspected kidney stone without an associated change in the proportion of diagnosis of kidney stone, diagnosis of significant alternate diagnoses, or admission to the hospital.

CT in Detecting Urinary Tract Calculi: Influence on Patient Imaging and Clinical Outcomes[1]

Radiology 2002; 225:441–449

CONCLUSION: Use of imaging for suspected UTC has increased markedly since the introduction of unenhanced CT, with little effect on acute care of patients in the ED.

"Bad Things"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"First Time" renal colic

IMPACT OF CT SCAN IN PATIENTS WITH FIRST EPISODE OF SUSPECTED NEPHROLITHIASIS

Other significant pathology
Mesenteric and retroperitoneal lymphadenopathy, possible lymphoma
Right adrenal adenoma
Right ovarian neoplasm with liver mass
Enlarged prostate
Right adrenal mass
Multiple liver lesions, possibly metastatic
Left renal cell carcinoma, abdominal aortic aneurysm
Splenomegaly, cause not yet determined
Right adrenal adenoma
Mesenteric lymphadenopathy, possible lymphoma
Possible ulcerative colitis
Left periureteric mass with hydronephrosis, liver metastasis
Right renal cysts, possible malignancy
Right adrenal adenoma
Right renal mass, possible malignancy
Retrocecal lymphadenopathy, possible metastatic testicular cancer
Left ovarian cancer
Lesion in right hepatic lobe
Splenomegaly, cause not yet determined

"Bad things"

Academic Emergency Medicine
Official Journal of the Society for Academic Emergency Medicine

ORIGINAL RESEARCH CONTRIBUTION

Prevalence and Clinical Importance of Alternative Causes of Symptoms Using a Renal Colic Computed Tomography Protocol in Patients With Flank or Back Pain and Absence of Pyuria

Chris L. Moore, MD, Brock Daniels, MD, Dinesh Singh, MD, Seth Luty, MS, and Annette Molinaro, PhD

Back pain or flank pain and no pyuria

Diagnosis	All CTs: All (n = 5,383)	All CTs: % of all	% of all
No cause of pain seen on CT	2,331	43.3	39.6
Kidney stone as cause of pain	2,569	47.7	54.9
Small stone (5 mm or less)	1,834	34.1	42.3
Large stone (>5 mm)	492	9.1	7.7
CT signs of passed stone	243	4.5	4.9
Non–kidney stone cause of pain	4,83	9.0	5.4
Acutely important cause	329	6.1	2.8
Follow-up recommended	119	2.2	2.0
Unimportant cause	35	0.7	0.7

Moore et al. Acad Emerg Med 2013;5:470-8.

"Bad things"

Acutely important alternate causes	*n*	%
Diverticulitis	55	16.7
Appendicitis	23	7.0
Mass concerning for new malignancy	34	10.3
Ovarian/adnexal/uterine	21	6.4
CT evidence pyelonephritis	95	28.9
Peri/intrarenal hemorrhage	9	2.7
Hydronephrosis w/o stone	22	6.7
Biliary (cholecystitis or choledocholithiasis)	8	2.4
Pneumonia	15	4.6
Bowel perforation	3	0.9
Bowel obstruction	9	2.7
Retroperitoneal pathology	5	1.5
Colitis or enterocolitis (treated)	3	0.9
Pancreatitis	10	3.0
Other (renal vein thrombosis, large mesenteric cyst, foreign body)	3	0.9
Aneurysm or dissection	4	1.2
Abscess (thoracoabdominal)	3	0.9
Traumatic injury	5	1.5
Post-operative findings (urgent)	2	0.6
Total acutely important alternate causes (% of all CTs):	329	(6.1%)

2.8% with BP/FP no pyuria

Moore et al. Acad Emerg Med 2013;5:470-8.

Incidental Findings

- Prevalence of 12.7% (95% CI 11.8-13.6%)
- 1 in 8 CT Renal Colic will have in incidental finding with follow-up imaging recommended

Incidental Findings on CT for Suspected Renal Colic in Emergency Department Patients: Prevalence and Types in 5,383 Consecutive Examinations

SA-CME

Mohammad Samim, MD, MRCS[a], Sarah Goss, MD[b], Seth Luty, MS[b], Jeffrey Weinreb, MD[a], Christopher Moore, MD[b]

Conclusions: Important IF occurred in 12.7% of non-enhanced CT scans performed for suspected renal colic in the emergency department and are more common in older individuals. Prospective studies that use radiographic recommendations to characterize IF and examine the outcome and cost of their workup are encouraged.

Key Words: Incidental findings, CT, renal colic

J Am Coll Radiol 2015;12:63-69. *Copyright © 2015 American College of Radiology*

COST-EFFECTIVENESS AND THE "R" WORD

Comparative effectiveness

vs.

Cost effectiveness

Beyond the "R Word"? Medicine's New Frugality

M. Gregg Bloche, M.D., J.D. N ENGL J MED 366;21 NEJM.ORG MAY 24, 2012

My Turn SCOPE

WHY I 'RATION' CARE

BY CHRISTOPHER MOORE

YOUR SON JUST got a concussion playing soccer. You want a CT scan to make sure he's OK—or do you?

As an emergency physician and a parent, I can see it both ways. Following the recent death of Natasha Richardson, we saw more patients coming to the ER for a head injury who might have previously just taken some Tylenol. Richardson bumped her head skiing, thought she was OK, and ended up dead. It's a scary scenario.

