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EVIDENCE-BASED MEDICINE FOR THE ED

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AHC Media

The Roles and Risks of Whole-Body Computed Tomography Scans in the Trauma Patient

Emergency departments in the United States are frequently confronted with trauma patients with varying degrees of injury. Clinically significant injuries may be missed, with devastating consequences for the patient. Concern for not missing any potentially serious injuries has led to an aggressive diagnostic approach with a goal of not missing any injuries. The CT scan has facilitated this approach, providing substantial information guiding management. However, CT scans have risks, especially when the pan-scan approach is used. The authors review the uses, advantages, and disadvantages of the pan-scan.

— Ann M. Dietrich, MD, Editor

Background

Emergency departments (EDs) in the United States received approximately 35 million trauma-related visits in 2007.[1] According to the Centers for Disease Control (CDC), unintentional injury accounted for 123,706 deaths in the same year, making it the fourth leading cause of death overall and the primary cause of death among people between 1 and 44 years of age.[2]

The trauma population constitutes a remarkably high-risk cohort for emergency care providers and trauma surgeons. The principles of Advanced Trauma Life Support (ATLS) aim to provide a simple and effective standardized approach for the assessment and care of injured patients. Between the patient with minor isolated trauma and the unstable patient with multi-trauma requiring immediate surgical intervention lies a complex group of various injury patterns that represents a significant gray area for any trauma care provider. Patients who are stable after initial clinical evaluation still might have serious injuries that require an expedient evaluation performed in an organized manner to avoid the significant morbidity and mortality associated with delays in localization and intervention.[3,4] Approximately 15% to 22.3% of trauma patients in whom injuries are missed have injuries that are clinically significant.[5] This prevalence of missed serious injury has led to an aggressive diagnostic approach with an emphasis on high sensitivity and early identification of all injuries. Initially, this aggressiveness was illustrated by the use of diagnostic peritoneal lavage (DPL), an invasive but highly sensitive diagnostic screening tool that decreased the number of missed intra-abdominal injuries. With the advent of computed tomography (CT), emergency care providers and trauma surgeons have increasingly relied upon this technology as an integral part of trauma evaluation and resuscitation.[6] The "traditional" imaging strategy includes plain radiographs of the chest, pelvis, and lateral cervical spine (C-spine), in accordance with ATLS guidelines; a Focused Assessment with Sonography for Trauma (FAST) exam; and selected CT scans as deemed necessary based on the physical examination, radiographs, or ultrasound assessment.[7]

The first generations of CT scanners suffered from a significant lack of

Executive Summary

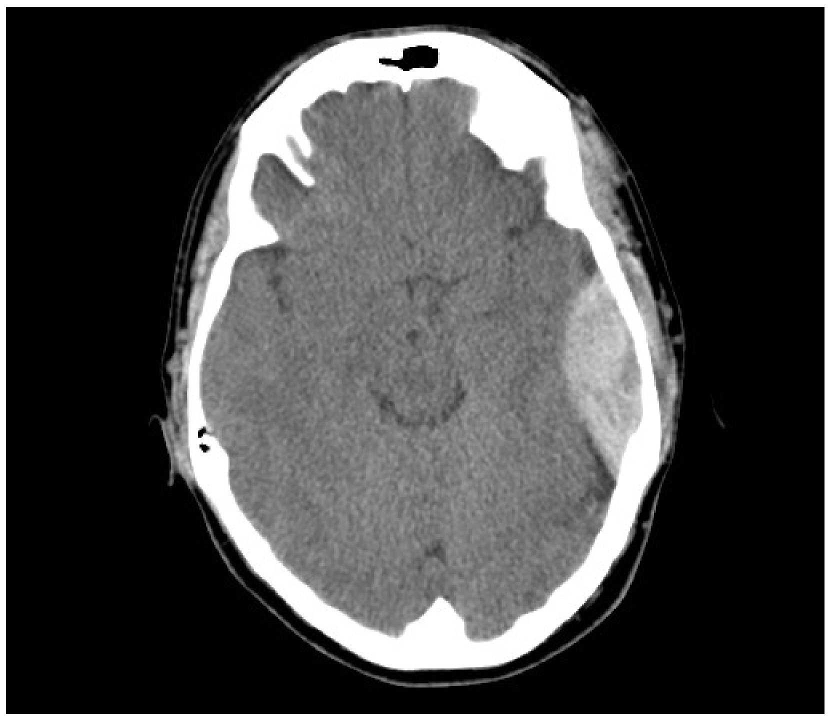
- Approximately 15% to 22.3% of trauma patients in whom injuries are missed have injuries that are clinically significant. This prevalence of missed serious injury has led to an aggressive diagnostic approach with an emphasis on high sensitivity and early identification of all injuries.
- Multiple studies have validated the hypothesis that CT is superior in accuracy and reliability compared with physical examination, laboratory screening, plain radiographs, and sonography alone in the evaluation of most serious traumatic injuries.
- A typical pan-scan involves a non-contrast CT scan of the head and contrast-enhanced scans of the neck, chest, abdomen, and pelvis.
- Recent studies have shown the single-pass pan-scan to be a viable, if not superior, alternative to conventional segmental whole-body protocols. The single-pass technique has been found to be accurate and timesaving, reducing acquisition time by as much as 42.5% and decreasing radiation dose.

