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Impact of CT Imaging in Emergency Medicine

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Abstract
Advances in imaging technology, particularly multidetector computed tomography (CT), have significantly changed the practice of emergency medicine. CT has become such a valuable tool in emergency clinical settings that it has practically become a standard imaging procedure. However, with the overwhelming proliferation of CT imaging, concerns have been raised regarding patient safety and radiation exposure. In particular, the long-term risk of radiation exposure is of concern, especially in young patients who are likely to undergo repeated and frequent imaging. Recent years have witnessed the advent of advanced CT techniques that can minimize radiation exposure, and this has become the subject of research. This paper explores how CT can be best and most safely used in emergency medicine and the latest techniques implemented to address the associated impacts. The paper also addresses the challenges confronting emergency physicians regarding the present and future use of CT in emergency medicine. (Carpenter et al.2020)

1. Introduction

Non-contrast computer tomography (CT) scan has long held a distinctive and essential position in the field of emergency medicine. Indeed, there are not many medical departments and specialties that rely so much on this diagnostic tool and have contributed to its popularity. The CT scan was first discovered by British engineer Sir Godfrey Hounsfield in 1971, who utilized the computer to construct two-dimensional slices from conventional tomographic X-rays of an object. Together with South African-born physicist Alan Cormack, Hounsfield presented his invention in a paper published in 1973.

Nowadays, CT scanning is widely employed as a diagnostic tool in emergency departments. CT scans are readily accessible and capable of providing both anatomical and functional imaging of varying structures and tissues within the body. The benefits of CT imaging in the emergency setting are many: rapid diagnosis and treatment, avoidance of delays in patient management, and identification of seriously unwell patients. The ability of CT to obviate several invasive procedures has profound implications for the obstetric, surgical, and medical care of emergency patients, although insufficient evidence means this should be considered in relation to available alternatives and in discussions with the patient. The current and potential applications of CT imaging within the emergency setting are wide and continue to expand. An example of the former is the recent extension of clinical guidelines on chest pain of recent onset, to include the use of CT angiography within this group of patients. Within the acute sector, CT scanning directly impacts clinical activity in a number of areas, such as the acute stroke pathway, head injury, and imaging of trauma patients. There are also many innovative new and near-patient techniques that could have a major effect on the investigation of the emergency patient, although research is in the preliminary stages in these areas. This is the setting in which speed is of the essence; decisions often have to be made on the best possible but incomplete data, and therefore the cost-benefit ratio of the CT technology in the information it supplies must be considered. It is this practical clinical perspective of CT in acute care that this text aims to address. We explore the uses of CT technology in the emergency department, the evidence underpinning this technology, and the clinical impact on patient care. We will cover both the benefits that CT brings to emergency care and the potential downsides. The text is divided into ten themed sections to provide a basis for understanding CT in the acute care pathway. To preserve flow and practicalities, some innovations, for example, sections on identifying the serious emergency patient, are presented slightly out of chronological order. The sections include: historical overview, applications in triage, safe imaging, patient flow, overall patient outcome, diagnosis, reducing negatives, limitations/delay, and future innovations. (Schalekamp et al.2021)

1.1. Background of CT Imaging

Imaging technology has progressed rapidly since the X-ray was discovered over 120 years ago. The computed tomography (CT) scan, first imagined in the early 1970s, was the revolutionary result. Pioneers of the new technology quickly established it as the medical imaging modality of choice. Skull imaging was the first application of clinical CT techniques, followed closely by cardiac CT imaging. Over the years, the development of faster and more powerful CT technology has transformed this modality, facilitating the replacement of many other diagnostic tools with this imaging system. CT imaging developed in the 1970s had limited resolution, resulting in the detection of larger pathologies. Traditional 'axial CT' limited scanning to a single plane, which decreased diagnostic value due to its inability to completely reconstruct three-dimensional (3D) anatomy. (Conlogue et al.2020)

Technological advancements designed for continuous rotational imaging in the 1980s with faster scan times provided the means for non-contrast angiography imaging and improved contrast-enhanced imaging with multiple slice CT systems in the 1990s. The introduction of dual scan CT in the early 1990s provided imaging with almost no injections, resulting in improved cost-effectiveness. Further improvement in CT imaging was achieved in the late 1990s with the introduction of helical volume imaging systems. New scanner designs in the early 2000s utilized 40- and 64-slice volume imaging to improve anatomy imaging and to provide increased dose efficiency. The introduction of dual-energy CT in the latter part of the 2000s provided better diagnostic capabilities with minor additions in radiation.

1.2. Significance of CT Imaging in Emergency Medicine

CT imaging plays a critical role in emergency medicine. When time is limited, CT can quickly provide health care professionals with remarkable images of the inside of the human body that show tumors, hemorrhages, and fractures with great detail. Trauma victims go directly from the emergency department to the CT scanner to determine the extent of internal injuries. Patients with acute chest and abdominal pain have a higher chance of a correct diagnosis and are discharged from the emergency department earlier when CT images are available. (Maddu et al., 2021)

CT imaging will not only enable emergency physicians to make the right treatment decisions rapidly, but will also help determine who should be admitted to the hospital and who can be discharged.