Several weeks ago, I saw a 15-year-old who was hit in the back of the head playing soccer. He wasn't knocked out, but initially wasn't sure where he was and seemed slow to answer questions. When I saw him, he had a slight headache, but his confusion was gone. He wasn't nauseated, his pupils were reactive, his neurologic exam was normal, and there was no external trauma. He'd suffered a concussion, but his parents wondered if something more serious had occurred. Wouldn't a CT scan show skull fractures and internal bleeding?

It's a question I hear often from parents, and I take it seriously. In a case like this, evidence shows the chance of a life-threatening injury is vanishingly small. Since we're dealing with radiation, a CT scan isn't harmless: some estimates put the long-term risk of cancer death from a single CT as high as one in 1,000—a risk that's greater in younger patients who have longer to live. (In an era when we are now doing more than 60 million CTs annually—up from 3 million in 1980—nearly one in six Americans may have one in any year.) And though there's concern with the ballooning expense of imaging, cost was not necessarily an issue. It's not going to stop a physician who feels a CT is needed. Don't want to get sued? Order the CT.

I guess that many emergency doctors in my situation would have done just that. But I didn't. I involved the patient and his parents in a discussion; they listened, and we decided together not to get one. I spoke with the boy's pediatrician and recommended that the patient follow up in the morning with "impact testing" to see if there were any postconcussive issues.

These kinds of conversations between doctors and patients need to happen more frequently. This wasn't "rationing"; in this case, not doing the test simply represented sound medical advice: in my opinion, the potential long-term harm to the patient outweighed the benefit. And he's doing fine now—back in school, but taking a break from contact sports.

MOORE *teaches at the Yale School of Medicine.*

CT dose

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	136.250-1438.750	17.63	791.27	Body 32
4	Helical	153.250-1223.250	1.45	34.14	Body 32
4	Helical	1226.500-1436.500	2.76	75.76	Body 32
			Total Exam DLP:	901.16	

1/1

Dose-length-protocol (DLP) X conversion factor (0.15)

regular dose 791.27 mGy-cm x 0.15 = ~11.9mSv

ultra-low dose = 109.9 mGy-cm x 0.15 = ~1.6mSv

CANCER RISK

Table 4. Estimated Number of Patients Undergoing Computed Tomography (CT) That Would Lead to the Development of 1 Radiation-Induced Cancer, by Type of CT Examination and Age at the Time of Exposure, Based on the Median and Interquartile Radiation Dose Observed

Anatomic Area, Type of CT Study	Patients, Median (Interquartile Range), No.					
	Age, 20 y		Age, 40 y		Age, 60 y	
	Female	Male	Female	Male	Female	Male
Head and neck						
Routine head	4360 (3290-5110)	7350 (5540-8620)	8100 (6110-9500)	11 080 (8350-12 990)	12 250 (9230-14 360)	14 680 (11 070-14 680)
Routine neck	2390 (1640-3540)	4020 (2770-5970)	4430 (3050-6580)	6058 (4170-8990)	6700 (4620-9940)	8030 (5530-8030)
Suspected stroke	660 (460-980)	1120 (770-1650)	1230 (850-1820)	1682 (1170-2490)	1860 (1290-2750)	2230 (1550-2230)
Chest						
Routine chest, no contrast	390 (290-630)	1040 (770-1670)	720 (540-1160)	1566 (1170-2520)	1090 (820-1760)	2080 (1550-2080)
Routine chest, with contrast	380 (270-650)	1020 (710-1740)	720 (500-1210)	1538 (1070-2620)	1070 (750-1830)	2040 (1420-2040)
Suspected pulmonary embolism	330 (230-460)	880 (610-1220)	620 (420-850)	1333 (920-1840)	930 (640-1280)	1770 (1220-1770)
Coronary angiogram	150 (130-230)	390 (350-610)	270 (250-420)	595 (540-920)	420 (370-640)	790 (710-790)
Abdomen and pelvis						
Routine abdomen-pelvis, no contrast	500 (380-770)	660 (510-1024)	930 (710-1430)	1002 (770-1540)	1400 (1080-2160)	1330 (1020-1330)
Routine abdomen-pelvis, with contrast	470 (380-700)	620 (510-930)	870 (710-1300)	942 (770-1400)	1320 (1080-1960)	1250 (1020-1250)
Multiphase abdomen-pelvis	250 (180-370)	330 (240-490)	460 (330-680)	498 (360-730)	700 (500-1030)	660 (480-660)
Suspected aneurysm or dissection	320 (210-390)	420 (280-510)	590 (390-710)	636 (420-770)	890 (580-1080)	840 (550-840)

Arch Intern Med. 2009;169(22):2078-2086

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Ultrasonography versus Computed Tomography for Suspected Nephrolithiasis

R. Smith-Bindman, C. Aubin, J. Bailitz, R.N. Bengiamin, C.A. Camargo, Jr., J. Corbo, A.J. Dean, R.B. Goldstein, R.T. Griffey, G.D. Jay, T.L. Kang, D.R. Kriesel, O. J. Ma, M. Mallin, W. Manson, J. Melnikow, D.L. Miglioretti, S.K. Miller, L.D. Mills, J.R. Miner, M. Moghadassi, V.E. Noble, G.M. Press, M.L. Stoller, V.E. Valencia, J. Wang, R.C. Wang, and S.R. Cummings

RESULTS

A total of 2759 patients underwent randomization: 908 to point-of-care ultrasonography, 893 to radiology ultrasonography, and 958 to CT. The incidence of high-risk diagnoses with complications in the first 30 days was low (0.4%) and did not vary according to imaging method. The mean 6-month cumulative radiation exposure was

CONCLUSIONS

Initial ultrasonography was associated with lower cumulative radiation exposure than initial CT, without significant differences in high-risk diagnoses with complications, serious adverse events, pain scores, return emergency department visits, or hospitalizations. (Funded by the Agency for Healthcare Research and Quality; ClinicalTrials.gov number, NCT01451931.)

