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CT Imaging in Abdominal, Pelvic and Flank Pain: Critical Points for the Emergency Physician in 2012

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CT Scans Use is Increasing Dramatically in Clinical Practice:

Many recent studies have demonstrated an exponential increase in the number of CT scans ordered in the Emergency Department, especially to investigate abdominal, pelvic and flank pain. One study looking at the difference between CT rates in 2001-2007 found an annual rate of increase from 51 CT scans per 1,000 patients in 2001 to 106 CT scans per 1,000 patients in 2007. This represented an annual rate increase of 10 CT scans per 1,000 patients (1). Another article confirmed this dramatic increase, showing a 330% increase in the rate of CT imaging from 1996 to 2007. A CT scan as documented to be a part of an ED patient encounter grew from 3.2% to 13.9% over this time period (2).

When looking directly at the overall rate of CT use in relation to the age of the patient, another study demonstrated some interesting facts. In a multi-state analysis of 226 ED's, the overall rate of CT scans ordered per adult patient was 16.7%. The rate was noted to increase dramatically by age, from a rate of 11.3% in patients between the ages 21-29 to 24.5% in patients over the age of 65 years. Even in the pediatric population, 5.3% of patients received CT scans (3). These studies emphasize how integral a CT scan has become to current Emergency Medicine practice, especially in the care of the elderly.

Improvements in CT scanning Technology:

So why the gigantic increase in the use of CT scanning in EM practice? Most significantly, there have been many advances in CT scan technology in recent years that have resulted in the ability to obtain extremely detailed images revealing a great deal of information about the human body. The first CT scans were obtained one slice at a time with a rotation speed of 5 seconds and a relatively poor image

quality of 80 x 80 pixels (4). Newer CT imaging utilizes a spiral or helical technique. The detector moves in a circular manner around the table gantry as it rapidly positions the patient through the imaging sequence. This allows for multi-dimensional imaging and very fast movement of the detector around the patient. In fact, speeds of one rotation in 0.33 seconds are now commonly achieved. This, in turn, leads to less motion artifact and better quality images. Newer CT technology also has vastly improved resolution to allow for an image quality of 512 x 512 pixels.

Furthermore, multi-detector row CT scan (MDCT) machines are now commonly in practice, with 64 detectors the common standard. This means that one rotation of the gantry around the patient will result in 64 slices obtained by the machine. Amazingly, this technology is rapidly evolving and 128 and 256 MDCT machines are already available in some centers and will be more widespread in the near future. Slice thickness has also decreased as CT imaging has evolved, allowing discrimination of smaller and smaller body structures. In the past, CT scan images could only practically achieve slices with thickness of 2-5 mm. Now, the current generation CT scanners can achieve image cuts with a slice thickness of 0.5-1 mm, due to the increased speed of imaging and better scan processing.

Another improvement has come from advances in computer software that have allowed for the routine reformatting of images into multiple planes. CT scans of the abdomen and pelvis routinely include axial, coronal and sagittal plane imaging to inspect the body from multiple angles. Body structures that may have been previously difficult to see in one body plane can now be better visualized by looking from additional views.

CT Scans Result in More Accurate Diagnosis and Increased Patient Satisfaction:

With these improvements in CT scan technology and the ensuing increase in the numbers of CT scans ordered from the ED for the evaluation of abdominal, pelvic and flank pain comes definitive pros and cons. On the plus side, there is evidence that immediate CT scanning in patients with acute abdominal pain increases the accuracy of the treating physician's diagnosis. In a retrospective review of 2,222 patients presenting with abdominal, pelvic and flank pain, 96.8% were correctly diagnosed following a CT scan (5). These are very high numbers and some have subsequently questioned the methodology of this study due to 2 main issues. The first is the question of whether all patients received comparable ED evaluations for their abdominal pain in addition to the CT scan. The second is the question of the reference gold standards used for defining the correct CT diagnosis. For a positive CT scan, these were the findings at surgery or autopsy and for a negative CT scan, these were an uneventful 1-month follow-up or a final diagnosis normally not expected to be identified on CT scan. However, we can still learn some valuable points from this study, as demonstrated by the breakdown of the diagnoses encountered on CT scan. In this study, appendicitis was correctly identified in 354 patients (15.9%). Other commonly diagnosed conditions included bowel obstruction in 190 patients (8.6%), diverticulitis in 182 patients (8.2%), GU pathology (stones, infection) in 131 patients (5.9%), pancreatitis in 72 patients (2.4%), gynecologic pathology in 54 patients (2.3%) and vascular diseases in 33 patients (1.5%). While the list of these above diagnosed diseases is impressive, the most commonly diagnosed condition was non-specific abdominal pain, which was diagnosed in 984 patients (44.3%). The conclusion from this study was that immediate CT scanning increases physician diagnostic accuracy. The authors also commented on the fact that 500 patients were immediately discharged from the ED following the CT scan. However, one might also conclude from this study that in almost half of these patients, the CT scan failed to diagnose a

defined etiology for the pain. This issue of non-specific abdominal pain is further discussed in the conclusion section of the article.

With this higher rate of CT use has come another interesting development. As CT scan technology has accelerated over the past years, our patient's perception on CT use has also changed. In a cross-sectional study of 1,168 ED patients presenting with acute abdominal pain, confidence in the medical evaluation was examined both with and without the incorporation of lab testing and CT imaging (6). Using a visual analog scale (VAS), the investigators found that the median confidence level was only 20 in patients who did not receive lab testing or a CT scan. The median confidence of patients who did receive lab testing and a CT scan increased 4 fold to a VAS confidence level of 90. This evidence confirms that patients feel more confident in their medical evaluation when these additional tests were integrated into their work-up. As EP's strive to provide the highest of patient satisfaction scores, there can be resulting pressure to include lab testing and advanced imaging in the evaluation.

CT Scans: Costs and the Risk of Radiation

While there are many benefits to ordering a CT scan to evaluate a patient in the ED, there are also definite minuses. The first is the cost of ordering a CT scan versus other types of imaging, like plain films or ultrasound. Looking at CPT codes for the Medicaid program in California, there is a dramatic difference between the reimbursement basic charges of plain films and ultrasound in relation to CT scans (7). A plain film X-ray series of the abdomen (CPT 74022) has a basic charge of $45.84, a limited abdominal ultrasound (CPT 76705) has a charge of $60.74 and a comprehensive abdominal ultrasound (CPT 76700) has a charge of $83.20. In comparison, a CT scan of the abdomen and pelvis without contrast (CPT 74176) has a basic charge of $195.24 and a CT scan of the abdomen and pelvis with intravenous contrast (CPT 74177) has a basic charge of $311.37. These charges should be interpreted in terms of the relatively lower reimbursement amounts allowed by California Medicaid in relation to the billed charges for imaging from many hospitals. Patients may be asked to pay a significant out of pocket expense to cover a trip to the ED that includes a CT scan of the abdomen and pelvis to make up the difference between the total of these hospital billed charges and the actual insurance reimbursement amount. Due to these increased costs, the ordering physician should consider balancing the pre-test probability of encountering a serious medical condition by ordering a CT scan with the higher economic costs of the test. Could alternate imaging studies like plain films or ultrasound suffice to provide high quality care at relatively lower cost?

In addition to the above discussion about the economic costs of a CT scan, there must also be increased recognition of the risk of radiation associated with a CT scan. Traditionally, radiation is quantified in several measurement systems. Today, sieverts are the more common quantifiable measurement system in the USA, although many texts will also refer to grays, rads or rems. The conversion between the measurement systems is that 1 sievert (Sv) is equal to 1 gray (Gy) and 10 millisieverts (mSv) is equivalent to 1 rad or rem. Looking specifically at a routine CT scan of the abdomen and pelvis, the average radiation dose is 16 mSv. Incorporating a multi-phase CT of the abdomen and pelvis with intravenous contrast (routine for a comprehensive assessment of vascular disease) the average radiation dose is 31 mSv (8). These levels of radiation should be interpreted in relation to that received with a plain film. For a chest radiograph, the average radiation dose is 0.1 mSv. For a plain x-ray series of the abdomen, the average radiation dose is 0.7 mSv (9). Thus, there is a roughly 20-fold difference in the radiation dose between a plain abdominal x-ray series and a non-contrast CT scan of the abdomen.

Importantly, when estimating a patient's potential risk for the development of cancer following a CT scan, it is necessary to also include the age of the patient in the calculus. One reference estimated very different risks of cancer for a CT of the abdomen and pelvis with intravenous contrast according to age (8). The estimated risk of cancer in a 20 year-old female was 1/470, in a 40 year-old female it was 1/870 and in a 60 year-old female it was 1/1,320. A very recent article in the Lancet advised caution in the ordering of CT scans for the pediatric population (10). This study looked specifically at CT scans of the head and the resultant risk for the development of cancer, specifically leukemia. In this large retrospective study, a positive association was encountered between exposure to radiation from a CT scan in children and the later development of cancers. The results of the study may be debated as to the conclusions stated by the authors for the following reasons. First, what was the risk to the patient of serious pathology discovered by CT imaging in relation to this calculated increased future risk of developing cancer? Second, can we generalize the results of a head CT study to CT of the abdomen and pelvis? However, studies like these do give one a cause for concern. A reasonable guideline would be that clinicians should carefully consider if a CT scan will change the medical management of a patient, especially when ordering these tests on pediatric and younger patients, where the risk of ionizing radiation may be relatively increased.

In addition, it is not uncommon for certain groups of patients to receive more than one CT scan over a defined period of time. An example is the patient with kidney stones, who may receive multiple CT scans over a lifetime. In an interesting abstract presented at the ACEP Scientific Assembly 2011, a retrospective review of ED patients from 2001-2007 demonstrated that 17% of these patients had 2 or more CT scans and 10 patients had more than 10 CT scans (11). Especially in cases of repeated ED presentations for a disease like renal colic, physicians might consider if an alternate imaging strategy, like ultrasound, might provide the essential diagnostic information as ordering a CT scan.

CT scans and Contrast: Intravenous Contrast

Now that the background for CT technology and use has been established, let's specifically discuss some important points and advances in the use of contrast agents. First, intravenous (IV) contrast agents allow better visualization of vascular structures that can be important in the diagnosis of certain pathological conditions to be discussed. Second, there have been improvements in the types of IV contrast agents currently in use. Older IV contrast agents were characterized as high osmolarity and ionic in nature. Newer contrast agents, characterized as low osmolarity and nonionic, have largely replaced these older agents.

In several studies, these low osmolarity and nonionic agents have a more favorable risk profile than the older agents. A large study of 29,508 patients examined the safety profile of these newer agents (12). Adverse events occurred in only 211 patients (0.7%). 89% were characterized as mild (urticaria being the most common) and only 2% characterized as severe (airway compromise). A newer study in 2011 looked specifically at immediate contrast complications in 633 patients receiving a low osmolar, nonionic agent (13). The study found a very low rate of immediate adverse reactions, with reactions occurring in only 5 patients and all of these were characterized as minor. Thus, improvements in the type of IV contrast agents now routinely administered to patients receiving CT scans in the ED have lowered the overall rate of complications, especially the incidence of severe reactions, like airway compromise.