Studies have shown that when a diagnosis is suspected by initial clinical, biochemical, and radiological evaluation, the results of a CT scan can confirm the likely disease in over 90% of cases. CT scans provide the radiological expertise to aid the emergency physician in his or her decision-making, thus reducing medical errors and improving patient safety and outcomes. As radiologists in emergency care, we know from the work that we do that many diagnoses made on clinical assessment and simple radiology studies like X-rays of a part of the body such as the abdomen, chest, or brain can and should be confirmed by a CT scan. In a study of emergency care visits involving tears to the posterior segment of the eye globe, a significant percentage of injuries that were not identified by physical examination were found and surgical intervention was required. Such tumors are commonly found in patients with a stroke or a heart attack, even in the absence of specific neurological symptoms. Therefore, if a CT is offered, patients with nonspecific symptoms that appear to be stable can be discharged or admitted for further diagnostic evaluation. Another study found that accelerating decisions about whether to send patients to the intensive care unit can improve outcomes when CT images also show acute brain bleeding, not just expansion of the brain. Little or no benefit was gained by using CT to make decisions in patients who had mild bleeds with no increase in brain pressure until six hours after symptom onset. There is a wealth of information on recent studies showing the impact of advanced CT imaging compared to traditional CT imaging on patient management and outcomes for patients presenting with head trauma. Remember, many of these patients with head injuries did not have major fractures or anesthetic concerns. How many are being missed that CT may help with in other associations? Having the best CT imaging available for patients who present with head injury in the ED, who we can't afford to keep in the hospital, may significantly improve their management and their outcome! We cannot just plan for major trauma, but also for those with minor injuries. (Afshar et al.2021)

2. Advancements in CT Technology

CT has become increasingly important in the management of emergency patients presenting with a wide spectrum of diseases, and these advances have greatly impacted emergency medicine. Over the past few years, advances in CT technology have resulted in faster acquisition times for CT imaging through the development of multi-detector and dual-energy CT scanners. In addition to faster scan times, other advancements including improved image resolution, optimized multiplanar reformations, additional physiological imaging capabilities including myocardial contrast, and left ventricular chamber evaluation with CT are important. These improvements in technology have facilitated the greater use of CT imaging for an ever-increasing variety of conditions, from known conditions to new diagnoses. Ensuring that patients can receive a rapidly acquired diagnostic test with high accuracy and sometimes specificity is integral to emergency medicine practice. The advances in CT technology have ensured that the use of CT has continued to grow, despite concerns for ionizing radiation, with an increase in CT utilization in U.S. emergency departments of 22% during the years 2006 to 2010. A significant increase in advanced diagnostic imaging for emergency department patients was observed. Although not all of this increased imaging workload or improvement can be attributed to CT, these results highlight the overwhelming use of CT within the current healthcare setting, particularly in the emergency setting. Moreover, shorter on-table times with faster CT scanning have demonstrated a significant influence on emergency patient flow, showing a reduction in emergency patient processing times for each reduction in imaging time. (Marin et al.2020)

2.1. Multidetector CT Scanners

Since their first clinical introduction more than two decades ago, multidetector CT scanners have become indispensable in emergency diagnostic imaging. The main component of multislice CT scanners is data acquisition by means of row detectors. By using two or more detector rows, CT scans can be performed more rapidly and image coverage can be increased. Increased scan speed is especially advantageous for imaging dynamic areas, such as the heart and coronary arteries during the arterial contrast enhancement phase. The introduction of tubes with increased tube current capabilities combined with an increase in the maximum number of collimations of the newest generation 320-slice CT scanner made scanning of the entire heart with high temporal resolution possible. The ability to cover a wide range of anatomy by acquiring large scan fields is crucial for the rapid visualization of complex anatomical structures necessary in emergencies. For example, CT in trauma is now considered the modality of choice for patients with multiple injuries where early detection of life-threatening injuries is required to guide patient management, including whether or not immediate intervention is needed. In the setting of suspected pulmonary embolism, CT may be the only modality needed to accurately and rapidly detect or eliminate this diagnosis. Immediate exclusion of alternative acute causes of symptoms can expedite patient management. The increase in the number of detector rows also meant an increase in the number of images generated, such that performing imaging studies that require dynamic acquisitions of different body parts was now possible within a single patient examination. Despite these many advantages, not all facilities will have accessibility to the latest CT scanners because widespread installation often has cost and technical implications. The subsequent availability of multidetector CT has particularly increased the role of CT in the initial evaluation and follow-up of patients with other traumatic injuries. (Qamar et al.2021)

2.2. Dual-Energy CT Scanners

Dual-energy CT is the latest concept of CT imaging that utilizes two different x-ray energy levels during the imaging process. Compared with conventional single-energy CT, dual-energy technology may enable improved tissue characterization, which may in turn improve diagnosis and treatment. Research and development have shown potential use of this new technique using a dual-energy CT energy delivery system. Despite the technological advancements in dual-energy scanners, further research is needed to determine how to best use this technique in the field of emergency medicine.

