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CT IMAGING IN ACUTE ABDOMEN: ROLE, TECHNIQUES, AND CLINICAL APPLICATIONS
A COMPREHENSIVE REVIEW FOR EMERGENCY RADIOLOGY PRACTICE

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ABSTRACT

One of the most challenging aspects of emergency medicine is the evaluation and diagnosis of patients presenting with acute abdominal pain. Since there is such a broad list of potential etiologies (e.g., benign and self-limiting conditions), patients who suffer from any of these problems can also be present with similar clinical symptoms. For nearly 20 years, CT has been established as the "gold standard" for imaging in emergency medicine related to acute abdominal pain. Of all the diagnostic imaging modalities utilized in the emergency department (ED); CT has become the most used form of imaging. In addition, CT has been shown to provide rapid results while having high sensitivity and the ability to image multiple organ systems with one imaging study. This paper will cover much of what you need to know about CT in acute abdominal pain; including CT imaging and techniques, rapid acquisition protocols and frameworks, distinguishing features of a CT exam; and the advantages and disadvantages of CT in acute abdominal pain; it will also address some potential advances in technology regarding CT imaging in the future..

KEYWORDS: Acute abdomen; CT scan; Emergency imaging; Contrast-enhanced CT; Abdominal pain; Radiology

1. INTRODUCTION

Acute abdominal pain is the commonest chief complaint of patients who present to an emergency department. There are countlesspossible causes of acute abdominal pain including self-limited gastroenteritis on one end of the continuum and a potentially fatal ruptured visceral on the other. The problem from the emergency physician's perspective is that patients present with the same signs and symptoms regardless of where they fall on that continuum. For most of the twentieth century, physicians and surgeons had to depend upon clinical examination, plain film x-rays, and considerable judgment when determining the cause of acute abdominal pain; exploratory laparotomy was common when a definitive diagnosis could not be made. However, there has been a significant paradigm shift away from previous methods of evaluating acute abdomen due to the advent of computed tomography (CT) imaging as a method of evaluating patients with acute abdominal pain. CT has significantly improved and refined the diagnosis of acute abdominal pain making the process of establishing a precise diagnosis much more efficient and patient-friendly than prior methods. CT scan offers higher spatial resolution images in seconds and cross-sectional views of the entire abdomen. They can be used concurrently for identification of findings such as inflamed tissue; obstructed bowel; ischemic bowel; perforated bowel; bleeding; malignancy; etc.

In most cases now, the significant acute abdominal pain patient will have had a CT scan performed prior to admission to the hospital or going to the operating room. (1)

2. The Role of CT in Acute Abdomen

CT in the clinical setting can provide much more than just a diagnosis and helps drive a variety of decisions related to patient management by providing four unique sets of data.

CT establishes diagnosis with more confidence than other imaging modalities such as plain radiograph and ultrasound, allowing for better understanding of the patient diagnosis, thus driving more effective treatment plans. CT also provides the ability to classify the severity of disease (i.e., uncomplicated appendicitis vs. perforated/abscess appendicitis; or mild edematous pancreatitis vs. necrotizing pancreatitis), which can greatly affect the planning of treatment and the patient prognosis.

Figure 1. Acute infected pancreatic necrosis with intro-lesional gas foci.

CT is also an important component of the decision-making process for the use of surgical versus non-surgical management. When a clinician questions whether to proceed with a surgical procedure immediately, admit the patient for a period of observation, or discharge the patient with an appointment for follow-up care, the data obtained from CT will assist the clinician in making an immediate or long-term decision regarding the most appropriate management for the patient.(2)

Lastly, CT has been shown to markedly reduce the number of unnecessary surgeries performed for conditions such as appendicitis. Since the introduction of CT as a preoperative tool, the incidence of negative appendectomy (i.e., surgical removal of a healthy appendix) has greatly decreased. This benefit has led to fewer complications for patients, reduced length of hospitalizations, and reduced costs to the health care system. (3)

3. CT Imaging. Protocols

There is no CT protocol that works for every case. Different health issues change how tissues look, how they get blood and how they get rid of waste. So, choosing the protocol is very important. Doctors need to know what options are available and pick the one to answer the patient's question. They must balance getting a diagnosis with keeping the patient safe and limiting radiation exposure. (4)

3.1 Non-Contrast CT (NCCT)

Doctors often use -contrast CT as the first imaging test when they think a patient has a kidney or ureter stone. These stones are dense. Show up well on CT scans without needing a contrast agent. In fact, using a contrast agent can make small stones harder to see.