The Iodine Connection: True or False?

There remains a common belief that persons who are allergic to seafood also have an allergy to iodine and cannot receive IV contrast agents for a CT scan without a significant risk of a reaction. It is true that the newer nonionic, low osmolar contrast agents do contain iodine. However, here is where the false beliefs exist. First, iodine is an essential element (# 53 on the chart of the periodic table of the elements) required by humans for production of thyroid hormones. Therefore, humans cannot have a true allergy to iodine. Instead, the allergic reaction that most humans manifest to seafood is a reaction to muscular proteins within seafood (14). In crustaceans this is most commonly a reaction to the protein tropomyosin. In fish, this is most commonly a reaction to the protein parvalbumin.

The common practice of asking a patient whether they are allergic to seafood is thus a controversial topic, as it does not directly determine whether a patient may manifest an allergic reaction to the newer IV contrast agents. In fact, the best question to ask a patient is whether they have had a reaction to a prior CT scan with these new IV contrast agents (15). If the answer is no, even in the face of a known seafood allergy, it is generally safe to proceed with the CT scan. If the answer is yes to a prior reaction to a CT scan with IV contrast, the next question should be what type of reaction was it? If the reaction involved swelling of the airway or respiratory difficulty, an alternate imaging strategy should be chosen if possible. If the reaction was urticaria or a rash, then a discussion with the patient regarding the risks and benefits of including IV contrast should be undertaken. If the benefit from giving IV contrast is high, premedication with intravenous steroids and histamine blockers may be considered prior to the exam. In these cases of a known contrast allergy, it would be advisable to obtain informed consent from the patient and to discuss the case prior to the scan with a Radiology colleague.

Contrast Induced Nephropathy: Should I be Concerned About My Patient?

Most authorities define contrast induced nephropathy (CIN) as an increase in the serum creatinine of 0.5 mg/dl following administration of an IV contrast agent. Most data on the rates of CIN comes from older studies where patients received cardiac catheterization with larger volumes of a high osmolarity contrast agent given via intra-arterial injection (16). However, newer data from 2011 using nonionic and low osmolarity agents given via the venous route for a CT scan show a much lower risk of CIN. In a study of 633 patients receiving IV contrast for a CT scan, 70/633 (11%) of these patients developed CIN (13). While this rate is still much lower than the historical rates of CIN, other published studies show a combined lower rate of CIN at closer to 5% (17).

So, knowing that CIN is less common with today's agents, is this a disease a clinician should be concerned about? The answer to this is that yes, while the rates today of CIN are lower today than in the past, it is still a bad disease for a patient to develop. In the 2011 study mentioned above, 6/70 patients who developed CIN went into severe renal failure, requiring dialysis. Of these patients, 4/6 ultimately died (13). So it is crucial for the clinician to decide which patients can safely receive IV contrast agents, without an undue risk of the development of CIN.

Traditionally, this determination has been made by checking lab tests to evaluate the serum creatinine. Many radiology centers have a protocol where patients with a serum creatinine above 1.5 -2.0 mg/dl will not receive IV contrast agents. However, this arbitrary cut off negates that the serum creatinine is directly related to the patient's sex and muscle mass. Therefore, more specific formulas like the Cockcroft-Gault Equation may better estimate a patient's actual risk for the development of CIN by calculating the glomerular filtration rate (18). The Cockgroft-Gault Equation incorporates the patient's age, weight and sex, in addition to the serum creatinine. Fortunately for clinicians, many mobile devices loaded with medical application program include this equation, making the calculation quick and easy to perform. A normal creatinine clearance is 90 cc/min or better. The risk of CIN increases with a creatinine clearance less than 60 cc/min, and even more dramatically in patients with a creatinine clearance of less than 30 cc/min.

As an example, let us determine the risk of CIN in a 65 year-old female with a serum creatinine of 1.5 mg/dl. By standard convention, this patient has a serum creatinine below the threshold above which IV contrast agents cause increased harm. However, plugging these numbers into the Cockgroft-Gault Equation, we calculate that her glomerular filtration rate is actually only 41 cc/min and that she is actually at higher risk for CIN. Therefore, a risk to benefit consideration should be undertaken in this case prior to giving IV contrast.

Finally, our patient should be asked if she is on medications that can potentially exacerbate complications from IV contrast, such as diabetic medications, like metformin, and antibiotics, like the aminoglycosides. In general, metformin should be held for 24-48 hours after IV contrast to avoid the possible development of lactic acidosis.

How About Oral Contrast?

This is a hot topic in both Emergency Medicine and Radiology as traditional imaging protocols for the evaluation of abdominal, pelvic and flank historically integrated oral contrast. However, with the inclusion of oral contrast, the time to ultimately obtain the study was prolonged. This was due to the need to drink a large amount of the contrast liquid and to allow it to pass through and entirely opacify the intestine prior to the study. Secondly, as will be discussed below, there is increasing evidence that omitting oral contrast in the majority of the ED CT scans performed to investigate acute abdominal pain will result in little decrease in diagnostic accuracy. Thus, this is an important area for discussion in many hospitals as ED's increase their patient census, and at the same time struggle to be more efficient with their patient evaluation times.

In general, there are two main types of oral contrast in widespread use. The first is barium sulfate. It is a thicker liquid that has a lower risk of aspiration, especially in the elderly and those with altered mental status. It comes in many flavors, making it potentially more palatable. However, it is not to be used in cases of suspected intestinal perforation, as barium in the peritoneal cavity has been associated with peritonitis. The second type is gastrografin, which is an iodinated agent that is mixed in water for patient preparation. While it a better choice in patients with potential intestinal perforation due to the lower risk of peritonitis and inflammatory reaction, it is a relatively thinner liquid than barium with a higher risk of aspiration. Thus, if oral contrast is to be given, the clinician should choose the best one for any given patient.

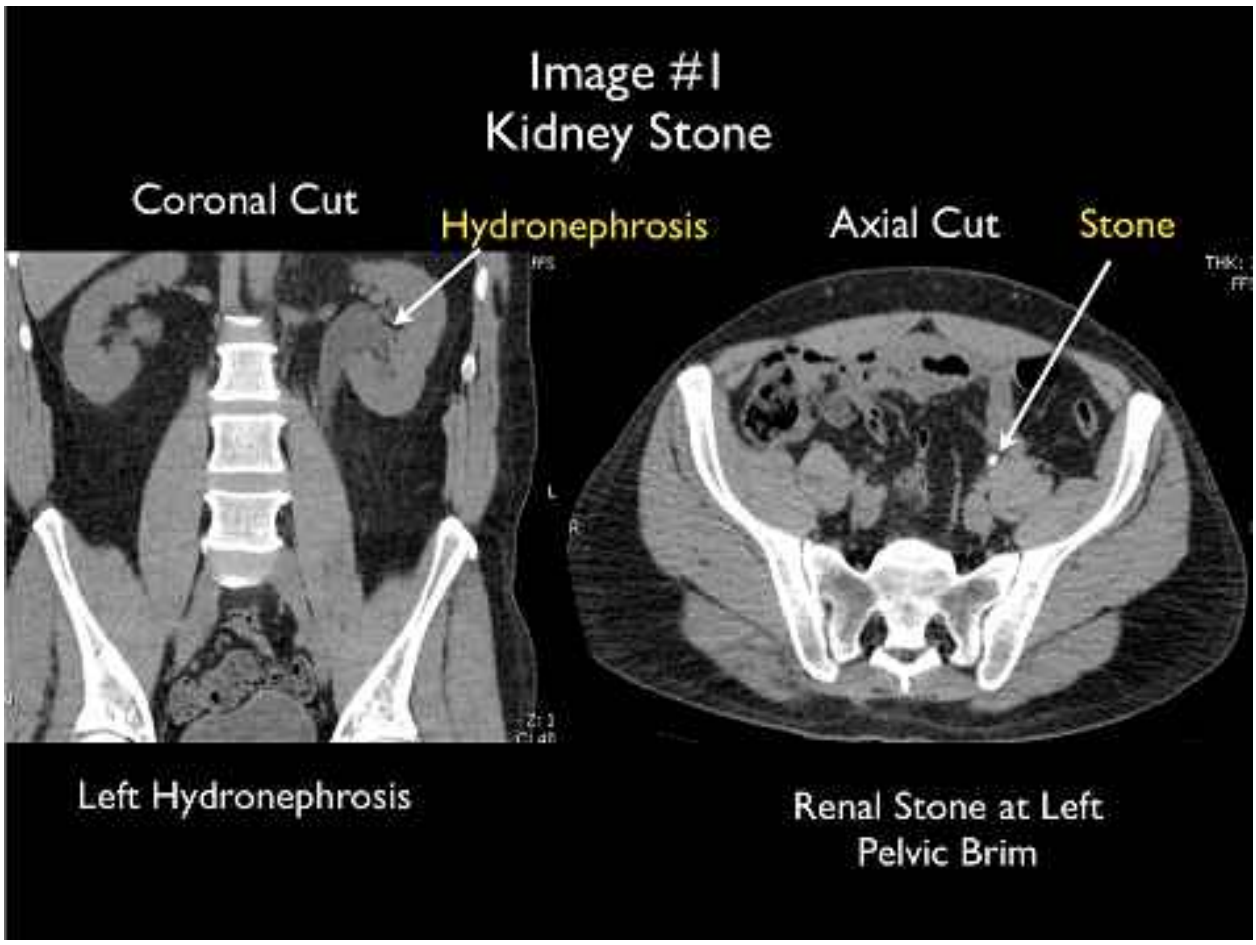
One older and often quoted study in 2004 found that there was a dramatic decrease in the ED time intervals required to obtain a CT scan if oral contrast was not used in patients being evaluated for abdominal pain (19). An average of 312 minutes was required for a non-contrast CT scan versus 599 minutes for a CT scan with oral contrast. Another recent study looking specifically at CT of the abdomen and pelvis found a decrease from 324 minutes to 297 minutes to obtain the scan if oral contrast was not included (20). The newest evidence for a large improvement in ED patient evaluation times when routine oral contrast was eliminated comes from Beth-Israel Deaconess Hospital in Boston, Mass (21). In a Radiology protocol to decrease the use of oral contrast agents, 95% patients evaluated with a CT scan of the abdomen and pelvis received oral contrast prior to the study and only 42% received oral contrast after. The results were dramatic, with a mean decrease in length of total ED stay by 97 minutes in those who did not receive oral contrast. In this study, no patient with a CT that was negative for any acute pathology had additional imaging at this institution within 72 hours that changed the diagnosis. While it is possible that patients were diagnosed later with alternate pathology or sought care at another hospital, these results provide a reasonable degree of quality assurance for the changes in the CT protocol. Further criticism of these studies is that differences in time to CT scan could potentially be affected by other factors besides contrast protocol, such as need for medical treatment, consults or other testing. However, the fact that all three of these studies have found an association between the addition of oral contrast to the CT protocol and increased ED evaluation times suggests the results have validity. This evidence has paved the way for many ED's to change their usual CT protocol for the abdomen and pelvis to a selective inclusion of oral contrast on a case-by-case basis in order to become more efficient.