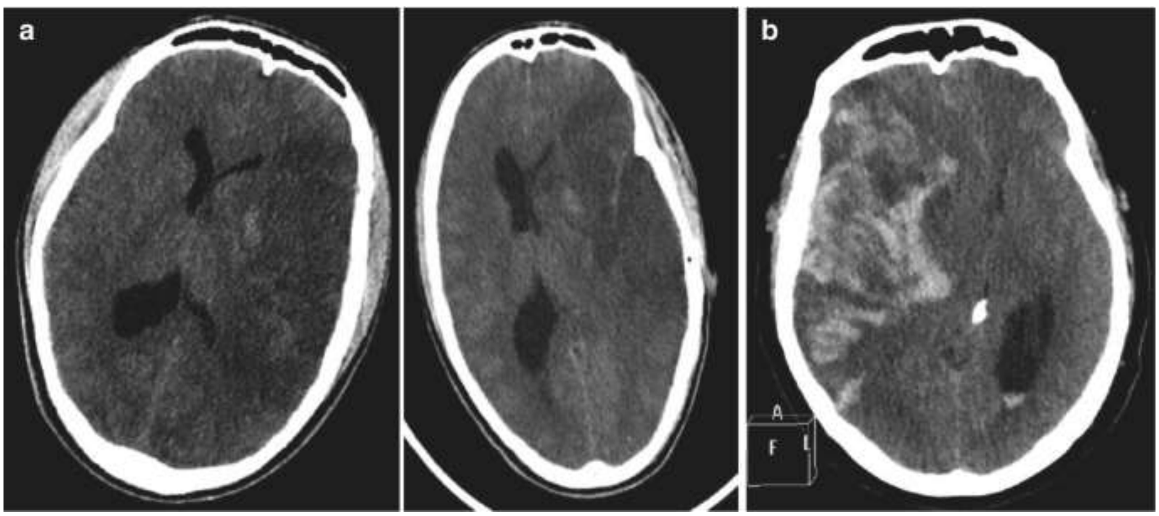
In recent years, dual-energy CT imaging has been developed and has been shown to be a feasible modality for the differential diagnosis of several pathologic conditions such as tumors, vascular diseases, and kidney stones. Dual-energy material decomposition algorithms can show multifaceted properties such as reduction of iodine load in dual-energy CT angiography, differentiation of lipid-rich adrenal adenoma from non-adenoma, differentiation of urinary calculi from phleboliths, and differentiation of uric acid stone from non-uric acid urinary calculi. In several studies, DECT showed good feasibility and accurate diagnostic performance compared directly or indirectly with other conventional grayscale images. (Gentili et al.2020)

Therefore, considering the relevance of CT in the management and decision-making processes and the relative ease in developing fast DECT scans, DECT could be the best dual-energy modality that would emerge in the future for many routine applications in emergency care. In particular, it would be very important to evaluate these modern scanners for their use in various time-based protocols and in particular in high- and low-dose single-source scanning formats. The extensive involvement of university hospitals, academies, and industries with commercial partnerships demonstrates real interest in these modern scanners for the development of advanced training and research programs to determine how best to integrate these systems and protocols into our emergency room in terms of time and cost.

3. Applications of CT Imaging in Trauma

CT imaging is significantly used in trauma due to the emergence of conditions, the high risk of complications in case of misdiagnosis, delayed treatment, or poor management, and the high potential for life-threatening conditions. Besides the clinical setting, imaging in trauma promotes a quick and predictive approach to injury detection and the formulation of the immediate treatment plan. Such a scenario results in an enhanced effect of imaging on patient care. Furthermore, CT is the gold standard for detecting crucial clinical conditions that are causes of life threats, such as fractures, bleeding in solid and hollow organs, and major vessels, illustrating how appropriate imaging in conjunction with clinical data can offer a very comprehensive profile of the patient in a single exam. Trauma patients are often not suitable for communication or resultant examination due to psychological or physical impairment. (Reitano et al.2022)

The use of CT in trauma can also contribute to improved patient management, thereby decreasing the length of hospitalization. There are some limitations in the CT application in trauma, which include over-diagnosis and unnecessary exposure to radiation that can occur when using a whole body CT protocol. Sensibly decreasing the radiation dose from CT while still maintaining a suitable diagnostic exam can be very challenging. The combination of clinical evaluation and imaging, including whole body CT, can significantly increase the sensitivity of detecting significant injuries. CT provides more accurate and sensitive images than conventional radiography for evaluating bone and thoracic injuries. Some studies have shown that larger portions of fractures can be more suggestive of specific mechanisms of trauma than other multi-trauma cases.



3.1. Head and Neck Trauma

CT in acute head and neck trauma. In head trauma, CT is extremely reliable in the identification of critical injuries including skull fractures, intracerebral hemorrhage, and extra- or subdural hematoma. Such injuries can often be visualized on a CT scan almost immediately post-trauma. This imaging can also differentiate between the extent of brain injury and would be invaluable for appropriate triage of trauma patients to critical care. Dense bleeds can prevent visualization of active bleeds and cannot be used as a means to clear the patient as another study of choice. CT scanning is not only useful in acute situations but can also identify chronic critical pathologies such as subdural hematomas, which can form days to weeks prior to the bleed leading to the clinical presentation. (Monteiro et al.2020)

Cross-sectional imaging has given the ability to visualize various areas of complex anatomical constructs, which has aided in the diagnosis, identification, and successful treatment of injuries that would not have been identified with standard radiography. Bone injuries can be identified such as the following: occult skull fractures are another pathology that remains clinically undiagnosed and never referred for further imaging; clinically significant skull base fractures, which can lead to leaks and infections; torn vessels and large vessel bleeds through arterial phases, which may give the surgeon clear indications of areas of concern for reconstruction and fixation; anatomical disruption which may necessitate surgical intervention for functional and aesthetic rehabilitation. Visualizing these areas of injury before surgery reduces the need for extra incisions and increases the success of the surgery.