This test is quick and safe, making it great for emergency situations. It avoids the risks of kidney damage from contrast agents or severe allergic reactions. This is especially important for sick patients whose kidney function is unknown.

Also using contrast agents in patients with bleeding or severe neurological symptoms can make it harder to see blood on the scan. For example, in stroke protocols or suspected bleeding in the back of the abdomen a non-contrast scan first helps doctors see the blood clearly. (4)

- **Key Clinical Indications for NCCT**
- Acute Nephrolithiasis: Finding kidney, ureter and bladder stones.
- Acute Intracranial Hemorrhage: Checking for suspected stroke or head trauma.
- Baseline Trauma Assessment: Looking for fractures or large bleeding in the abdomen before using a contrast agent.

3.2 Contrast-Enhanced CT

Contrast-Enhanced CT is the way to take pictures of the abdomen when there is a problem. When we add dye to the blood it helps the doctor see the blood vessels and organs more clearly. This is helpful when we are trying to find out if there is an infection.

The special dye makes the blood, and some tissues show up clearly in the picture. This makes it easier to see what is normal and what is not. For example, if there is a pocketpush the wall of the pocket will show up clearly because it is swollen and thereisa lot of blood in it. The fluid inside the pocket will not show up much.

In some cases, like when the bowel's not getting enough blood, the special dye is the only way to know what is going on before it is too late. Without the dye the bowel might look okay. With the dye we can see if it is not getting enough blood. If it is not getting blood the doctor will know that it is a big emergency and the person needs surgery right away. (5)

3.3 Oral and Rectal Contrast

Bowel opacification with contrast agents given by mouth or rectum is used to highlight problems in the bowel.

These problems include obstructions, perforated organs and inflammatory changes.

Types of contrast agents

ral contrast agents used in CT bowel imaging are broadly classified into positive contrast media and negative or neutral contrast media. Each type has a specific purpose and helps improve the visualization of the gastrointestinal tract during a CT examination.

Positive contrast media make the bowel appear bright or white on CT images because they have high radiodensity. These agents are commonly prepared using dilute barium sulphate or special iodinated contrast solutions. They are particularly useful for outlining the bowel lumen, identifying perforations, fistulas, leaks, or abnormal communications, and distinguishing the bowel from surrounding structures. Positive contrast enhances the visibility of the gastrointestinal tract and provides clear anatomical details, making it valuable in many diagnostic situations.

Negative or neutral contrast media, such as water or milk, have low radiodensity and do not significantly alter the appearance of the bowel on CT images. Instead of making the bowel brighter, these agents gently distend the bowel loops, allowing better assessment of the bowel wall and surrounding tissues. Neutral contrast is especially useful in evaluating inflammatory bowel diseases, bowel ischemia, and tumours because it allows optimal enhancement of the bowel wall after intravenous contrast administration. (6)

With the development of modern multidetector CT (MDCT) scanners and advanced imaging techniques, it has become possible to evaluate many bowel conditions without the routine use of oral contrast agents. High-resolution CT images provide excellent visualization of the bowel wall and adjacent structures, enabling radiologists to detect inflammation by assessing the fat surrounding the bowel as well as changes within the bowel wall itself. This approach has significantly improved the speed and efficiency of emergency imaging. (7)

An additional advantage of omitting oral contrast is the reduction in examination time. Typically, an oral contrast agent requires 60 to 90 minutes to travel through the gastrointestinal tract before adequate imaging can be performed. In emergency situations, such as suspected appendicitis, bowel obstruction, or abdominal trauma, waiting for the contrast to reach the bowel may delay diagnosis and treatment. Therefore, non-contrast bowel CT protocols are increasingly preferred when rapid evaluation is required.