sensitivity and specificity and were limited by the amount of time required for the scan (separating the patient from the monitoring of the trauma resuscitation bay). The introduction of multi-slice CT scanners has both improved diagnostic accuracy and reduced the time of scanning significantly.[8] Multiple studies have validated the hypothesis that CT is superior in accuracy and reliability compared with physical examination, laboratory screening, plain radiographs, and sonography alone in the evaluation of most serious traumatic injuries.[9-16]

The number of CTs performed in EDs for injury-related conditions nearly doubled between 1998 and 2007.[6] CT now has a well-established role in the secondary evaluation of trauma, and the concept of a whole-body CT scan, or "pan-scan," has become more accepted as an adjunct for definitive assessment of injuries during the early stages of trauma management.[6,17,18] A typical pan-scan involves a non-contrast CT scan of the head (*see Figure 1*) and contrast-enhanced scans of the neck, chest, abdomen, and pelvis. Some protocols also include dedicated reconstructed views of the rest of the spine or other osseous structures. (*See Figure 2.*) Modern multi-detector CT scanners have the ability to produce specialized studies such as fine cuts through the facial, orbital, and temporal bones, as well as CT angiography of the body and extremities (these are not included in most "standard" pan-scans).[19] Naturally, since departmental policies and CT manufacturers differ, institutions tend to have slightly different whole-body CT protocols. Strategies for reducing scan time, improving image quality, and decreasing radiation exposure are being investigated.[17,19,20]

Recent studies have shown the single-pass pan-scan to be a viable, if not superior, alternative to conventional segmental whole-body protocols. A single-pass CT scan captures the neck and body portions in a single scan, usually with multi-phased contrast injection. Conventional pan-scans usually incorporate pauses and multiple overlapping scans to