Patient Cases: How Best to Protocol a CT Scan for the Evaluation of Abdominal, Pelvic and Flank Pain

Case #1:

A 48 year-old male presents to the ED complaining of the acute onset of right flank pain present now for 3 hours. He is previously healthy with no significant past medical history. He appears uncomfortable, moving around in the bed. His vital signs are normal. On examination, his tenderness is most prominent in the right flank, but he also has some right lower quadrant tenderness. His urine dips positive for blood, without leukocytes or nitrite. Other blood work is normal. An intravenous line is established and analgesia is given with improvement. The decision is made to order a CT scan to investigate the etiology of the pain. Should IV contrast, oral contrast or both be included?

Many clinicians would conclude that this is likely a kidney stone and consider ordering a non-contrast CT scan. The evidence for the accuracy of the non-contrast enhanced CT scan (NCECT) in the evaluation of renal colic is supported by many studies, one of the most highly quoted being a study of 292 patients with acute flank pain. NCECT performed with reformatted 2 mm slices performed well with a sensitivity of 97% and a specificity of 96% (22). Plain films had been used extensively prior to this study to investigate renal colic and the more common radiopaque stones, calcium oxalate and struvite, could frequently be visualized. However using plain films, it had been difficult to visualize radiolucent kidney stones, like uric acid and cystine stones. On CT imaging, all 4 major types of stones appear bright, making them easier to visualize (23). The patient's CT is shown in image 1.



CT imaging of renal colic in the ED became a very popular test. A retrospective study that looked specifically at CT utilization for cases of suspected renal colic between the years 1996 to 2007 found that the rates increased from 4.0% to 42% (24). This information gained by a renal CT scan is incredibly detailed, allowing precise determination of both the location of the stone as well as the size. In addition, NCECT was shown to be able to accurately rule out alternate pathology from renal colic. In a large study of 1000 patients, ureteral calculi were found in 557 patients (25). An alternate or additional diagnosis was made in 101 patients (10%). Appendicitis and gynecologic pathology were the most commonly encountered conditions. A second study looking at the similar question found a rate of alternate diagnosis to renal colic in 12% patients (26). A third study classified the etiologies of the significant proportion of patients found to have alternate pathology from a kidney stone (27). Of these patients, 49/500 had alternate urological pathology (renal cyst, mass), 37/500 had GI pathology (appendicitis, diverticulitis), 22/500 had gynecologic pathology (ovarian cysts) and 4/500 had vascular pathology (3 had leaking abdominal aortic aneurysms). From these studies, it became apparent that NCECT could visualize a large array of abdominal-pelvic pathology, in addition to kidney stones. This was great news for proponents of NCECT for general abdominal and pelvic imaging, as we will discuss further below. However, as far as the impact on the ultimate medical management of kidney stones, the results were mixed. The same study that documented a large increase in the rate of CT utilization for suspected renal colic found no appreciable change in the overall rates of the diagnosis of kidney stones or requirements for hospital admission (24).

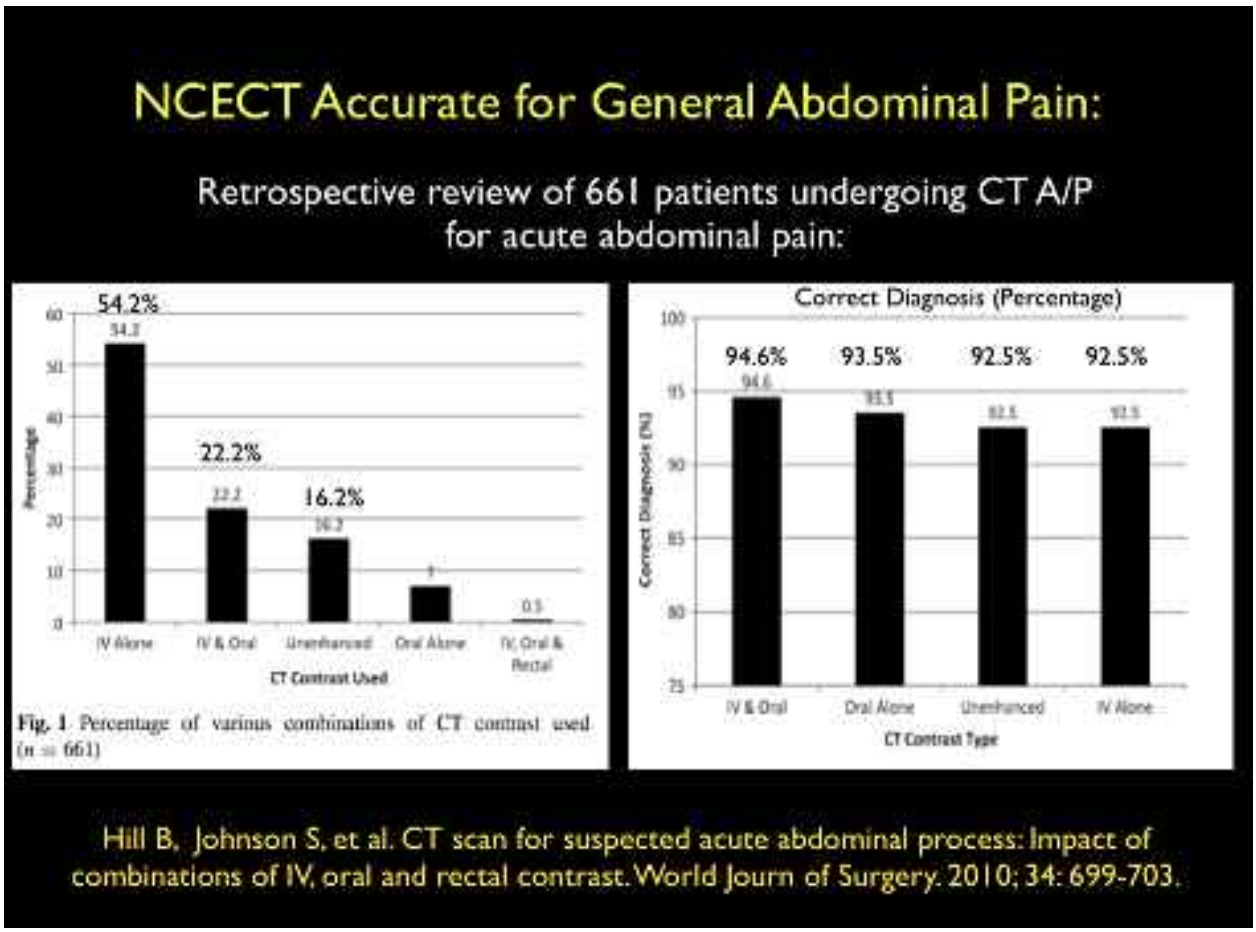
Thus, returning to our patient above, if one was going to order a CT scan, the correct protocol for suspected renal colic would be a NCECT. However, before ordering the NCECT scan for the evaluation of flank pain, clinicians might ask what the pre-test probability is of both renal colic or of an alternate diagnosis? Is a vascular disorder in the differential diagnosis of this patient where IV contrast should be added? If renal colic is the leading contender and other pathology is very low in the differential, will a CT scan ultimately change the patient's management? Could another imaging modality be used instead? While most seasoned clinicians would agree that in older patients without a history of renal colic, or in complicated cases like infected stones needing a procedure, CT scanning makes sense. However, there may also be room for consideration of the test utility in the management of uncomplicated cases of renal colic.

Case #2:

A 32 year-old female presents with acute right lower abdominal pain for 1 day. She appears uncomfortable, lying quietly on the bed. Vital signs are normal and she has no fever. Physical examination is significant for right lower quadrant tenderness with guarding, but no rebound. On her gynecological examination, she has no cervical discharge or cervical motion tenderness. She does have mild right adnexal tenderness. Her urine pregnancy test is negative and her urine dips negative for blood, leukocytes or nitrite. Her lab tests are significant for a mildly elevated white blood cell count. You suspect appendicitis, but want to rule out the usual suspects, such as gynecologic or alternate gastrointestinal pathology. The ultrasound suite is closed for the night and no ultrasound machine is available for a bedside exam at this time, so your imaging options are limited to CT scanning. How best to protocol the study? Should the patient receive oral contrast, intravenous contrast, both or even a NCECT?

First of all, how good is CT imaging for the diagnosis of appendicitis? In a retrospective review of 2,871 patients, 675 (23%) had confirmed appendicitis at surgery. CT had a sensitivity of 98.5%, a specificity of 98%, a negative predictive rate of 99% and a positive predictive rate of 93%. As CT scanning became increasingly integrated into the ED evaluation of these patients, the overall appendicitis perforation rate decreased from 28% in 2000 to 11.5% in 2009 (28). One can conclude that CT is therefore an excellent test for appendicitis. Second, does the increased usage of CT scanning for the evaluation of suspected appendicitis ultimately decrease the negative appendectomy rate (NAR)? In a retrospective review of 1,425 patients, when CT imaging was performed pre-operatively in only 32% patients, the NAR was 16.3%. When CT imaging was performed pre-operatively in 95% patients, the NAR was decreased to 7.6%. The largest decrease in the NAR was observed in younger adult females, where pre-operative CT scan decreased the NAR from 20.8% to 7.6% (29). In his comprehensive textbook of Emergency Medicine Radiology, Dr. Broder does an excellent review of many of the studies that look at pre-operative CT scan and its utility in decreasing the NAR (30). Many of these studies have definite flaws and would benefit from a randomized controlled research design. However, our patient falls into the category of being a young female, where a pre-operative CT scan might make the biggest difference in decreasing the NAR.