However, oral contrast agents still have an important role in selected cases. When the bowel anatomy is unclear, when there is suspicion of a leak or fistula, or when better delineation of the intestinal lumen is needed, positive or neutral contrast media provide additional

diagnostic information and improve image interpretation. Thus, the choice of contrast agent depends on the clinical indication, patient condition, and imaging objectives.

Diagnostic Value in Complex Scenarios

Distinguishing Bowel Loops from Fluid Collections:

In patients after surgery with pelvic abscesses oral or rectal contrast helps to tell a fluid-filled bowel loop from an infection. (8)

Identifying Extravasation

In cases of suspected bowel perforation seeing contrast leak outside the bowel provides proof of a problem.

Evaluating Fistulas

Contrast agents show connections between the bowel and other parts of the body such as the bladder, skin or other bowel loops.

3.4 Multiphase Imaging

Many current CT scanners can get images at time intervals after a contrast agent is given. Because the contrast media moves through the system before it is filtered by the kidneys, timing the scan just right allows the target tissues to be captured at their best. Each imaging time goes with a phase of both vascular and parenchymal enhancement, which include:

Arterial Phase which happens 20 to 40 seconds after the contrast agent is given.

This phase is mostly used to find out if there is active bleeding and to look at the vascular anatomy, such as aneurysms or acute arterial blockages. This phase is divided into two parts: an arterial phase for mapping the blood vessels and a late arterial phase at 35 to 40 seconds. The late arterial phase is very useful for finding tumors that have a lot of blood vessels, such as liver cancer or neuroendocrine tumors which get their blood supply from the hepatic artery. (9)

Portal Venous Phase which happens 60 to 80 seconds after the contrast agent is given.

This is the useful phase for looking at the solid organs in the abdomen, the bowel and the mesentery. At this point the contrast has gone through the arteries and capillary beds. Has collected in the portal venous system. The liver tissue is at its brightest making it easy to see lesions that do not have much contrast like liver metastases. Most acute abdominal

conditions, such as appendicitis or gallbladder inflammation can be checked thoroughly during this time.

Delayed Phase which happens 3 to 5 minutes after the contrast agent is given.

This phase is particularly useful for looking at problems in the tract and assessing specific liver or adrenal lesions. This phase is also called the equilibrium or excretory phase. It shows the contrast as it leaves the normal tissues and collects in the kidneys, ureters and bladder. It is essential for mapping tumors in the tract and telling apart benign adrenal tumors, which lose contrast quickly from malignant tumors or metastases which keep contrast longer. Multiphase Imaging is very useful for getting a picture of what is going on in the body. CT scanners use Multiphase Imaging to get images at times, and each time gives different information about the body. Multiphase Imaging is a tool for doctors to diagnose and treat many different conditions. (10)

Figure 2. Acute appendicitis with appendicolith and appendicular abscess. Axial images show appendicular abscess (arrows). Appendicolith is seen at its base (open arrows).

4. Common Conditions and CT Findings

4.1 Acute Appendicitis

Appendicitis is the most common reason for emergency abdominal surgery throughout the world, and when uncertain about the diagnosis it is considered the reference standard for imaging based on the clinical presentation. The characteristic CT findings for appendicitis include an enlarged, non-compressible appendix (greater than 6 mm in diameter), circumferential wall thickening with enhancement of the mural structure, and edema around the appendix fat due to adjacent inflammation. An appendicolith, or calcified structure within the appendix, is also present and indicates a higher chance of perforation. For perforated appendicitis, there will be air outside of the bowel, fluid collections around the bowel, and

possibly abscess around the appendix. This has clinical significance because the management of a perforated versus an uncomplicated appendicitis may be very different. (11)

4.2 Acute Pancreatitis

In mild cases of pancreatitis, CT findings can range from basically normal to slight peripancreatic fluid and a slightly enlarged pancreas. As the severity of pancreatitis worsens, the pancreas will become more enlarged and will have strands of inflammatory fat in the peripancreatic area. Finally, in the worst cases, areas of necrotic pancreas will be present as non-enhancing areas of the pancreas, which has significant prognostic implications. The CT Severity Index (Balthazar score) is a commonly used method for grading the severity of the disease and guiding triage decisions.