N ENGL J MED 371;12 NEJM.ORG SEPTEMBER 18, 2014

NEJM US vs. CT

Table 3. Primary and Secondary Study Outcomes According to Study Group.*

	Point-of-Care Ultrasonography (N=908)	Radiology Ultrasonography (N=893)	Computed Tomography (N=958)	P Value
High-risk diagnosis with complication — no. of patients (%)	6 (0.7)	3 (0.3)	2 (0.2)	0.30
Radiation exposure — mSv	10.1±14.1	9.3±13.4	17.2±13.4	<0.001
During emergency department enrollment visit	6.5±9.4	4.7±8.4	14.1±9.6	<0.001
From enrollment to 30 days	1.2±4.4	1.8±5.4	1.0±3.9	0.19
30–180 days	1.5±5.5	2.1±6.8	1.2±4.8	0.08
Accuracy for diagnosis of nephrolithiasis‖				
Sensitivity — % (95% CI)	85 (80–89)	84 (79– 89)	86 (82–90)	0.74
Specificity — % (95% CI)	50 (45–54)	53 (49–57)	53 (49–58)	0.38

NEJM US vs. CT

Accuracy for diagnosis of nephrolithiasis‖	POC US	Rad US	CT
Sensitivity — % (95% CI)	85 (80–89)	84 (79– 89)	86 (82–90)
Specificity — % (95% CI)	50 (45–54)	53 (49–57)	53 (49–58)

Table 1. Median reported SN/SP for modalities of interest in studies relative to non-contrast CT (based on the evidence report).

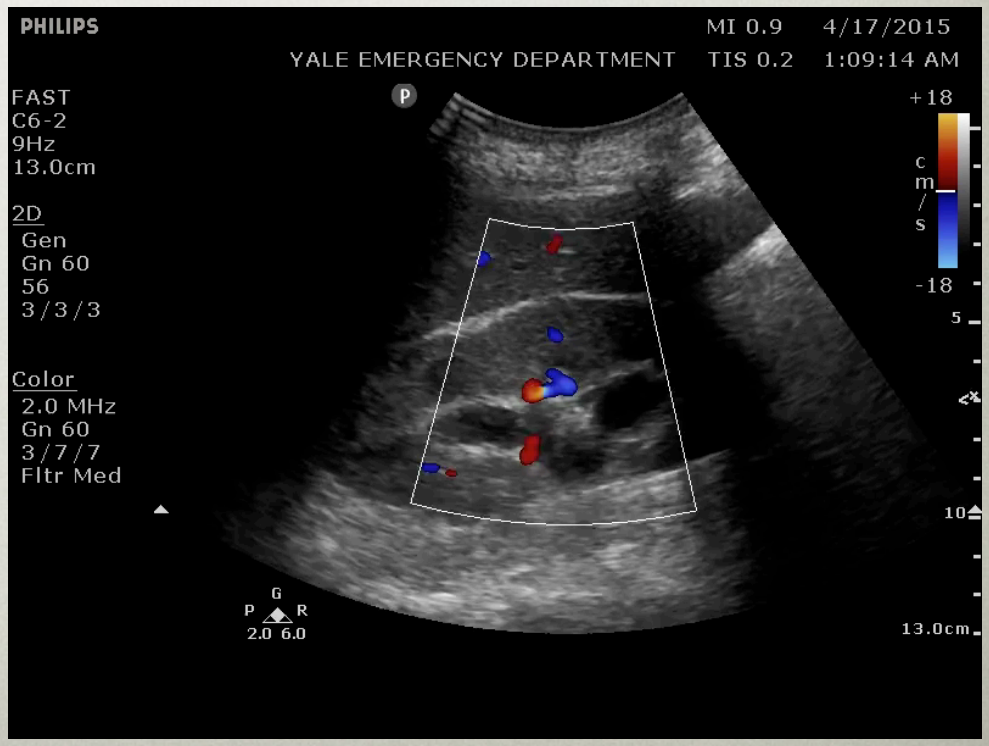
Modality	Median SN	Median SP
Conventional radiography	57%	76%
Ultrasound	61%	97%
Intravenous pyelography	70%	95%
MRI	82%	98.3%
CT (not as gold standard)	98%	97%