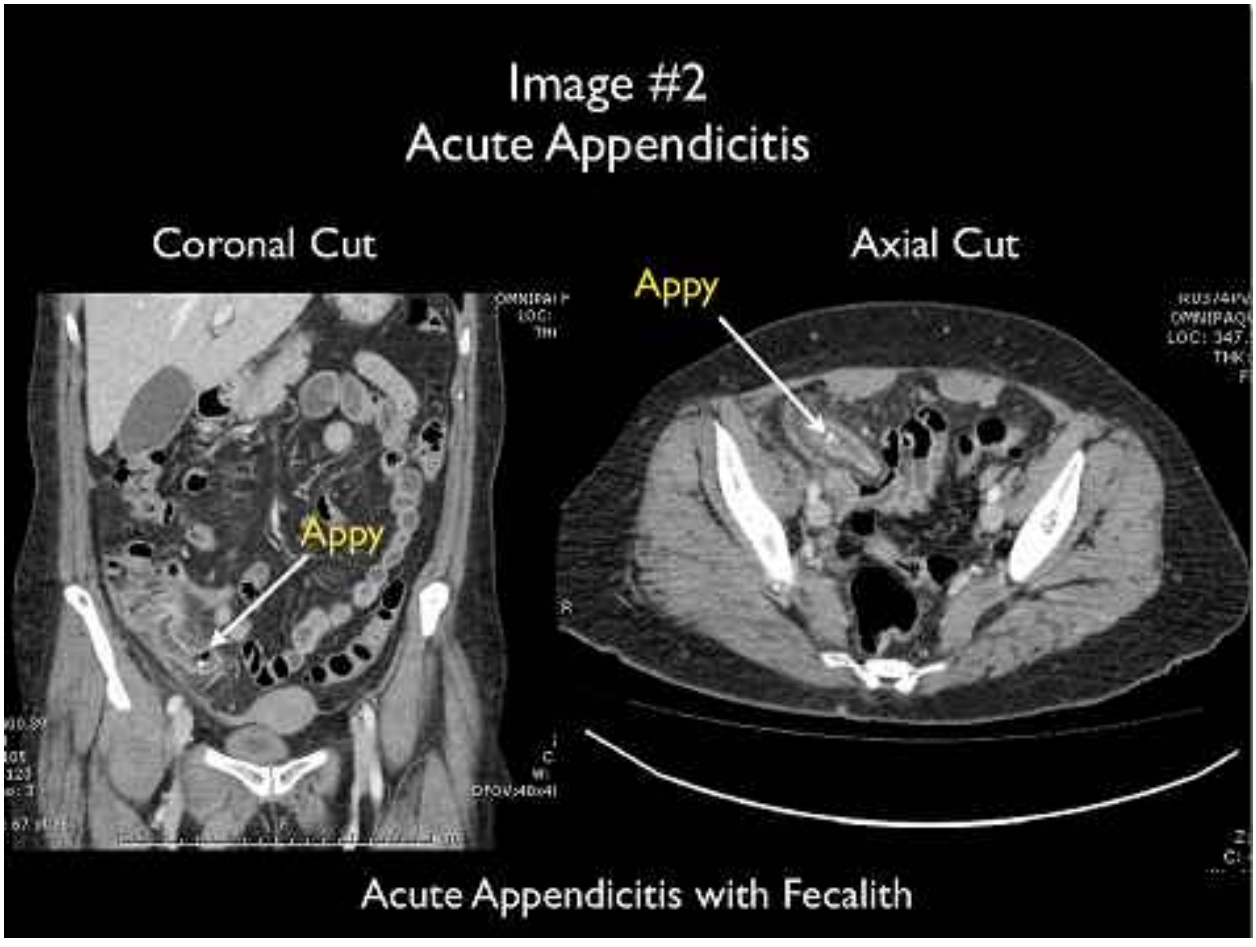
Next, how best to protocol the study with regard to contrast? In a retrospective review of 661 patients being evaluated for undifferentiated abdominal pain, patients were scanned with different contrast protocols and the percentage of correct diagnoses were correlated to each protocol (Table 1).



54% of patients received IV contrast only, 22% received IV and oral contrast and 16% received no contrast. The percentage of correct diagnoses made with each protocol was 94.6% with both oral and IV contrast, 93.5% with oral alone and 92.5% without contrast (NCECT). The conclusion of the study was that while the use of IV and oral contrast can slightly improve the diagnostic capability of CT imaging for acute abdominal pain, the difference from a NCECT was not statistically significant (31). There are some definite limitations to this study as the overall study group was relatively small and not powered to look at specific types of CT diagnoses. In addition, as noted above in the percentages, certain protocol groups had quite differing numbers of patients. Therefore, although the results are quite interesting, we should look at it as preliminary research in this area that would benefit from confirmation with future studies that include larger patient cohorts. Another study that gained a lot of recent attention was a meta-analysis that specifically looked at the diagnostic accuracy of non-contrast MDCT imaging of acute appendicitis. This analysis pooled 7 studies that included a total of 1,060 patients. NCECT was found to have a pooled sensitivity of 92.7% and a specificity of 96.1%. The positive likelihood ratio was 24 and the negative likelihood ratio was 0.08. This study concluded that the diagnostic accuracy of NCECT for the ED diagnosis of acute appendicitis is adequate for clinical decision-making (32).

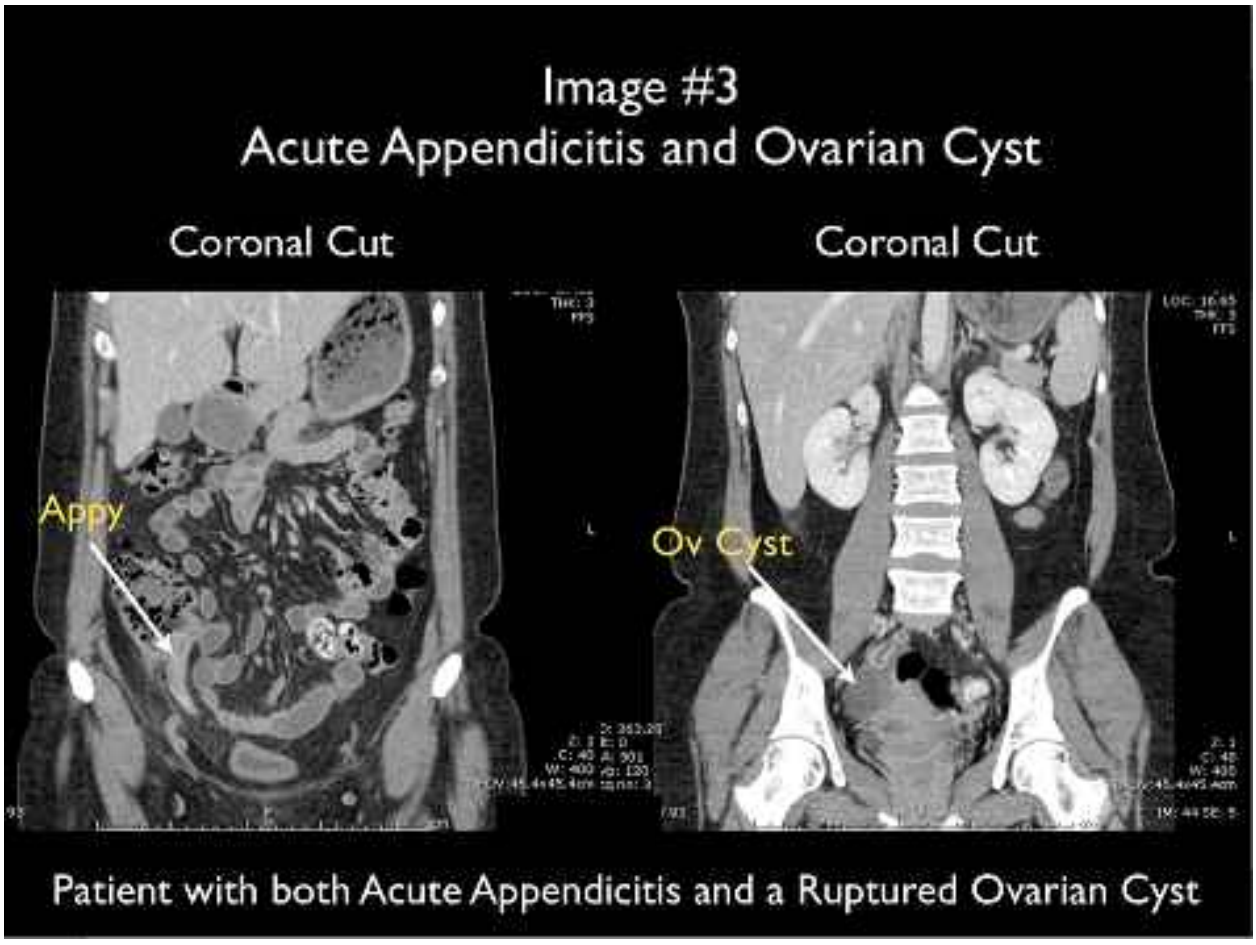
Based on these studies, many ED's have established a protocol together with their Radiology colleagues to avoid the routine use of oral contrast in CT scan of the abdomen and pelvis to evaluate acute abdominal pain suspected to be acute appendicitis. As mentioned above, this has resulted in measurable decreases in the time needed to obtain a CT scan. The routine use of IV contrast remains in place in most protocols for the evaluation of suspected appendicitis. However, the above studies would suggest that a NCECT would have a diagnostic accuracy that would still be high enough for good clinical decision making in the ED for the most common causes of abdominal pain, like appendicitis. Still physicians should order a NCECT for the evaluation of general abdominal pain with the recognition that the study results on this area would benefit from more research with larger patient cohorts. In addition, certain types of rarer pathology, especially the vascular diseases such as mesenteric ischemia, portal vein thrombosis and arterial dissections, will not be best imaged without IV contrast. Therefore, the Emergency Physician should always carefully consider the differential diagnosis in a patient before deciding on the appropriate CT scan contrast protocol. Primarily, would IV contrast improve the imaging results?

Image 2 demonstrates the patient's CT scan. Note the dilated appendix measuring greater than 6 mm in width, the presence of a fecalith and peri-appendiceal fat stranding.



Mesenteric fat stranding is an important diagnostic sign for acute appendicitis, along with the diagnosis of many inflammatory conditions in the abdomen and pelvis, and should be specifically looked for when evaluating a CT scan for appendicitis (33). The presence of prominent mesenteric fat makes this fat stranding more easily appreciated. Thus, there remains some debate whether it would be advisable to include oral contrast in a very thin patient who lacks the prominent mesenteric fat to improve the diagnostic accuracy of the CT scan.