Figure 1.Recurrent pancreatitis with splenic artery pseudoaneurysm. (a–b) arterial phase and.

4.3 Bowel Obstruction

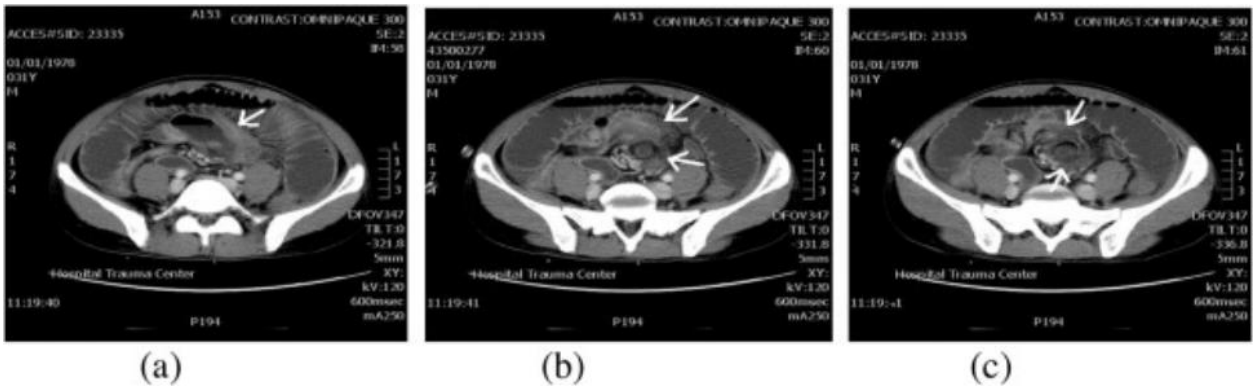

Figure 4 Small bowel obstruction. Axial images (a–c) show dilated small bowel with air fluid level and the site of entero-enteric intussusception (arrows).

CT scans have been found to provide a very detailed picture of the body and its internal workings, particularly the intestines. In fact, it is now considered the preferred imaging modality for suspected bowel obstructions (due to its superior ability to evaluate these patients) and provides far more diagnostic content than standard abdomen films. The classic signs of a mechanical bowel obstruction include distended loops of bowel above the obstruction; air-fluid levels in a stepladder fashion; and the presence of a transition zone. Above all else, however, CT scans can also detect the underlying cause of the obstruction (adhesion, hernia, tumor or volvulus) and confirm whether there has been bowel ischemia. This is achieved by evaluating whether the bowel wall thickness has increased, whether there are areas of gas in the bowel (pneumatosis intestinalis) or the presence of gas in the portal vein; all of which will help to determine the urgency of surgical intervention. (12)

4.4 Gastrointestinal Perforation

The presence of free air in the abdominal cavity is demonstrated on CT by the presence of a hypodense collection beneath the diaphragm or anterior to the liver. The presence of free air in the abdominal cavity is considered the most sensitive test for diagnosing gastrointestinal perforation; CTs are much more sensitive to the detection of free air than an upright chest x-ray, especially in cases where there are only small amounts of free air. In addition to identifying the presence of air, CT allows for the identification of the location of the perforation and an assessment of how much peritoneal contamination is present, both of which are important for surgical planning.