In pediatrics, CT is often used in cases of mandible and maxillary fractures due to the available ability for a variety of reconstructions available radiographically. For other areas of injury, the patient is often transferred to a tertiary hospital with on-site advanced radiographic imaging. As the pediatric population has a much higher lung count, the risks of radiography are often replaced by the need for further investigation and findings on a physical examination. Limitations and Irradiation Risk: The level of radiation that comes with CT exposure is one of concern. Yet, the benefits the technology has in trauma clearing cannot be replaced. The experience and comfort level of medical imaging professionals has led to improved algorithms involving lower doses of radiation, dual energy, and a higher count of slices with less radiation. The overall literature consensus has highlighted that the radiation dose from CT in the neck area is less likely to cause harm compared to the over 4000 children as young as 0–14 in the U.S. alone who died from non-intentional injuries, with over 70% of children diagnosed with head injuries which were often investigated with CT to determine the extent of their head injuries. (Cotterill, 2023)

3.2. Chest Trauma

As a modality that has revolutionized the field of trauma, CT holds added value for the accurate imaging of the chest in a setting where imaging can be limited by reduced availability of equipment. In general, CT is the optimal imaging modality to evaluate chest trauma due to the exquisite imaging of thoracic structures it can obtain, including the mediastinum, heart, diaphragm, lungs, pleurae, and thoracic great vessels. CT can detect a wide variety of trauma-related injuries, including pulmonary contusions, hemothoraces, pneumothoraces, rib fractures, thoracolumbar spine fractures, solid and hollow organ injuries, thoracic great vessel injuries, tracheobronchial injuries, esophageal injuries, and sternal fractures. Chest CT not only has a role in diagnosing specific injury patterns but may also be used to provide early trajectory data and detect dangerous patterns of injury or underestimated trauma in occult thoracic injuries.

In radiology literature, case reports and case series of chest trauma also appear, one of which recently reported a case of blunt chest wall perforation of the left ventricle, which was diagnosed by lung windows during the evaluation of a rib fracture with CT. Rapid scanning strategies are suggested to improve workflow in the emergency setting, where chest CT is not only indicated for life-threatening chest injuries but also has the potential to speed up patient management in the absence of available red flags in selected patients. A limitation with chest CT in the emergency population is the presence of a high number of young trauma patients who can potentially develop stochastic radiation risks. This warrants an optimized scanning protocol that has to balance low-dose settings and high image quality for the detection of trauma-related injuries. Chest CT scans in an emergency setting are usually interpreted by specialists in radiology and emergency medicine, sometimes in preclinical trauma CT units. (Dogrul et al.2020)

4. Role of CT Imaging in Stroke Evaluation

In the era of emergency medicine, CT imaging has become a mandatory part of even the basic evaluation of a stroke patient. The rapid discrimination of ischemic versus hemorrhagic stroke is indispensable for proper patient direction. Also, the swift identification of the symptom onset is vital to determine if intravenous thrombolysis is a possibility. Advances in stroke neuroimaging, including cerebral sonography, perfusion CT, CT angiography, and extended diffusion-weighted imaging, are part of an advanced stroke protocol, corresponding to more of the local and regional healthcare facilities rather than the standard pre-hospital level. The indications for thrombolysis have evolved from exclusion criteria to computed tomography-based inclusion criteria. CT imaging accuracy is further used in decisions on the appropriate time to begin antithrombotics and to decide how aggressively to treat the blood pressure when it is elevated. (Sheth et al.2023)

CT imaging also provides a vital role in the determination of the extent of stroke. To distinguish an ischemic from a hemorrhagic stroke, CT is very accurate. A subarachnoid hemorrhage is easily demonstrated by CT. A large intracerebral hemorrhage demonstrates the amount of brain that is dead and the mass effect from the bleeding, which may require surgical removal. Proper stroke classification is an axis on which appropriate treatment lies. Evaluating the extent of hypoattenuation helps in ancillary stroke care, usually by the degree of long-term damage. Admission stroke severity and age are important predictors of mortality and functional outcome after symptom onset, but clinical examination is not always complete at initial presentation. CT imaging provides an accurate and timely way to complete these examinations.

4.1. Ischemic Stroke

Ischemic stroke accounts for between 80% and 85% of overall strokes, and CT imaging is used to guide routine clinical diagnosis and management. The primary treatment for ischemic strokes is intravenous thrombolysis and mechanical thrombectomy by specialized teams. Neuroimaging is essential in correctly identifying patients eligible for these treatments. To be effective, it must be performed as soon as possible. The more time taken to confirm an ischemic stroke, the more brain tissue will die during this period, thereby reducing the time window for treatment. CT imaging can identify ischemia as early as 20 to 30 minutes after ischemia onset.