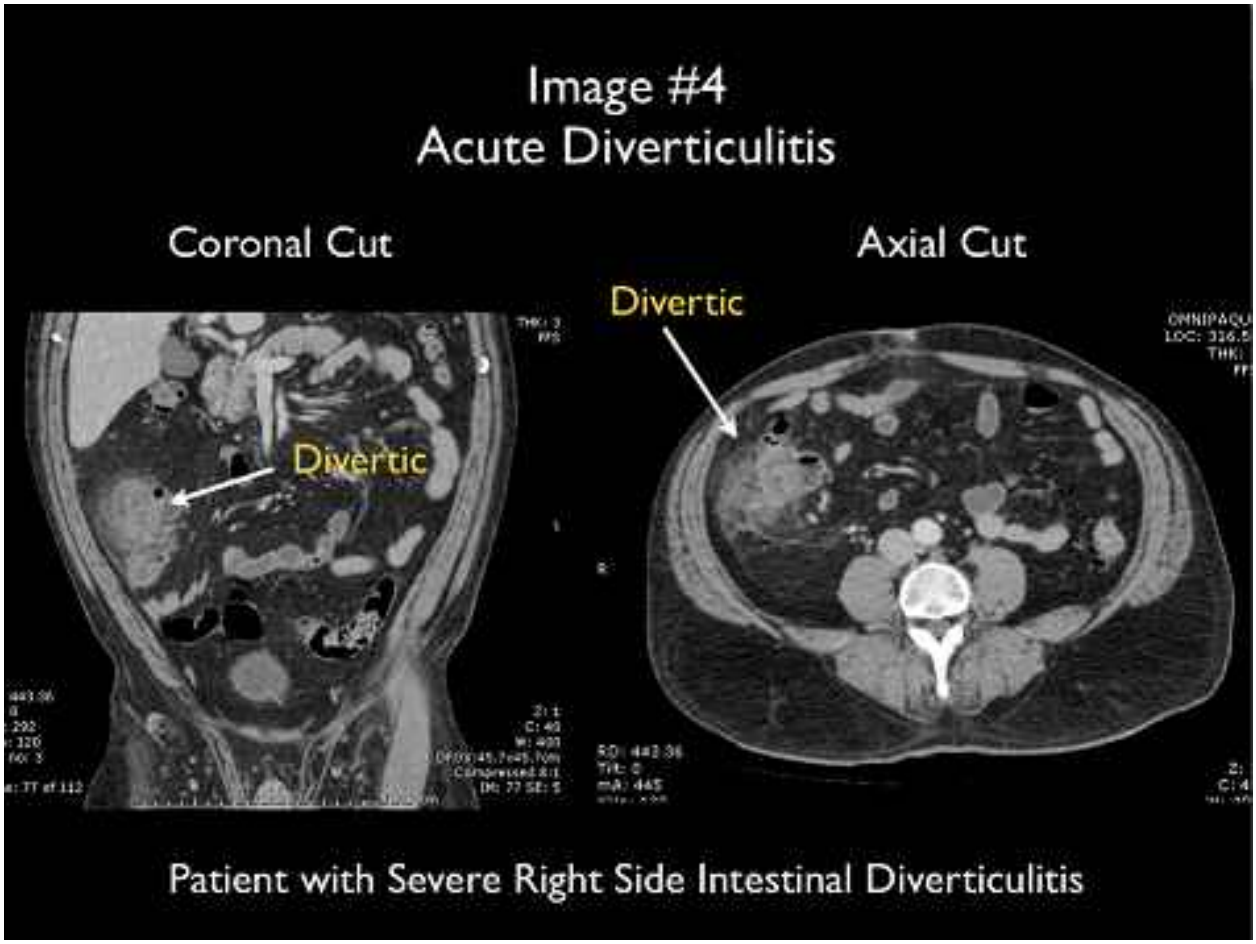
Interestingly, let's consider the case of another young woman who presented with right lower quadrant pain and had an initial pelvic ultrasound that demonstrated a ruptured right ovarian cyst. Because the patient continued to appear ill with worsening right lower quadrant abdominal pain and the development of a low grade fever of 100.8˚ F, a CT scan was obtained and shown in image 3. While a ruptured right ovarian cyst is identified, an inflamed appendix is also seen. Granted this is an unusual case, but the power of CT scanning in evaluating a range of pathology within the right lower quadrant, especially in young women, can be illustrated here.



Case # 3:

A 55 year-old male presents with right lower quadrant abdominal pain for 2 days. His vital signs are significant for a heart rate of 108 per minute and a fever of 101˚ F. His urinalysis is negative and his labs are significant for a white blood cell count of 17,000. An intravenous line is placed, labs sent and analgesia administered. Could this patient have acute appendicitis? Should Surgery be consulted and the patient dispositioned immediately to the OR? Could he have an alternate illness not requiring surgical management? If we are going to perform a CT scan, what type of protocol should we consider?

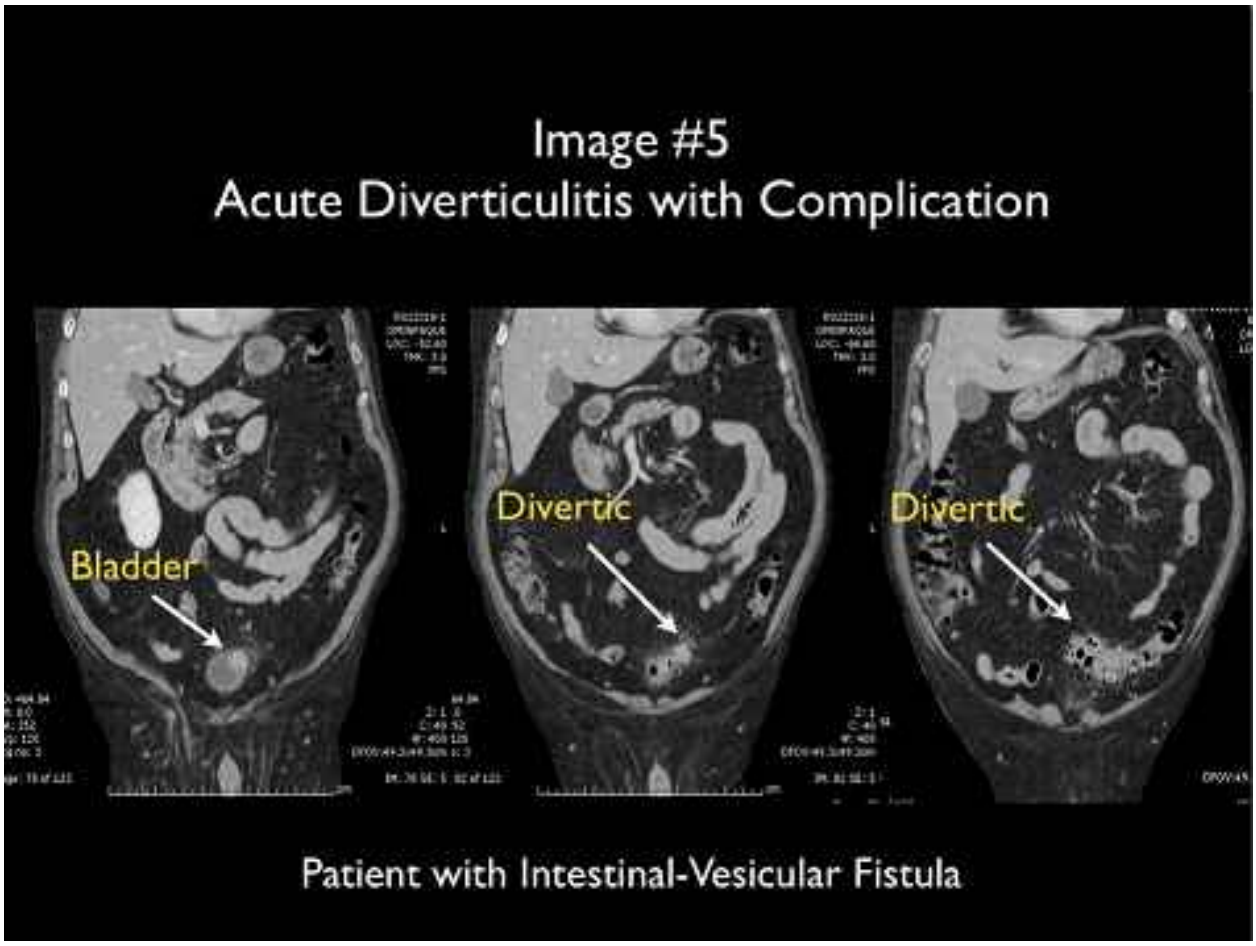
The patient's CT scan in demonstrated in image 4.



This patient has prominent diverticulitis. While more commonly seen on the left side of the abdomen, a substantial amount of cases may involve the right side of the intestine. In addition, younger patients whom were initially thought to have appendicitis are increasingly being diagnosed with diverticulitis (34). The further tip-off on the presence of diverticulitis is the prominent mesenteric fat stranding adjacent to the inflamed intestine. Note how well seen the pathology is seen with just intravenous contrast. For diverticulitis, one study found that oral contrast can generally be omitted to speed the time to get the scan, similar to appendicitis. It should be noted that this study did include rectal

contrast (35). Another study suggested that a NCECT was adequate for imaging of diverticulitis and that neither IV, oral or rectal contrast was necessary (36).

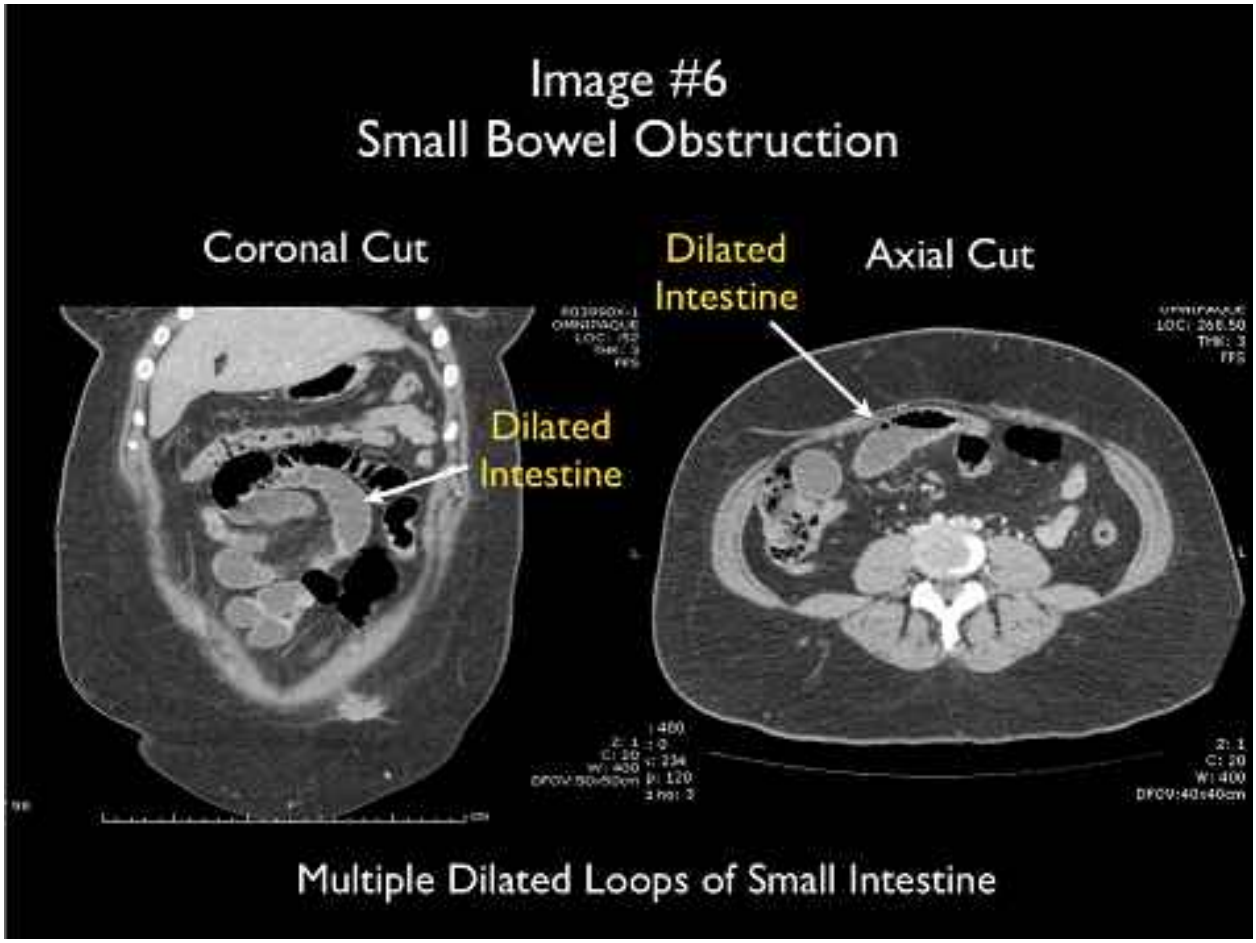
The most common classification scheme for diverticulitis is the Hinchey classification (37). CT imaging has the ability to discern these different stages of diverticulitis, allowing rapid determination of which patients may benefit from an operative procedure. CT imaging also can detect many of the complications of diverticulitis, like an intestinal-vesicular fistula seen in 5, that has developed in a severe case.