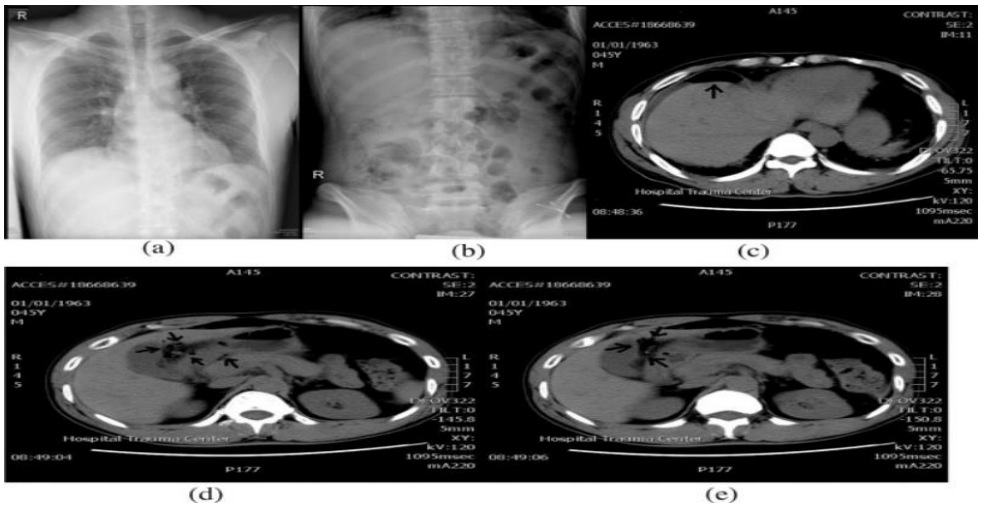

Figure 2F.Perforated duodenal ulcer. Chest (a) and abdomen (b) AP sitting X-ray shows no obvious free air under the diaphragm. Axial (c–e) images show free intraperitoneal air and collection in the anterior peritoneal surface of the liver, and around the du.

4.5 Renal Colic

CT can identify stones within the urinary tract at virtually any location along it, while providing information regarding other characteristics of the urinary tract, such as expansion of the ureter, inflation around the kidney, or swelling of the kidney due to fluid accumulation

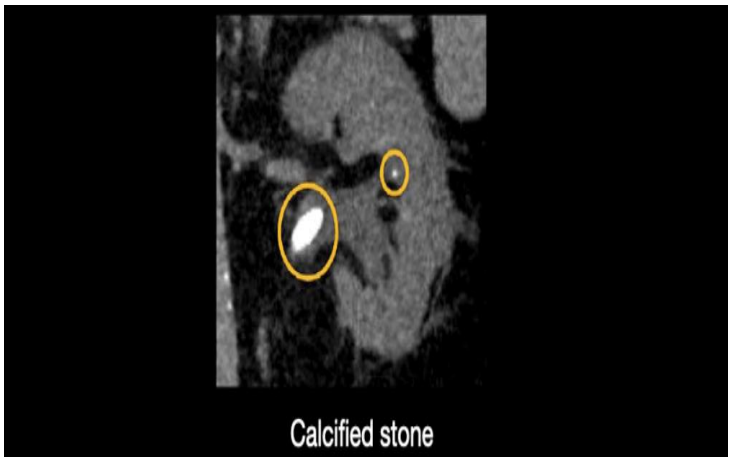

Figure 6 Calcified Stone.

(known as hydronephrosis), which result from obstruction due to stones, in addition to ruling out life-threatening conditions (such as a ruptured abdominal aortic aneurysm) that might present with flank pain.

Figure 7Abdominal Trauma.

4.6 Abdominal Trauma

The use of CT has significantly changed the way abdominal trauma is evaluated and treated. With rapid scanning ability in modern multidetector CT technology, a complete assessment

of the entire body can now be done in less than one minute. The physician may have immediate access to detailed images of injuries sustained by the liver, spleen, kidneys, bowel, and mesentery. The severity of solid organ injuries, the presence of active bleeding from an artery, and the presence of other injuries to the skeleton are all evaluated from a single examination. The information obtained from a CT examination allows the physician to determine which patients should go directly to surgery, which should have an angiographic embolization performed, and which may be treated non-operatively.

5. Advantages of CT Imaging

The widespread adoption of CT imaging in the treatment of patients in an emergency department setting has been facilitated through a number of factors that can be attributed to the uniquely.

Speed: CT imaging technique making it particularly well-adapted for use on very ill patients. Modern multi-detector scanners will perform a complete CT of the abdomen and pelvis (a few minutes) in 10 seconds of scanning time.