Using CT, early ischemia appears as a loss of gray and white matter differentiation, becoming increasingly hypoattenuated over time until it becomes characteristically darker than the unaffected white matter. The affected area tends to have a wedge-shaped appearance, the point of the wedge pointing to the core of the ischemia. In some cases, the site of occlusion can be seen. Such findings on a CT scan provide a snapshot of the extent of the emergency, and decision-making in the emergency department is influenced by the results of these scans. CT images have keenly influenced the direction of rescue medicine in emergency departments. Further advancements with CT scanners have meant that the detection of increasingly smaller areas of infarction is possible, particularly odorless infarctions. Combined vessel and tissue imaging can estimate the areas of the brain that are either already dead or (Driscoll et al., 2022)

4.2. Hemorrhagic Stroke

The CT scan remains the gold standard in the evaluation of hemorrhagic stroke. Due to the rapid identification capabilities of a CT scan, it is the best imaging test to help guide urgent treatment strategy. Patients who show no bleeding on initial screens using the NIHSS independently or those who arrive outside of the thrombolytic window and present with substantial cerebral hemorrhage should have CT scanning of the head without contrast to affirm the diagnosis. Once clinically stable, these individuals should then follow advanced imaging by a CTA to visualize the vasculature and the extent of hemorrhage if the patient has not already received therapy. When cerebral hemorrhage is confirmed and cerebral aneurysm is confirmed by the initial advanced imaging, the preferred examination is non-contrast CT of the head to assess the size and location of the hemorrhage.

The two most widely recognized types of bleeding in the brain are intracerebral and subarachnoid hemorrhage, and both are readily visualized on non-contrast CT scans. On a non-contrast CT scan, parenchymal hemorrhage has a density of greater than 50 Hounsfield units compared to the normal isodense ventricles, indicating a hyperdense region of hemorrhage. Visualizing blood collection in the cerebrospinal fluid surrounding the brain is also seen on CT without contrast or a CT angiogram. Visualizing the full profile of subarachnoid hemorrhage is essential because the volume and extent of bleeding can affect morbidity and mortality of these patients. However, sometimes it is not as easy as one would think to pick up intracranial bleeding on a CT scan. The sensitivity of early CT scans for acute bleeding is 94 percent. Modern head CT scanner slices are thin enough to assess most aspects of the brain that should be examined. Sometimes, it is still difficult to visualize bleeding, especially within the first few hours. There are two advancements that are being researched to combat this challenge: the use of thin slices of imaging protocol and the stroke protocol. It was found that acquiring thin slices decreased the rate of patients who had to have different imaging protocols and increased confidence in rejecting the emergency rarely ischemic problems of intracranial hemorrhages. Ultimately, being able to rule out an intracranial hemorrhage is an essential part of the stroke protocol, especially in the emergency department. The ability of a CT scanner to scan a person takes between 3 to 5 minutes, making the scan compilation from start to finish approximately 15 minutes long. The short time span is critical for the patient because it will help guide stroke treatment options in a timely manner. (Shiri et al.2021)

5. CT Imaging in Abdominal Emergencies

Acute abdominal conditions are the most common emergency presentation to an emergency department. Conditions such as appendicitis, diverticulitis, or bowel obstruction are encountered daily in a busy ED, and it is incumbent upon the emergency physician to have a high index of suspicion for these pathologies. Initial screening is often undertaken with ultrasound; the premise behind this is that an ultrasound scan can change the clinical trajectory of the patient. Ultrasound, however, has a significant error rate, and therefore cross-sectional imaging is often utilized.

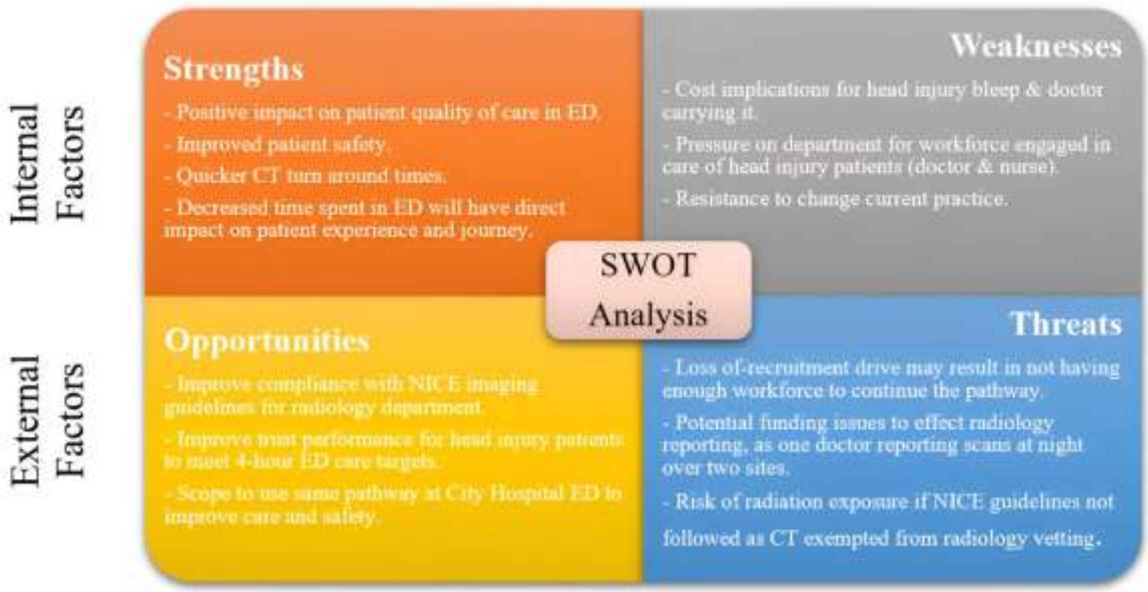
In this context, computed tomography (CT) is the imaging modality of choice, owing to its ability to accurately diagnose both intra- and extra-luminal pathology. Time to diagnosis is paramount, as prolonging this could potentially result in increased morbidity and mortality; therefore, in this context, the role of CT in an emergency setting is vital. The accuracy of CT in regard to diagnosis has been well established. The sensitivity and specificity of CT for appendicitis are 94% and 95%, respectively, compared with clinical scripts of between 70% and 84%. As a result, CT is vital in confirming or excluding the diagnosis of appendicitis, especially in obese patients or in female patients of reproductive age where ultrasound may be less sensitive. However, the true power of CT lies not in excluding the diagnosis of appendicitis but in identifying an alternative diagnosis in 28-31% of cases, as early as the CT report itself. This CT report led to direct surgical management. This is known as the triad of treatment. (Minordi et al., 2022)