CLINICAL EFFECTIVENESS PROTOCOLS FOR IMAGING IN THE MANAGEMENT OF URETERAL CALCULOUS DISEASE: AUA TECHNOLOGY ASSESSMENT

An ultrasound is performed

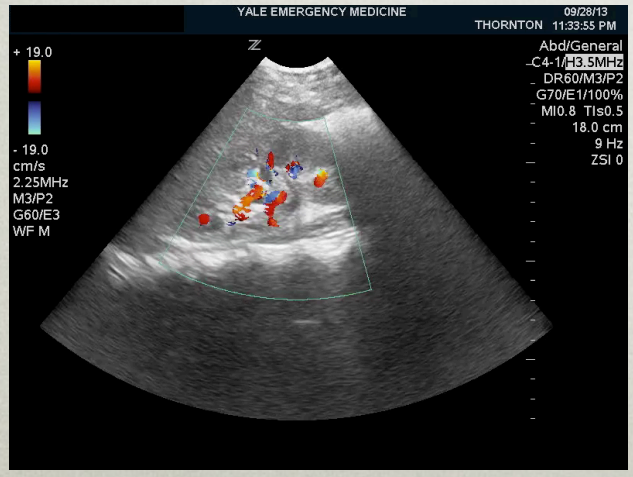
The following ED US is performed. Patient is improving but still some pain. Would you order further imaging in the ED?

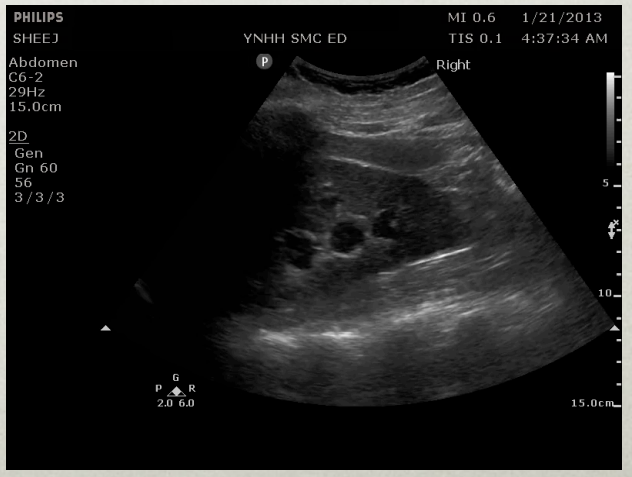
1) No further ED imaging
2) KUB
3) CT
4) Other



Hydro - Training

Test and Reference Standard	Sensitivity (95% CI), %	Specificity (95%CI), %
Hydronephrosis on ultrasonography vs hydronephrosis on CT		
All	72.6 (65.4–78.9)	73.3 (66.1–79.4)
Attending physician with fellowship training	92.7 (83.8–96.9)	81.4 (63.8–91.5)
Attending physician	61.5 (40.5–79.0)	77.9 (59.9–89.2)
Experienced resident	70.4 (59.3–79.5)	70.6 (59.6–79.7)
Inexperienced clinician	72.7 (54.4–85.7)	65.0 (45.3–80.6)
Moderate hydronephrosis on ultrasonography vs any hydronephrosis on CT		
All	31.3 (19.3–46.1)	94.6 (90.3–97.1)
Attending physician with fellowship training	38.2 (4.9–88.2)	98.3 (82.8–99.9)
Attending physician	23.1 (7.2–53.7)	97.1 (89.7–99.2)
Experienced resident	37.0 (19.6–58.7)	90.8 (80.4–96.0)
Inexperienced clinician	26.0 (10.4–51.6)	93.8 (83.2–97.9)



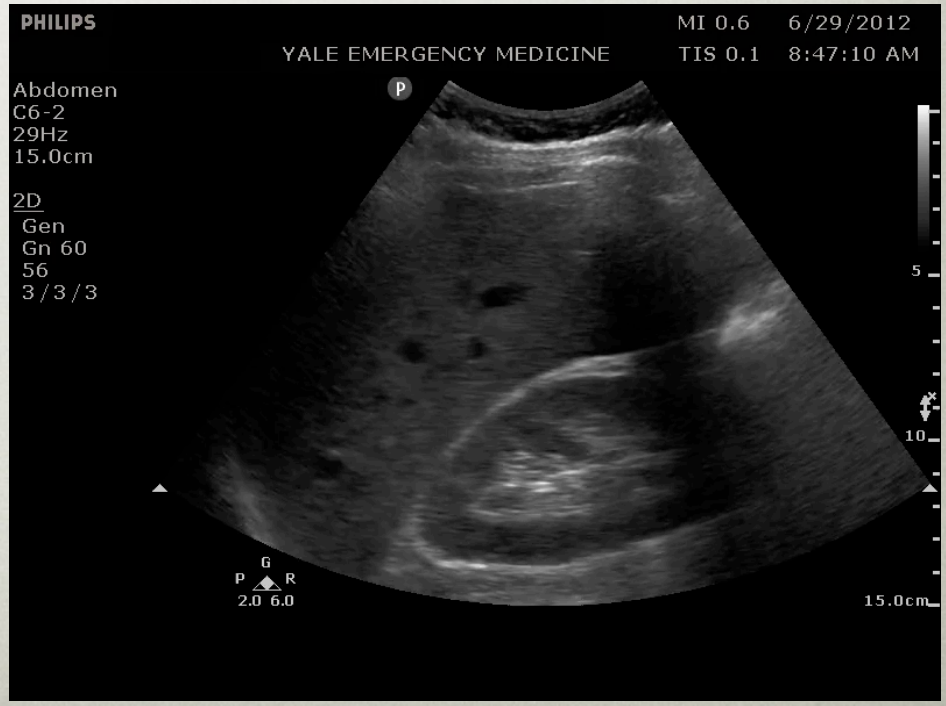


Herbst et al., Ann Emerg Med 2014;64:269-276.