Diagnostic accuracy: In terms of its performance for diagnosing acute abdominal issues, CT imaging typically shows sensitivity and specificity values of greater than 90%.

Comprehensiveness: A CT scan of the abdomen allows full evaluation of all solid and hollow organs in one exam (so-called "whole body view").

Reproducibility: CT images can be viewed, shared, compared to prior studies and discussed with others at any point after the image has been taken while ultrasound images cannot be.

Surgical planning: CT provides the anatomical information necessary for the surgeon to plan the incision, anticipate the findings at surgery, and educate the patient about what they will experience. (13)

6. Limitations and Considerations

CT is a good diagnostic modality but there are limitations you should consider when using it. The most common limitation is the ionizing radiation exposure to the patient; a routine abdominal CT scan exposes the patient to anywhere between 5 and 15 mSv of ionizing radiation, which is equivalent to many years of background radiation exposure, but while the risk to an individual using CT for one (1) test is low, the total population exposure to CT-related radiation is a definite concern due to the higher number of CT scans being completed each year. This is especially true for younger patients and patients who require repeated testing due to the higher risks of radiation exposure compared to older patients.

Contrast Nephropathy -The concern about nephropathy following the use of iodinated contrast in patients with pre-existing renal impairment remains a continuing issue. Prevention of this through adequate pre-hydration before the administration, minimization of contrast media dose to the lowest level required, and using iso-osmolar contrast agents are useful strategies to minimize the likelihood of contrast nephropathy.

Contrast allergies, although infrequent, can occur anywhere between mild urticaria to life-threatening anaphylaxis and may require the appropriate screening and use of a pre-medication protocol.

In pregnancy, CT is used judiciously to weigh the risk of potential radiation exposure to the fetus against the possibility of missing a serious diagnosis. If CT is needed due to obstetric emergencies, ultrasound is the preferred first investigation, followed by MRI as needed for more detailed imaging.

Cost and availability are also important considerations. CT scans are significantly more expensive than either ultrasound or plain film X-ray, and there is considerable variation in the availability of CT scanners among institutions and healthcare systems. (14)

7. Comparison with Other Imaging Modalities

Table. Comparison with other modalities.

Modality	Advantages	Limitations
Ultrasound	No radiation; real-time; safe in pregnancy; bedside availability	Operator-dependent; limited by bowel gas and body habits; incomplete field of view
Plain Radiography	No radiation; excellent soft-tissue contrast; preferred in pregnancy	Limited diagnostic sensitivity; poor soft-tissue contrast; cannot localize cause
CT scan	High sensitivity and specificity; rapid; comprehensive; reproducible; guides intervention	Radiation exposure; contrast risks; cost; limited availability in low-resource settings
MRI	No radiation; excellent soft-tissue contrast; preferred in pregnancy	Slow; expensive; limited emergency availability; claustrophobia; metallic implant restrictions

8. Clinical Impact

The influence of CT in managing acute abdomen cannot be exaggerated. CT has been shown in various studies to alter the working diagnosis in between 30 and 50% of patients suffering from acute abdominal pain, and changes in clinical management occur in the same numbers.

Routine preoperative CT for suspected appendicitis has also significantly decreased negative appendicectomies in many hospitals from historical rates of 15 to 30% to less than 5%.

In addition to altering the outcome for the individual patient, CT has produced system-wide changes in the delivery of emergency medicine. Patients who receive CT earlier in their stay within the emergency department have been found to be triaged more accurately and have an overall reduced length of time prior to a definitive plan being developed andare therefore admitted to the appropriate level of care more reliably. These improvements lead to shorter hospital stays, lower complication rates, and more efficient utilization of surgical resources. (15)

9. Future Perspectives

Technology in computerized tomography will continue to advance rapidly within the next ten years, leading to innovations and enhancements that will have effects on the practice of emergency medicine.

The emergence of low dose CT protocols through the development of iterative reconstruction algorithms and dose modulation software has resulted in diagnostic quality comparable to standard dose, at a fraction of the radiation dose. This is especially relevant for children and patients who require serial imaging, as it reduces the cumulative radiation dose that would have otherwise been a result of having multiple CT scans.