There are, however, several important points that need to be taken into account, particularly in relation to radiation exposure, the added time of undergoing a CT scan, and patient selection. In light of these, considerable work has been undertaken to modify protocols and refine imaging. In order to keep scan protocols within an acceptable balance between radiation exposure and diagnostic efficacy, the utilization of low-dose CT protocols has been studied. A factorial randomized controlled trial in adult patients with suspected appendicitis showed that low-dose CT can reduce the effective radiation dose to 29% compared with standard-dose CT. Furthermore, and somewhat surprisingly, this study demonstrated that low-dose radiation did not reduce CT accuracy compared with standard-dose CT. In the future, we will likely see a change in CT technology, likely with improved reconstruction techniques, as has happened over the last 30 years in CT imaging. Dual-energy scans may also help guide treatment options in physiologically unstable patients in emergency settings, helping to stratify patient risk. Magnetic resonance imaging may be seen as potential in the diagnosis of the more common but complex bowel pathology because it does not use ionizing radiation centered on the pelvis. Other current future potential applications include rapid imaging sequences; CTA head, neck, and whole axial to diagnose internal or external bleed; cardiac CT for embolism; and a dual cavity to diagnose aortic dissection and intra-abdominal hollow viscous perforation. (Luís et al.2021)

5.1. Acute Appendicitis

The role of CT imaging in establishing the diagnosis of acute appendicitis is well established. As a common surgical emergency, presenting with a triad of anorexia, right iliac fossa pain, and pyrexia, diagnostic uncertainty is well recognized. Even with the establishment of emergency general surgical clinics, definitive diagnosis can be difficult, and time is of the essence. A CT scan will pick up early appendicitis that has not perforated and is seen in up to 90–95% of patients. The scan can pick up alternative diagnoses and, in addition, may aid not only diagnosis but also guide treatment. In our recent prospective study of 80 adult patients, those with a negative early laparoscopy had an earlier CT, and so the mean time in hospital was significantly reduced. (Moris et al., 2021)

CT with intravenous contrast uses the increased vascularity of the inflamed appendix and the adjacent mesentery, and increased trans-peritoneal permeation of the inflammatory cells. A detailed CT interpretation of the appendicitis appearances is not the remit of this chapter. The specificity of CT is 90–98%, with a sensitivity of about 90%. Often there is positive clinical and CT correlation, obviating the need for a diagnostic delay, typically investigating other signs. However, it is reiterated that children should only have CT if it is necessary to help confirm a diagnosis of appendicitis after consultation with pediatric surgical specialists and taking into account the use and extent of ultrasound.



5.2. Gastrointestinal Bleeding

One of the common applications of CT imaging in emergency situations is diagnosing the cause of gastrointestinal bleeding. Considering that massive hemorrhage can lead to circulatory collapse and death, patients presenting with acute and significant bleeding need intervention. A CT angiography in these patients can accurately identify the source of the bleeding, allowing preemptive surgical treatment. To expand the utility of CT angiography in basal conditions, various techniques have been developed to enhance the contrast of the vasculature or detect underlying pathologies. For example, portal venous phase imaging has been traditionally used to enhance parenchymal evaluation and therefore has been preferred in detecting vascular pathology. A positive scan in these conditions will point to the cause of the bleed, but a negative scan will not rule out angio-detectable vascular pathology – an important consideration in designing imaging protocols for hypotensive patients.

CT imaging has influenced the treating physician's decision by detecting extraluminal bleed. From a technical point of view, the visualization of hemorrhage will be enhanced by performing images in the portal venous phase with a maximum possible delay. Intra-arterial and/or venous phases require injection of contrast media, but visualization could be incomplete and provide limited benefit. Another limitation of adding CT angiography or arterial phase is the increased radiation dose, as well as the risks of potentially nephrotoxic contrast media. Taken together, it is recommended to use a delayed venous or parenchymal phase to visualize bleeding. Current recommendations underline the importance of balancing the benefits of visualization by CT angiography with the radiation exposure in hypotensive patients. In aortic angiographies, this leads to a practice of performing only arterial-phase imaging covering the whole aorta. (Giannopoulos et al., 2022)(Bowman and Moonesinghe2021)

In conclusion, CT imaging in patients with gastrointestinal bleeding has great potential provided a protocol exists for those situations and any technical or logistical hurdles are sorted prospectively. Major advances in image reconstruction such as dual-energy CT and synthetic imaging could have the potential to revolutionize the management of patients with gastrointestinal bleeding as further clinical studies are awaited to validate these preliminary findings.