An ultrasound is performed

The following ED US is performed. Patient is improving but still has pain. Would you order further imaging in the ED?

1) No further ED imaging
2) KUB
3) CT
4) Other



Why Get a CT?

- Concerned this is not a kidney stone, may be something "bad"

- Pretty sure it is a kidney stone/ not something "bad", but want to know how big the stone is, where it is located

What can help you with this?

S.T.O.N.E. Score

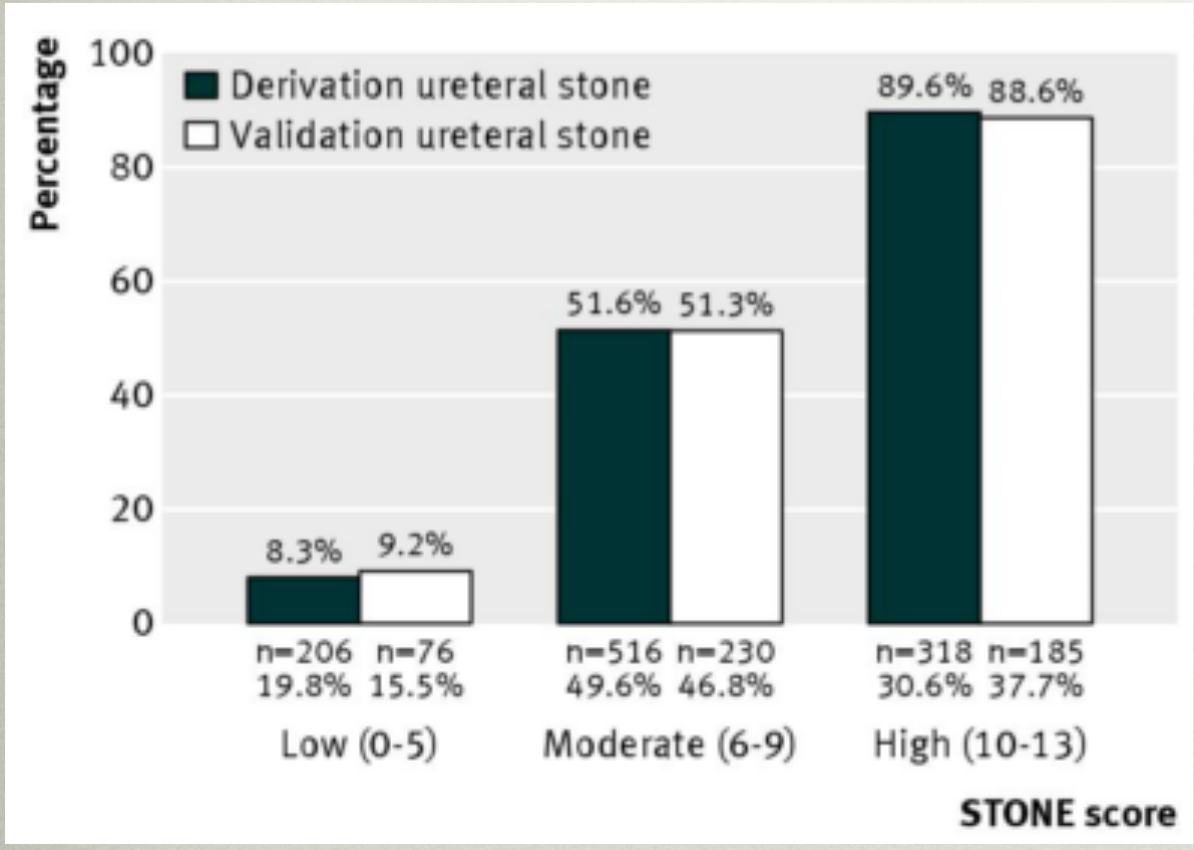
Table 3| **STONE score, factors, and categories**

STONE score by factors and categories	Odds ratio (95% CI)	Points
Sex		
Sex:		
Female	1	0
Male	4.31 (3.13 to 5.98)	2
Timing		
Duration of pain to presentation:		
>24 hours	1	0
6-24 hours	1.85 (1.27 to 2.70)	1
<6 hours	6.34 (4.26 to 9.33)	3
Origin		
Race:		
Black	1	0
Non-black	6.77 (3.79 to 12.64)	3
Nausea		
Nausea and vomiting:		
None	1	0
Nausea alone	1.98 (1.38 to 2.86)	1
Vomiting alone	5.26 (3.53 to 7.93)	2
Erythrocytes		
Hematuria (on urine dipstick):		
Absent	1	0
Present	5.61 (3.96 to 8.04)	3
Total		0-13

- Sex
  - Male +2
- Timing
  - <6h +3
  - 6-24h +1
- Origin
  - non-black +3
- Nausea
  - Nausea alone +1
  - With vomiting +2
- Erythrocytes
  - any blood on UA dip +3

Moore et al. BMJ 2013;5:470-8.