Case # 4:

A 67 year-old female presents with acute abdominal pain accompanied by nausea and vomiting for 2 days. Her past medical history is significant for an open appendectomy and a C-section. On physical examination, her vitals signs are within normal limits. However, she appears uncomfortable and her abdomen is distended with diffuse tenderness. A bowel obstruction is suspected, but the plain films that are ordered are non-diagnostic. A CT scan is ordered. Should oral contrast in addition to intravenous contrast be administered?

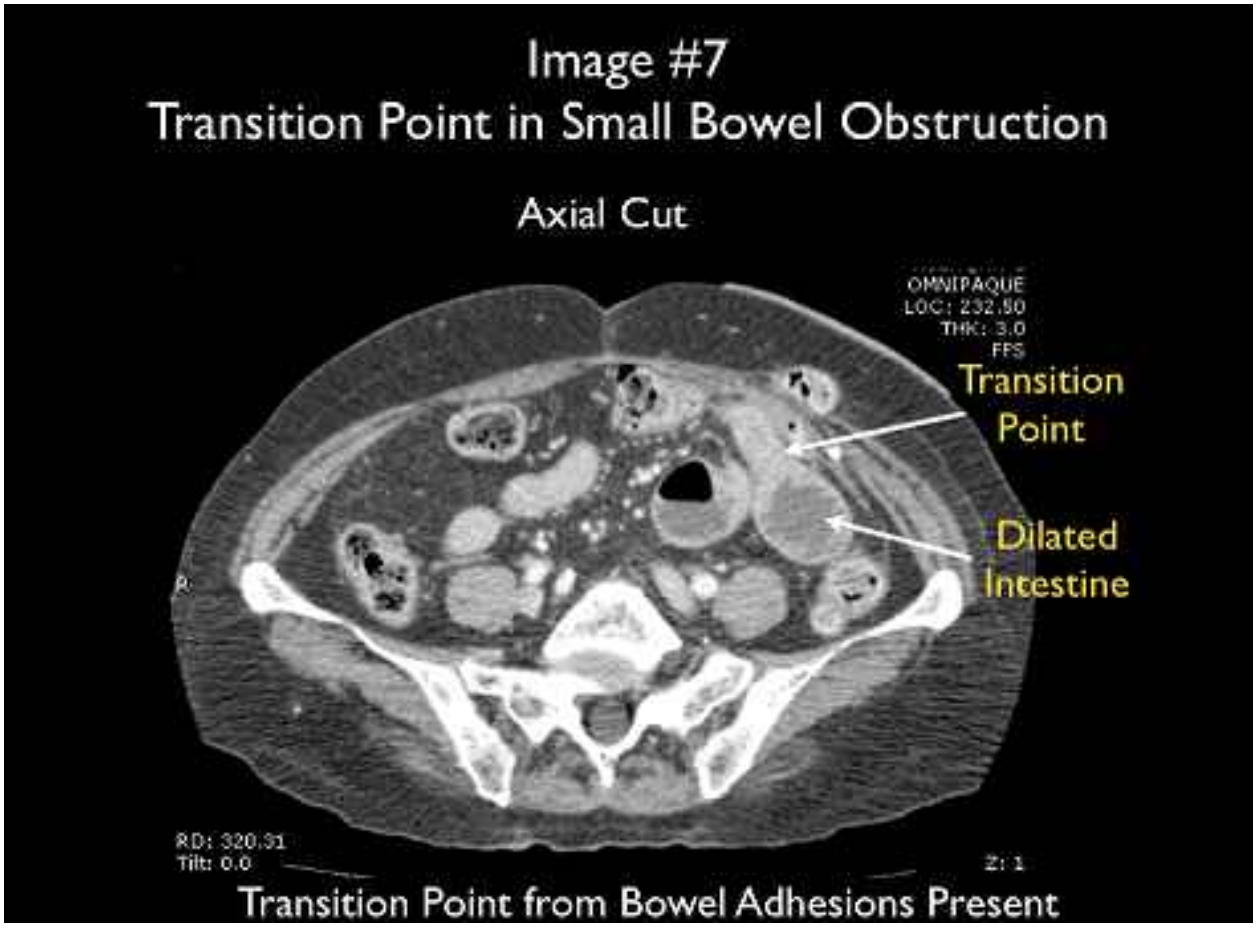
The patient's CT scan is shown in image 6.



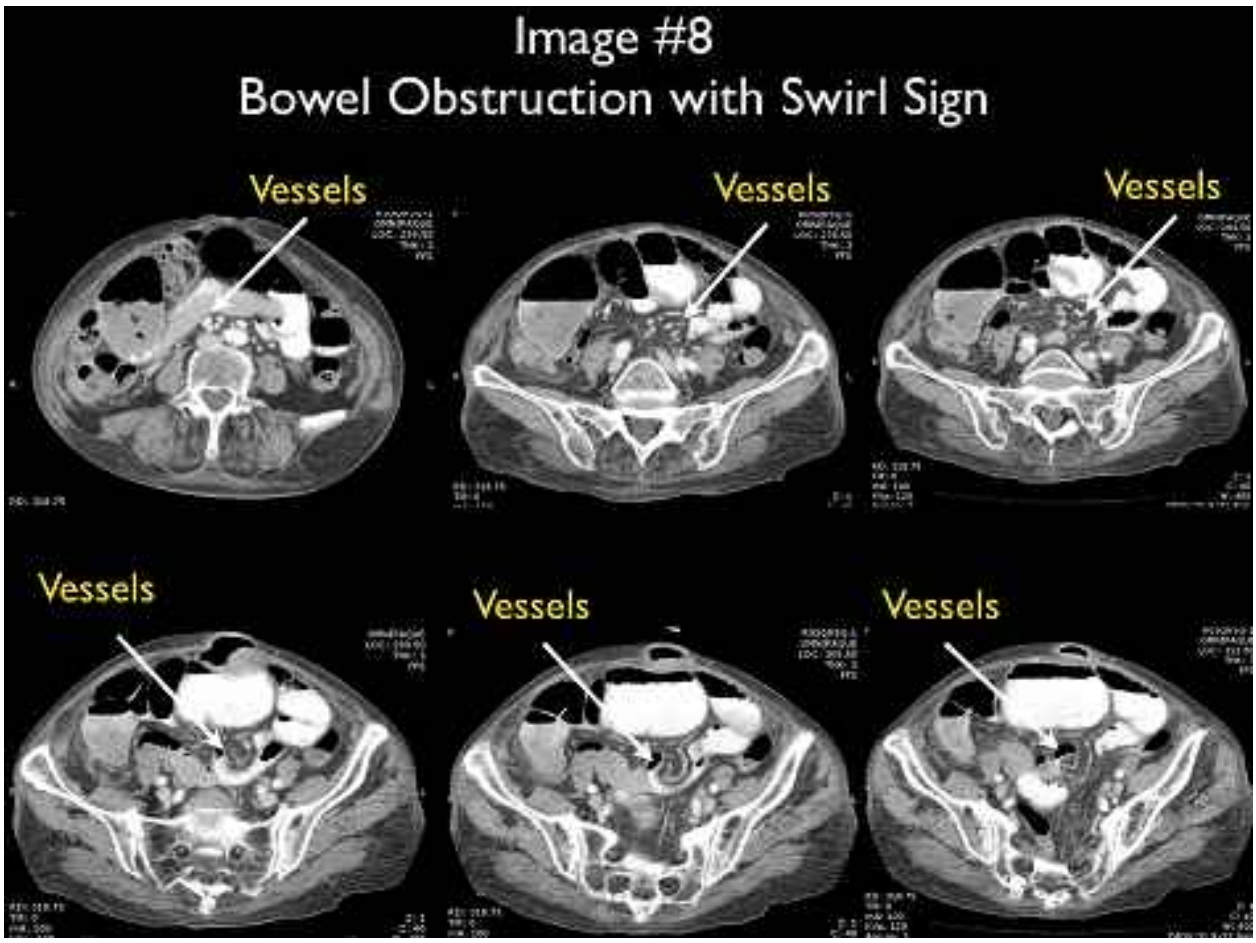
CT criteria for small bowel obstruction is an intestinal diameter greater than 3 cm. Severe obstruction will be manifest by a greater than 50% difference in caliber of the intestinal size before and after a discrete transition point (38). There is now general agreement that oral contrast as a part of the CT scan is not necessary in most cases of small bowel obstruction. Accumulating intestinal fluid often adequately opacifies the bowel (39). CT is a very good test for the diagnosis of bowel obstruction, as shown in a meta-analysis that pooled 11 studies for a total of 743 patients. CT imaging had a sensitivity of 92% and a specificity of 93% for the diagnosis of complete bowel obstruction. CT has a sensitivity of 83% and a specificity of 92% for detection of intestinal ischemia associated with obstruction. Where CT may not be as accurate is in some subtle cases of early or partial bowel obstruction (40).

While traditionally all bowel obstructions were managed operatively, recently there has been a change in management toward non-operative therapy. CT scanning may be helpful in planning the optimal therapeutic course by predicting which patients will potentially need an operation. Several past studies have demonstrated that either the presence of a transition point or the whirl sign were helpful in

determining the need for surgery. The presence of a distinct transition point had a sensitivity of 100% and a specificity of 23% for surgical management (see 7).