6. Radiation Dose Considerations in CT Imaging

The burgeoning use of computed tomography (CT) in emergency medicine to answer challenging diagnostic questions has stirred important concerns regarding radiation dose. It is well established that radiation exposure conveys particular risks to young and high-risk patient populations. Continuous optimization of CT protocols dealing with trauma and follow-up is critical in order to minimize radiation burden while obtaining the necessary diagnostic images. However, this must be done in a way that the diagnostic quality remains acceptable. A number of organizations and societies have issued consensus standards, guidelines, and recommendations to help physicians order and prescribe imaging procedures of the highest value to their patients with the goal of avoiding the potential risks of radiation.

In establishing such guidelines, it is important to strike a balance between the risk scenario involved with disease or injury and the risk of being exposed to radiation during the diagnostic procedure. In some cases, the risk of radiation could be higher than the risk of the condition itself. As an example, consider a patient with weak clinical signs of venous thromboembolism (VTE) who has been classified as moderately high risk by Well's score in the ER. In such a case, a CT pulmonary angiogram may not be justified due to the risk of contrast nephropathy and the radiation dose in relation to the risk of the disease itself. There are currently advances in the CT technological capacity which allow better low voltage scanning that delivers less radiation dose, as well as power injector methods for provisional imaging as opposed to complete imaging. Super-thin CT angiography acquired in good hemodynamic periods that avoid any breath-holding can provide a good anatomical analysis sometimes equivalent to a complete diagnostic. In the emergency setting, it is not necessarily enough for prescribers to have protocols for levels of ionizing radiation. Rather, good education in risk-benefit ratio in this setting is paramount given the sometimes rushed decision-making that is intrinsic to these situations. (Kunkler et al.2023)

7. Quality Assurance in CT Imaging

Quality assurance is a critical component of clinical CT imaging services for both inpatient and emergency exams. It is only by establishing explicit, objective protocols that care can be taken to ensure the diagnostic accuracy and the safety of the patient. The equipment must be maintained and regularly calibrated to optimize performance. Protocols must be established to ensure that the equipment remains in calibration during operation. Protocols must also be established to screen and monitor scanner performance on a routine basis. CT is a complex system, with numerous potential sources of error. To ensure consistent results, multiple quality control measures must be in place and evaluated on a routine basis.

Facilities that perform CT scans are advised to develop protocols and a system of routine quality control activities to ensure that these examinations are performed to an adequate standard of image quality and patient safety. Standards are available as guidance for the development of these quality control protocols. The basic document for the establishment of a radiological quality assurance program in all of medicine is a booklet that recommends that medical physicists be responsible for the development of protocols and procedures for equipment evaluation and quality control measures to ensure that images are of diagnostic quality and that all technologists and other support personnel are adequately trained to perform these quality control activities and are responsible for performing daily quality control and monitoring equipment performance. The radiologists who read the images must be responsible for communicating to the technical personnel any aspect of equipment performance that substantially affects the quality of the diagnostic studies. Programs for the training and continuing education of radiologists are available at annual meetings and through courses. The booklet also strongly suggests that the physicist assist in establishing written procedures for testing. Case studies have demonstrated that implementation of best practice guidelines in clinical settings can significantly reduce the occurrence of inappropriate exams and prevent diagnostic oversights.

State and federal programs exist to oversee quality imaging standards. The use of clinical practice guidelines, which are revised editions of previous parameters, has been established. More recently, quality measurement standards were instituted by various medical organizations for the care of emergency patients. Facilities can improve performance through adherence to guidelines, the development of institutional protocols that standardize emergency medicine practice patterns, and additional routine quality assurance measures. When performed correctly, quality assurance programs can significantly reduce the frequency of unnecessary imaging in emergency patients, prevent diagnostic mistakes, and improve patient outcomes. A robust quality assurance program can increase patient care by decreasing errors while providing cost containment and decreasing patient radiation dose exposures. (Karunarathna et al., 2024)

8. Integration of CT Imaging with Clinical Decision Making

Although initiated on the basis of the pre-test probability of a condition, emergency physicians use CT as a key step in the clinical decision-making process. For many clinical presentations, diagnosis is important primarily because it guides therapy. For example, in emergency stroke, diagnosis is important because delayed treatment adversely affects outcome. These two examples illustrate the latter problem with simple use of the HRCT result; that is, if diagnosis is only important for therapeutic implications, then we need to move from diagnosis to treatment as soon as the image is acquired. And therapy can’t start until the diagnosis is made - not until the report arrives; this highlights how important it is for a good relationship and clear working protocol between ED staff, ED radiologists, and specialists who should be aware of the new CT data.