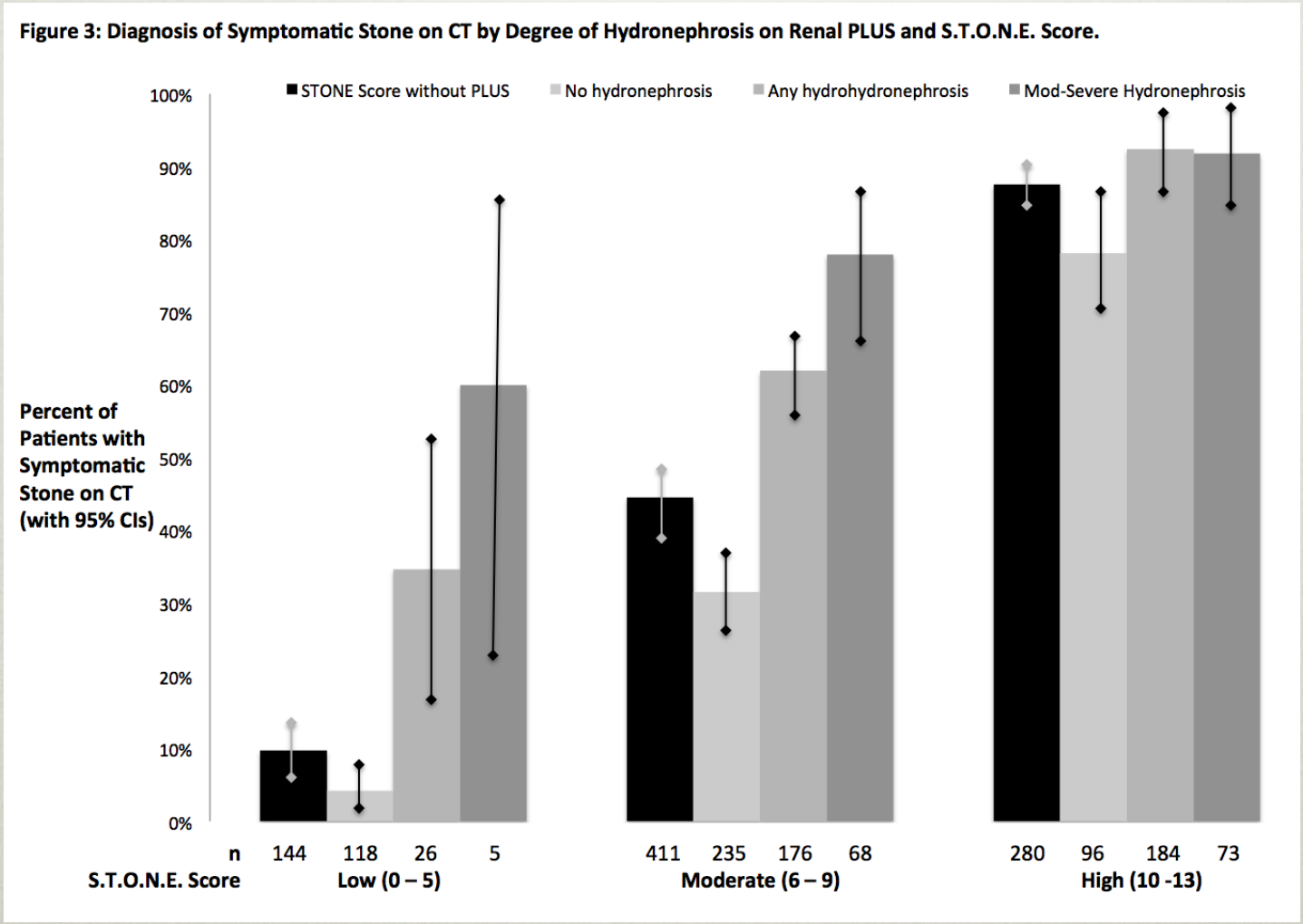
S.T.O.N.E. Score



- Sex
  - Male +2
- Timing
  - <6h +3
  - 6-24h +1
- Origin
  - non-black +3
- Nausea
  - Nausea alone +1
  - With vomiting +2
- Erythrocytes
  - any blood on UA dip +3

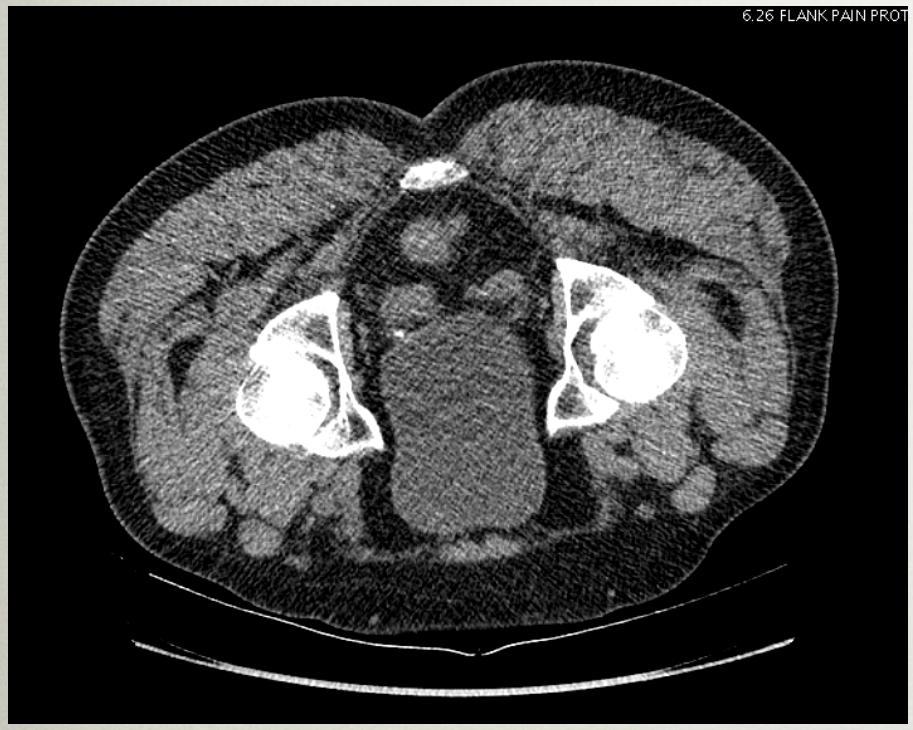
Moore et al. BMJ 2013;5:470-8.