The presence of the whirl sign had a sensitivity of 70% and a specificity of 90% for the need for an operation (see image 8) (41).



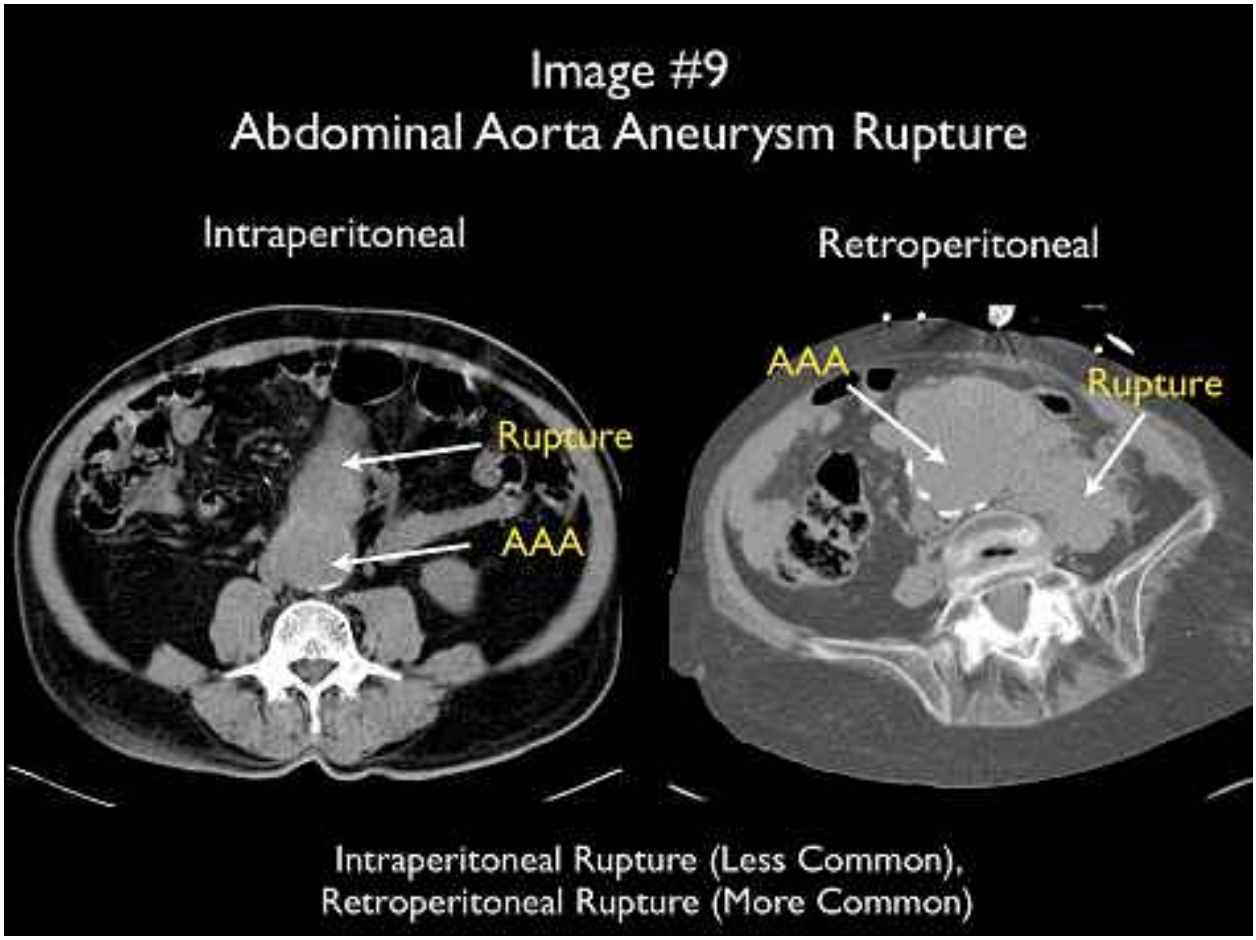
As seen in the image sequence, the whirl sign is denoted by a twist of the vascular pedicle with a swirling of mesenteric soft tissue, vessels and adjacent bowel loops that was originally described in intestinal malrotation, but is also found in mid-gut obstruction. A second study found the odds ratio for a positive whirl sign indicating a bowel obstruction needing surgery was 25 (42). However, while these CT findings and study conclusions are quite interesting, clinicians should be mindful that the etiology for the bowel obstruction and the patient's clinical findings should take precedence over imaging findings in planning optimal treatment. This point is highlighted as more recent studies have raised some doubt on the validity of the transition zone alone as a specific indicator for surgery and the literature continues to evolve on this subject (43).

While there is controversy about the management of simple small bowel obstructions, the presence of associated intestinal ischemia should be cause to consider more aggressive treatment. Ominous signs for the presence of associated bowel ischemia in the setting of a bowel obstruction include the presence of a definitive closed loop obstruction, where the bowel is noted to be compressed at 2 points, forming a C or U-shaped loop. Other findings include thickening and attenuation of the bowel wall, the presence of a halo or target sign, pneumotosis intestinales and gas present in the portal vein (44).

Case # 5:

An 80 year-old male presents complaining of pain to the abdomen and back for 2 days. He was referred to the ED from a primary care clinic where a 'pulsatile abdominal mass' was palpated. He appears

comfortable. His vital signs include a blood pressure of 110/84 mm Hg, a heart rate of 108 bpm, a respiratory rate of 12 and a temperature of 99˚ F. A bedside ultrasound is performed immediately and confirms the suspicion of an abdominal aortic aneurysm. Surgery is consulted and a CT scan is requested. However, a CT scan to include intravenous contrast will not be approved unless a serum creatinine is obtained first. While the patient appears relatively stable right now, his vital signs indicate a state of compensated shock and his condition may worsen at any time. The decision is made to immediately obtain a CT scan without intravenous or oral contrast, to see if the essential clinical information can be gained. The CT image obtained from the patient is shown in image 9 (left side).



Note that this patient has the relatively infrequent intraperitoneal pattern of abdominal aortic aneurysm (AAA) rupture. The NCECT is able to demonstrate the AAA and area of rupture in excellent detail. For comparison, the more common pattern of retroperitoneal rupture of AAA is also shown in image 9 (right side). One can appreciate that the AAA and the surrounding retroperitoneal area with hemorrhage are also well seen without contrast. In fact, one of the more specific signs for the prediction of aneurysm rupture, the 'crescent sign', is often best appreciated on NCECT (45). The crescent sign is a bright area of high attenuation that is seen either within the luminal thrombus adjacent to the vessel wall or within the actual aortic wall (46).

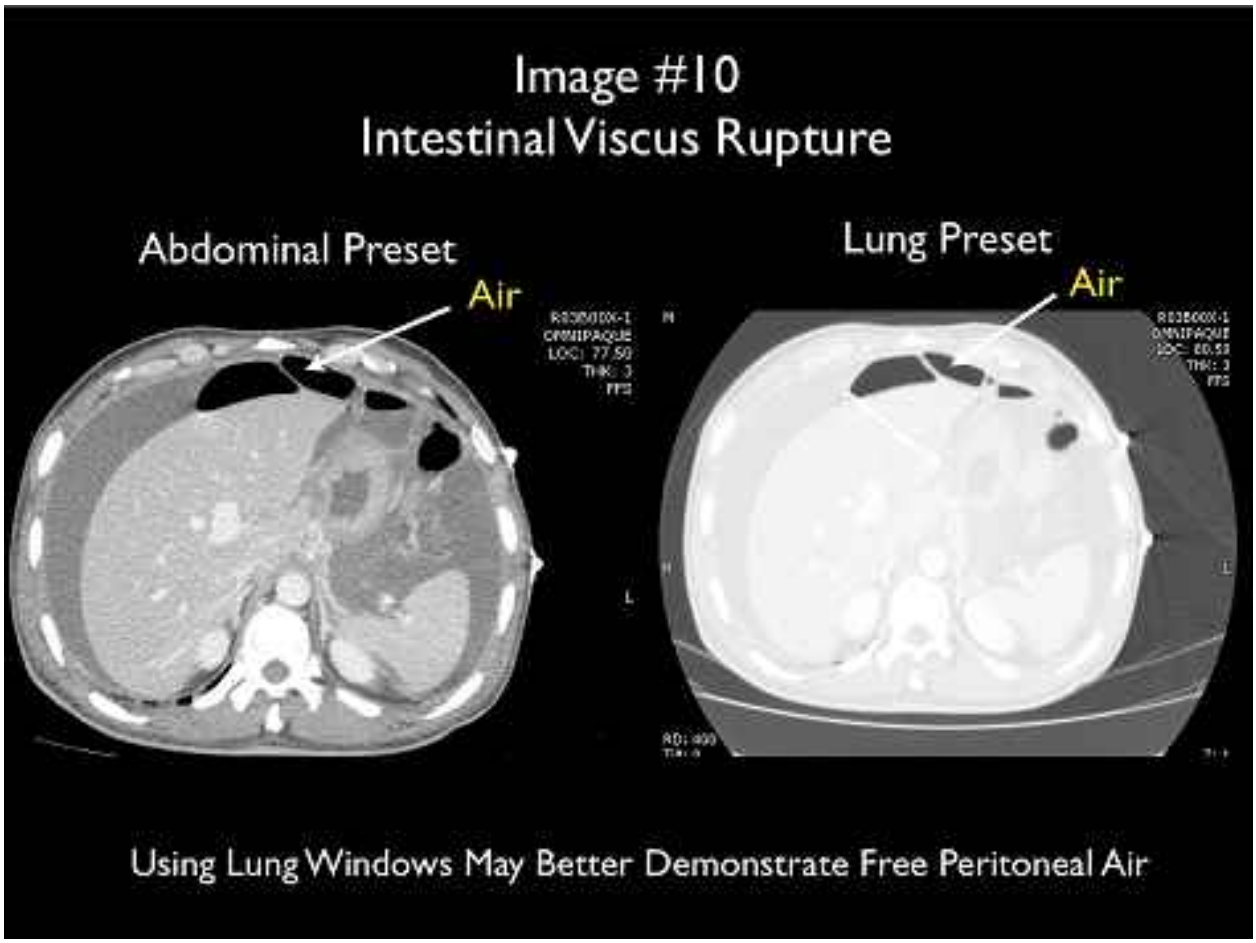
One can take away from this case, that a patient's vital sign stability plays an important role in deciding the best imaging strategy for AAA. Because of the time sensitive nature of this disease, it is crucial for the EM and consulting Surgery team to decide together on the best diagnostic pathway. If the patient is unstable, bedside ultrasound should potentially be the only imaging exam performed in sequence with resuscitation and preparation of the patient for immediate transfer to the OR. If the patient is stable at the time, but there is a question about the possibility of deterioration while waiting for labs, a NCECT can often rapidly provide the essential information for clinical decision making. In a stable patient without high likelihood of imminent decline, the general guideline for imaging AAA's would be to include CT phases both before and after the administration of intravenous contrast. The administration of IV contrast can demonstrate smaller areas of rupture that may not be seen as well on NCECT (47). Aortic dissections that propagate into the abdomen (Stanford Class B) would also require IV contrast for optimal imaging. Finally, in the increasing patient population with a prior AAA repair by vascular endograft where a leak is suspect, both unenhanced and enhanced imaging sequences are optimally needed. Endovascular endoleaks are best detected and analyzed for the likelihood of complications with the use of both of these phases (48).