There are many examples in ED practice where a positive CT finding directly leads to rapid initiation of specific treatment. There are, of course, countless other emergency medicine scenarios where CT findings guide the ED or general physician in continuing and/or further therapies to prevent deterioration, reduce the likelihood of relapse, or improve outcome. Communicating CT findings to other clinical staff within the ED is a clear issue, however, and researchers have reported poor concordance between radiologists' and non-radiologists' interpretations of images from various body parts in adults and children. ED predetermined CT criteria allow for the safe discharge of minor head injury patients, in turn preventing unnecessary ionizing radiation. In combination with a carefully taken history and good physical examination, some minor head injury patients require only a period of observation and not a CT. Physicians find new abnormalities on interpretive radiological work-up in less than one-quarter of those patients or children that the emergency physicians feel need an acute lab, body CT, or head CT. Each new abnormality on lab result or CT helped make the diagnosis or treatment in only 1% of further ED work-up. ED staff had borrowed a portion of the definitive diagnosis and treatment from the initial ED clinical presentation in adult head injury patients and in multiple body systems in children. A significant percentage of emergency trainees would discharge head-injured patients who satisfied the CT criteria after 4 hours of ED observation alone if they had no CT with a normal hospital CT and were fully informed prior to the CT of the very low sensitivity for non-surgical abnormalities. The average ED length of stay for emergency head-injured patients was 351 minutes, with the majority requiring assessment of early CT. In a portion of the cases, the initial assessment was the only objective abnormality that impacted clinical management. The patients with added inpatient investigations such as skull x-ray did not significantly differ from those in whom there was no significant change observed in the assessment plans. The aim of our review is to provide a practical action plan for best practice with or without work-to-rule. (Handelsman et al.2024)

9. Challenges and Limitations of CT Imaging in Emergency Medicine

A serious concern when thinking about protocol optimization and targeted imaging strategies is the fact that CT technology is not available everywhere. The equipment's availability does not remove all problems of still being able to make fast use of it. Even with optimal availability, delays come with multiple sources of potential diagnostic errors and are open to ethical criticism as they shift now available critical information into the future. Also, availability factors might pose concerns about medical practice culture and the potential overreliance on technology, resulting in reduced clinical examination competence.

Imaging offers neither diagnosis nor therapy but is an inevitable tool to obtain a presumable correct differential diagnosis with high speed and some potential adverse effects on both sides. Trade-offs to assure a shorter ED stay include avoided frequent control imaging, potential lower accuracy for minor injuries that would heal anyhow, and adverse events resulting from imaging examinations. Concerns have been raised about patient factors interacting with time pressure such as intense fear and anxiety or inability to remain motionless. Also, the high radiation exposure during CT scans poses an ethical risk, especially in younger patients. Not owning CT technology, an ethical dilemma evolves if it becomes common knowledge that ED CT is only available in some, but not all, EDs. This becomes most obvious when different standards of care are compared across countries and continents, indicative of overall differing investments in healthcare. It appears to be most critical when comparing culturally similar countries in terms of healthcare economy, such as central European countries. Especially at an IM level, at least in parts of the Western world, patients seem to expect a temporally high standard of medical care to be delivered, allowing for the direct undertaking of any imaging or interventions that might be feasible at first glance. Moreover, the necessity of workflow improvement, especially with respect to clinical people's communication between ED staff and radiologists, has been recognized for quite a while. (Malone, 2020)

10. Future Directions and Innovations in CT Imaging

There are future directions and innovations in CT imaging that may eventually revolutionize emergency medicine, along with the rest of medical care in the modern era. First, new technology is being developed, such as artificial intelligence and machine learning, to allow for maximized diagnostic potential through the integration of complex algorithms to help identify and categorize findings as a substitute for scan interpretation, as well as enable new possibilities in patient care. The speed and resolution of scan acquisition in CT systems continue to improve at relatively steady intervals, and so innovations may have recently focused on reconstructing images produced from CT scans. With continued improvements to both scanning speed and resolution, we can expect innovations to lean more towards the area of image processing, which can create new scanner-specific and patient-specific outcomes from data less affected by voluntary or involuntary motion. Similarly, developments will help bridge technical innovations between imaging modalities to produce higher value care. With continued advancements in each area, further integration of modalities such as nuclear medicine or magnetic resonance imaging may improve resolution and anatomical detail. As CT evolves, so too must patient treatment, and strategies in triage and support, including networking health care providers and emergency medical services, alternative care, social work, and mental/behavioral health care, must use this advanced diagnostic ability for the good of all patients. With the integration of each new technology and each new indication, ongoing education, re-education, and follow-up are necessary if early and preventative medicine is to keep pace with the benefits provided by the studies. Finally, as with all new and innovative uses of advanced technology, care must be taken to ensure long-term accessibility and community-based support, regardless of socioeconomic background in considerations of patients as a whole. Future innovations are likely to involve a shift toward diagnostic aid in the prehospital field, with improvements in speed and clusters of organ pathology. We could predict, for example, improved C-spine evaluation and extracranial vascular imaging in patients undergoing CT imaging. Additional research into CTA-head and CT perfusion could provide improved out-of-hospital and in-hospital stroke care. (Makrides et al.2023)

Finally, efforts and research projects that look at improving head trauma guidelines can be expected, particularly through innovation with regard to diagnosing undiagnosed or missed cases of injury while also showing new outcomes at both favorable proportions and external implications. As with other directions, all these technologies will need to be paired with options that allow for ease, patient cost, recovery time, and lack of sustained complications. There is no doubt that new and better emergency medical practices have been influenced by the advent of CT scanning and associated computer technology. Possibilities are numerous. No existing CT technology specific to emergency care has been found to have a false favorable result, but a theoretical reason for concern is finding multiple minor abnormalities that may not need treatment, causing risk of harm, using resources, and causing concern in patients. The effect of technological obsolescence is a potential disadvantage. It is likely that new technologies will need user updating and do so often. For example, if an institution uses proprietary applications, they might find themselves dependent on their developers, certain that the local pertinent to the vendor's development and the rate at which the active network is being conducted to implement the directing technologies can be comparable. (Hsieh & Flohr, 2021)

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