S.T.O.N.E. PLUS
(POINT-OF-CARE LIMITED ULTRASOUND)



Accepted, in revision, Ann EM.

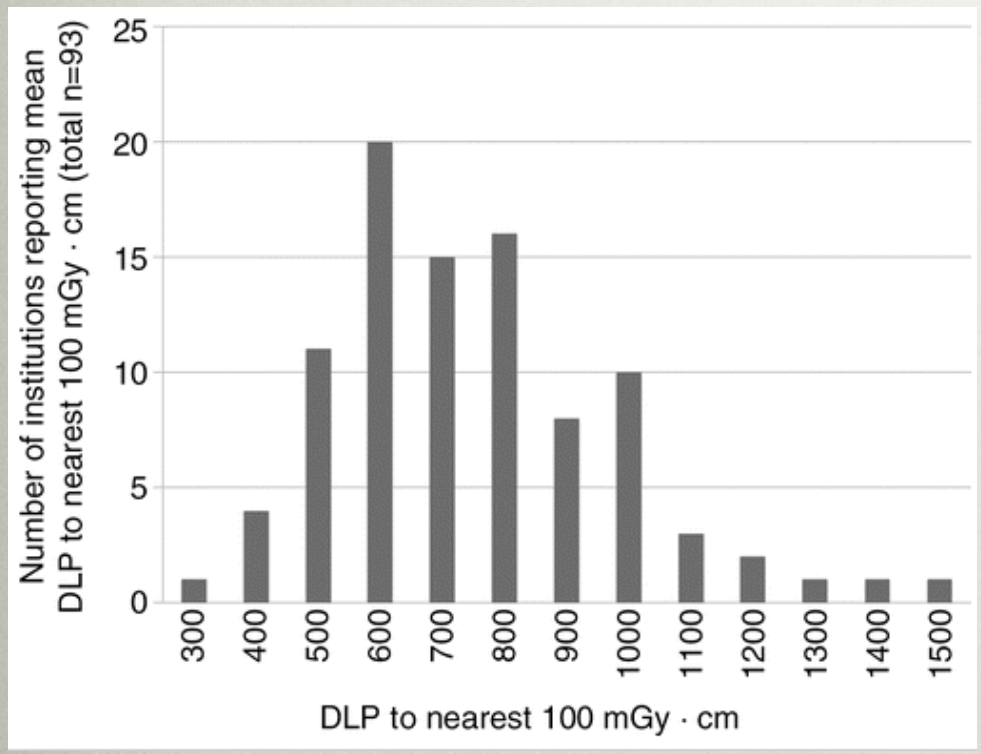
"ULTRA" LOW DOSE CT



- ~85% CT radiation dose decrease (~11mSv to ~1.5mSv)
- Overall sensistivity 90.2%; specificity 98.9%
- 96.0% sensitive for stones requiring 90d intervention

Moore et al. Ann Emerg Med 2015;65:189-198.