The largest innovation on the horizon will be artificial intelligence and machine learning, which represent some of the most revolutionary innovations currently being researched and developed. There are now several AI powered technologies that are being developed and validated to assist physicians with the automated detection of appendicitis, bowel obstruction, aortic disease, and pulmonary embolism, which, based upon early report data, are already capable of detecting some of these entities with the same degree of accuracy as experienced radiologists. Human supervision will continue to be key, but AI will eventually be utilized as an advanced triage tool to help identify critical findings for timely intervention and to help facilitate the reporting of findings from large numbers of emergency department patients (greater than 200,000 patients per year) in a timely manner. Many advanced centers already use dual energy CT (DECT). The DECT can give information about tissue composition that traditional CT could not, therefore it is improving the characterization of lesions in the adrenal glands, uric acid stones, and bowel ischemia. The use of portable CT systems is being investigated (to some degree) for use in intensive care units and or remote or resource-limited settings, regardless of that they have a lower resolution compared to stationary scanners.

Advances in photon counting technology and spectral CT potentially will improve image quality and reduce radiation doses both at the same time.

10. CONCLUSION

Acute abdominal pain remains one of the most challenging clinical presentations encountered in emergency medicine due to its wide range of possible causes, varying clinical manifestations, and the need for rapid identification of potentially life-threatening conditions. Disorders affecting the gastrointestinal, hepatobiliary, genitourinary, vascular, and gynaecological systems may present with similar symptoms, making accurate diagnosis based solely on clinical examination and laboratory findings difficult. Delays in diagnosis or inappropriate management can result in increased morbidity, unnecessary surgical interventions, prolonged hospitalization, and even mortality. Therefore, the availability of a rapid, accurate, and comprehensive imaging modality is essential for effective patient care.

Computed tomography (CT) has revolutionized the diagnostic approach to acute abdominal pain and has become the imaging modality of choice in many emergency settings. The introduction of multidetector CT (MDCT), high-resolution image reconstruction, multiplanar reformations, and optimized contrast protocols has significantly enhanced the ability of clinicians to evaluate abdominal pathology with remarkable precision. CT provides detailed visualization of abdominal organs, bowel loops, mesentery, blood vessels, and surrounding soft tissues within a matter of minutes, enabling prompt identification of inflammatory, infectious, traumatic, obstructive, ischemic, and neoplastic conditions.

One of the most significant advantages of CT imaging is its ability to provide rapid and consistent anatomical information, allowing emergency physicians and radiologists to establish a definitive diagnosis early in the patient's clinical course. This has led to a substantial reduction in unnecessary exploratory surgeries and hospital admissions while improving diagnostic confidence and facilitating appropriate medical or surgical management. CT imaging has also contributed to shorter emergency department stays, faster treatment decisions, and improved patient outcomes across a broad spectrum of acute abdominal conditions, including appendicitis, diverticulitis, bowel obstruction, perforation, pancreatitis, and vascular emergencies.

Recent technological advancements have further expanded the role of CT in emergency radiology. Low-dose imaging protocols, iterative reconstruction techniques, dual-energy CT, artificial intelligence-assisted image analysis, and rapid multidetector scanners have

improved image quality while minimizing radiation exposure and reducing scan times. These innovations continue to enhance diagnostic accuracy and patient safety, making CT an increasingly indispensable tool in emergency medical practice.

The integration of CT imaging into emergency diagnostic pathways has transformed the management of patients presenting with undifferentiated abdominal pain. In many modern healthcare facilities, patients can undergo comprehensive evaluation and receive a definitive diagnosis within an hour of arrival, allowing timely initiation of appropriate therapy. As imaging technology continues to evolve, the importance of CT in emergency medicine is expected to grow even further. Rather than replacing clinical judgment, CT serves as a powerful extension of the physical examination, providing objective and reliable information that supports evidence-based decision-making. Consequently, CT imaging has established itself as the gold standard for the evaluation of acute abdominal pain and will continue to play a pivotal role in improving diagnostic efficiency, optimizing patient management, and enhancing overall quality of emergency healthcare.

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