While we are on the subject of vascular emergencies, how about making the diagnosis of mesenteric ischemia with CT scan? Previously, it was taught that one had to obtain an angiogram to make this diagnosis. However, with the improvements in CT technology, a recent meta-analysis demonstrated a pooled sensitivity of 93.3% and a specificity of 95.9% for mesenteric ischemia. This study demonstrates that CT is actually a very good test for the diagnosis of mesenteric ischemia (49). Intravenous contrast would be considered the current standard for the CT imaging in mesenteric ischemia. However, in later cases of this disease, a NCECT can demonstrate some of the diagnostic features of this disease, such as pneumatosis intestinales and portal gas (50). As mentioned above, another vascular emergency, portal vein thrombosis, can also only be visualized on CT scan with IV contrast. This is a less common diagnosis, but one which should be considered in a patient with upper abdominal pain, especially in the setting of a hypercoagulable state.

Case # 6:

A 42 year-old female with a history of 'stomach ulcers' presents to the ED complaining of acute abdominal pain. Her abdominal exam is significant for rigidity and rebound. An intestinal perforation is suspected and an abdominal radiographic series is obtained, but fails to demonstrate free air in the peritoneal cavity. A CT scan is therefore ordered. The patient is appearing sicker, but the Surgeon would like a CT scan before taking her to the OR to confirm the diagnosis. Since time is of the essence, how about a NCECT looking specifically for intestinal perforation? Should oral contrast be given?

The image from patient is shown here in image 10.



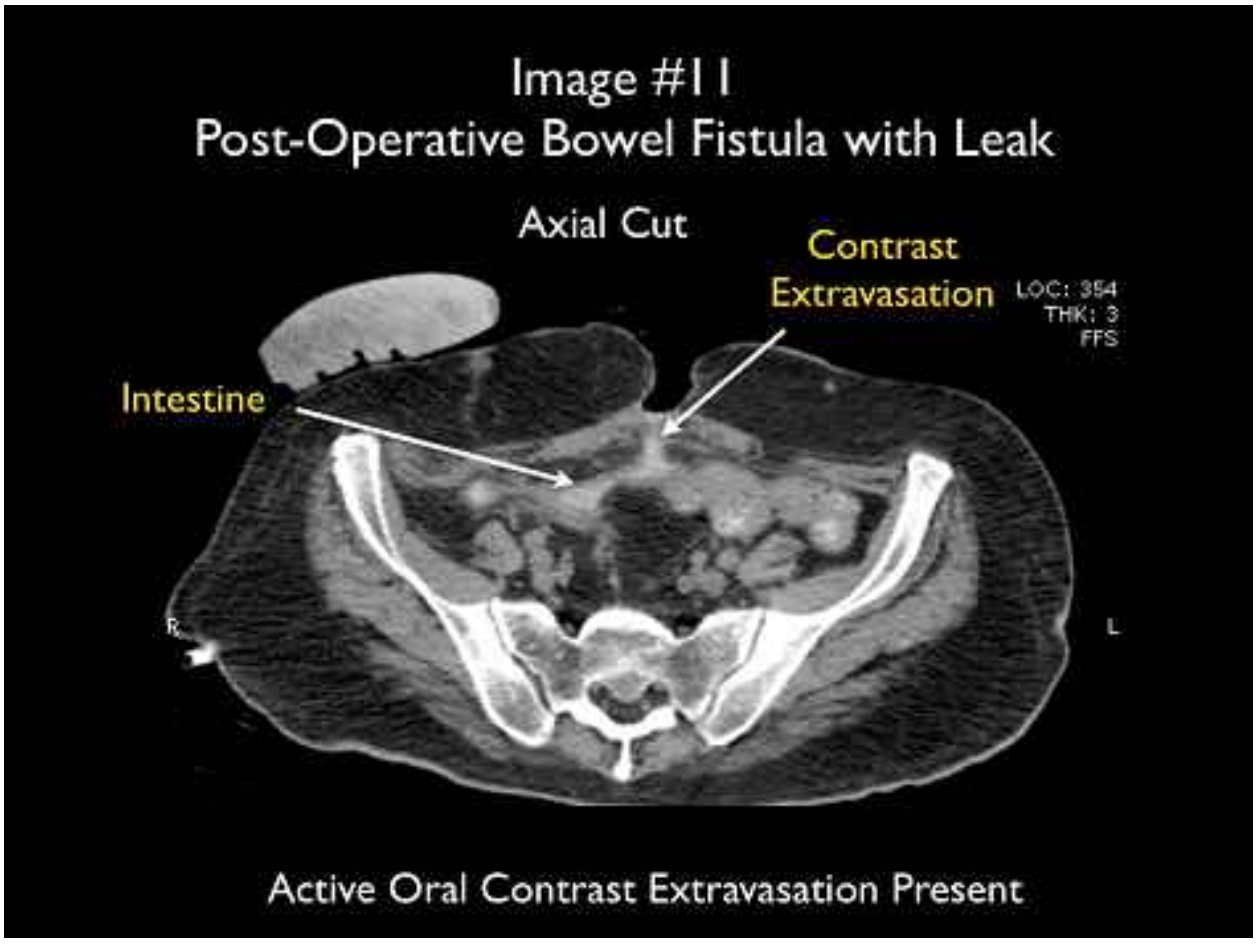
Interestingly, studies show that a NCECT can often adequately image intestinal perforation, especially when the CT presets are switched from abdominal to lung windows, to better delineate the presence of free intra-peritoneal air (51). If one was adamant on using oral contrast to more optimally demonstrate the perforation, a limited amount of gastrografin could be used.

Case # 7:

A 67 year-old male presents with acute abdominal pain for 3 weeks. His medical history is significant for a recent subtotal colectomy with end ileostomy for undetermined colitis. The patient appears ill and has a fever of 100.5˚ F. A post-operative fistula or abscess is suspected and the consultant Surgeon requests a CT scan.

Unfortunately, his labs demonstrate the development of acute renal failure with a serum creatinine of 6.0 mg/dl (baseline 1.2 mg/dl 2 weeks prior). In this patient, CIN as discussed above would be a very high risk if IV contrast were administered. An argument could be made to immediately dialyze the patient after this CT scan. However, as was pointed out prior, CIN is a very bad disease with a high mortality in affected patients. Thus, it would be better to skip the IV contrast if possible.

How about oral contrast? As mentioned above, there is less need for the routine use of oral contrast with new generation CT technology. Interestingly, oral contrast may be beneficial is in this patient, where the finding of active extravasation of the contrast agent would confirm the bowel leak. Gastrografin would be preferred here instead of barium, due to the risk of barium induced peritonitis. The CT image obtained from the patient is shown in image 11. Note that presence of active oral contrast extravasation from the bowel anastomoses, indicating a leak requiring immediate surgery.



Conclusions:

CT imaging has now become integral to the evaluation of patients presenting to the ED with acute abdominal, pain and flank pain. CT technology has improved dramatically over the last years, so that this test is now a very accurate one for the diagnosis of a range of pathologic conditions. Both Emergency Physicians and their patients have embraced the use of CT scans and the numbers demonstrate a huge increase in the reliance on this technology. Thus, it has now become routine that if the ED CT scanner is broken for even a short time, contingency emergency plans are rapidly put into place. In this situation, hospitals may go on diversion and plans may be made to access CT machines outside the ED.

While the above cases do demonstrate the power of CT scanning in accurately diagnosing a wide range of pathology, there are reasons for concern as the use of this test becomes more widespread. The radiation incurred in a CT scan, as well as the increased economic costs of the test, are significantly higher than with other common imaging modalities. Physicians should carefully consider the pre-test probability of their patient having a significant pathologic condition prior to ordering the scan. It is worth emphasizing that in one large study, almost half of the ED patients evaluated with CT scan had non-specific abdominal pain (5). Could plain films, an ultrasound or even a strategy of expectant management with a next day re-check provide the same excellence in care as immediately ordering a CT scan?

As far as ordering CT scans, over the last few years there has been a major pendulum swing away from the routine incorporation of oral and intravenous contrast in every CT of the abdomen, pelvis and flank. A large amount of newer literature referenced above supports a more select policy to the use of contrast. In the majority of patients, oral contrast offers a relatively small benefit in the diagnostic accuracy of a CT scan. It is has also been found to significantly increase the time needed to obtain the test. The one exception where it can be helpful is in the patient with a post-operative state, in whom a bowel leak or fistula is suspected. While IV contrast is currently still included in many CT scans of the abdomen, it will be interesting to see if with more advanced CT technology coming in the future, this will remain in routine use. In the imaging of vascular pathology, intravenous contrast does offer a definite benefit in reading the scan. However as mentioned above, many times a NCECT may give the essential clinical information to initiate definitive treatment, even in cases of AAA rupture. In other more common diseases, like appendicitis, IV contrast is probably most useful in reading subtle or early pathology. The majority of inflamed appendices can be well visualized on a NCECT (32).

Finally, if a CT of the abdomen and pelvis obtained on an ED patient is read as negative, can that patient be safely discharged with a diagnosis of non-specific abdominal pain? Most authorities would suggest yes, with certain definite caveats. First, it is possible that a CT scan could be ordered too early in the course of a disease process to fully demonstrate the pathology. This is probably a very rare phenomenon, but inevitably veteran clinicians have tales of a patient who returned relatively soon after an initial negative CT scan with diagnosed appendicitis. As the sensitivity of CT for this disease is excellent and currently improving, this is probably becoming an issue more related to whom is reading the CT scan. Is this an attending body CT Radiologist with 20 years experience or someone relatively junior? In any case, it is always prudent to give the patient good discharge plans and optimally, a re-check appointment in 1 day or so. A second caveat is knowing that CT imaging may not be the optimal test for diagnosing certain pathology, most commonly gallbladder disease and gynecologic disorders, where ultrasound may be a better diagnostic modality. Third, a final caveat is understanding that CT

scanning is not accurate for the diagnosis of many types of early abdominal and pelvic cancers, like that of the colon, cervix or ovary. Thus even in a patient with a negative CT scan in the ED, if that patient is above age 50 or if there was a strong family history of colon cancer, it would be the current recommendation for that patient to be referred for a colonoscopy. This should be mentioned to these patients and they should be referred to their primary care doctor for testing. In women, it would be reasonable to also refer them to their OB/GYN physician for routine pap testing and further evaluation as needed.

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