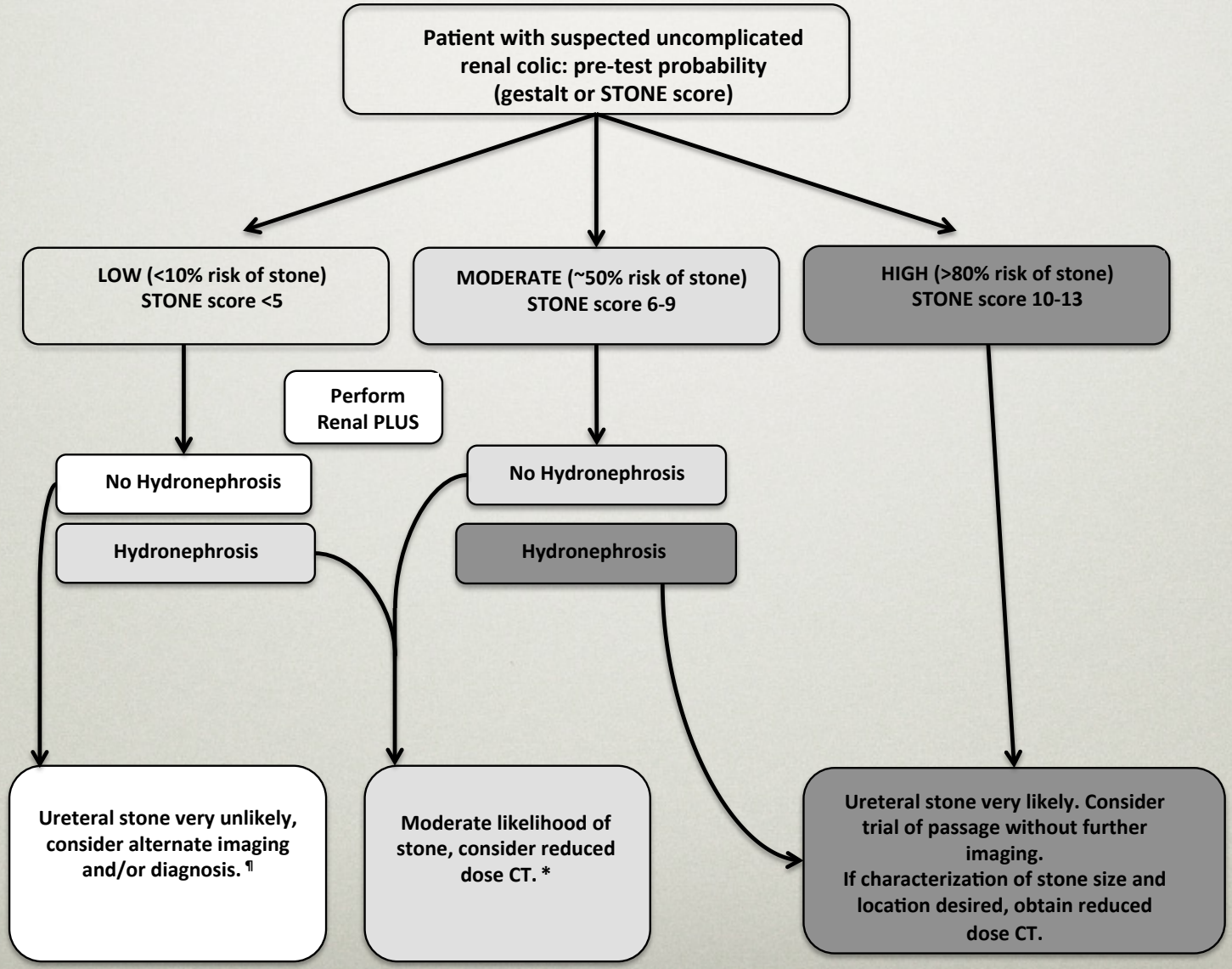
Dose Variation in Renal Colic CT



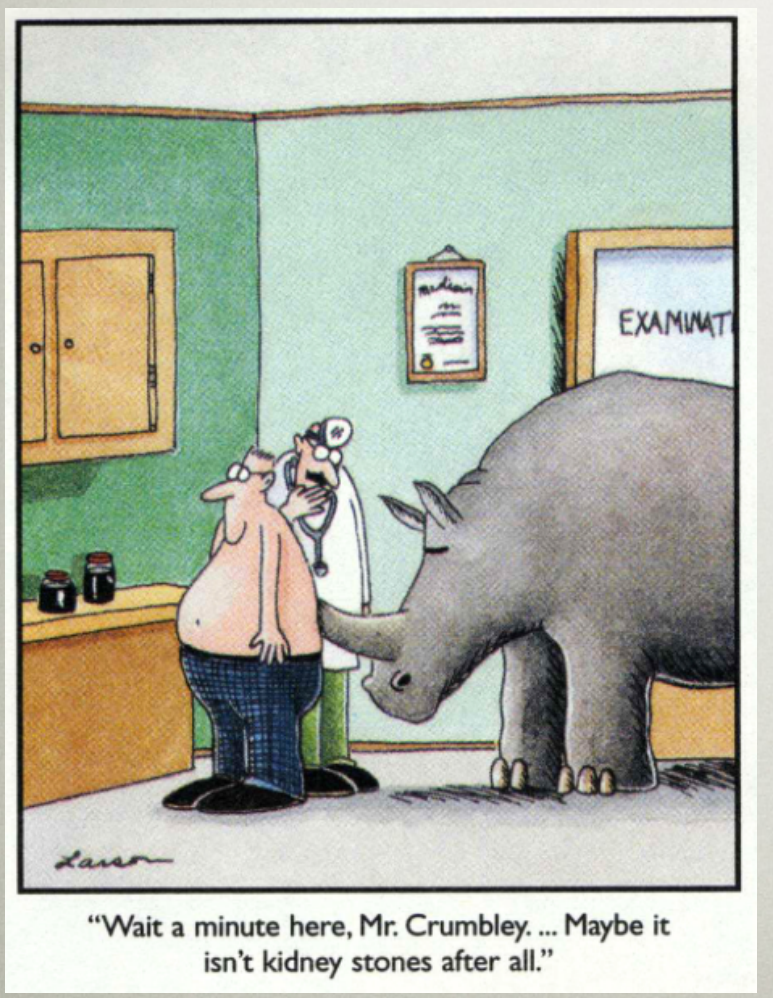
- 49,903 CTs from Dose Index Registry
- "Low dose" defined as <3mSv
- 2% of CT Renal Colic "low dose" (DLP ~200mGy*cm)
- Average 11.2mSv

Lukasiewicz et al., Radiology 2014;271:445-451.

An Imaging Algorithm



Take Home…



"Wait a minute here, Mr. Crumbley. ... Maybe it isn't kidney stones after all."

- First time renal colic with classic presentation does **NOT** *require* a CT
- Be aware of the benefits (?) and downsides of CT (IF, radiation, $)
- An objective clinical prediction rule (the STONE score) and bedside US may help determine need for CT
- Be aware of the challenges of diagnosing hydro on ultrasound
- If you do a CT, consider reduced dose; understand what your institution does, and offers (email me if you don't have)