Figure 1. Epidural Hematoma

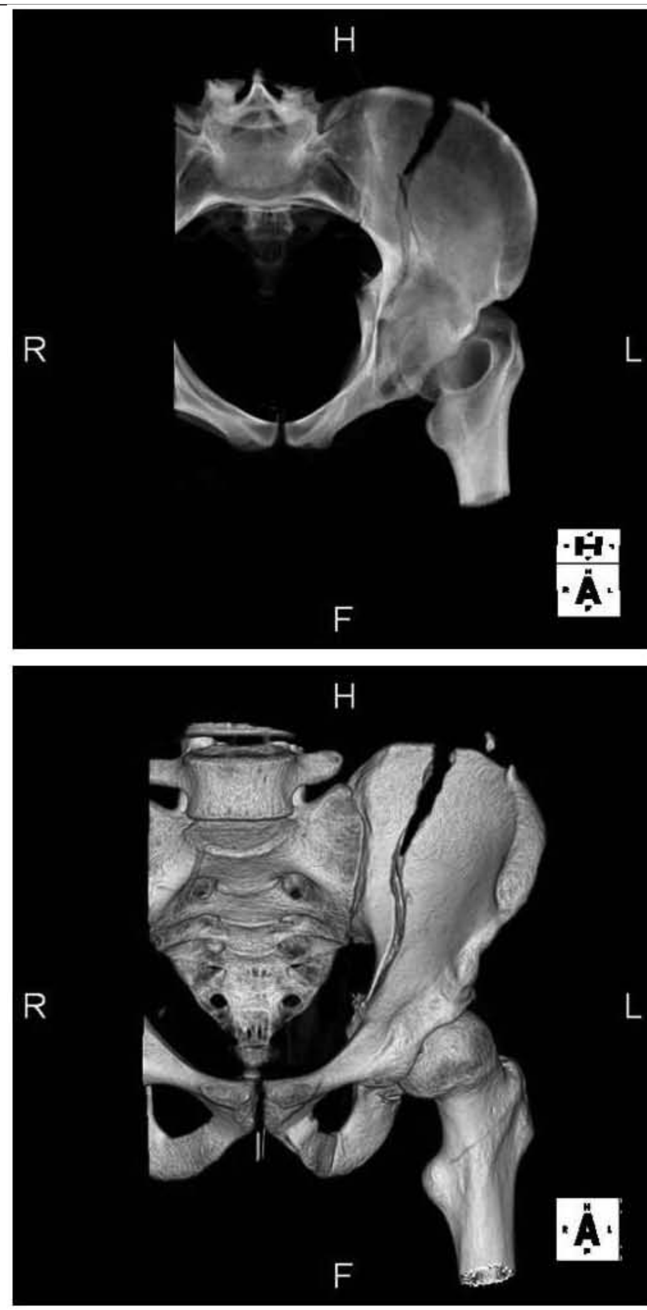


CT of a 26-year-old male on warfarin for a mechanical heart valve replacement. He fell from a ladder, sustaining an epidural hematoma. Image courtesy of University of Maryland School of Medicine Department of Emergency Medicine.

achieve separate portal and arterial phases. The single-pass technique has been found to be accurate and time-saving,[17,21] reducing acquisition time by as much as 42.5%[19] and decreasing radiation dose.[22]

The immediate benefits of CT are easy to recognize: A significant amount of clinical information can be gained in a short period of time in a noninvasive manner, which aids in triaging, surgical planning, and disposition. Multiple studies have suggested that the sensitivity of CT has progressed to the point that a negative study can effectively eliminate the possibility of significant traumatic injuries, allowing patients who otherwise might have required observation for hours or days to be discharged home earlier.[8,17,23-26] Few experts dispute the necessity of pan-scanning patients with significant physical evidence of multi-trauma (*see Figure 3*), those with massive blunt or penetrating injuries, and those in whom the physical examination is unreliable because of altered mental status, depressed level of consciousness, or significant distracting injuries.[27-29] However, an ongoing debate focuses on the utility of the pan-scan as a standard part of the evaluation of patients with moderate trauma and of those without clinically evident injuries who have normal laboratory values and plain radiographs.[30,31] The concerns are not without merit, as the pan-scan protocol poses several risks for the patient: radiation exposure, allergic reaction to contrast, contrast-induced nephropathy, and contrast extravasation.

Figure 2. Iliac Wing Fracture



Two versions of 3D reconstructions of an iliac wing fracture in a 24-year-old male who was injured in a high-speed motor vehicle crash. Images courtesy of University of Maryland School of Medicine Department of Emergency Medicine.

Potential Benefits of Pan-Scan

Diagnostic Yield. As discussed above, the initial management of trauma patients involves an aggressive attempt to identify all injuries early. The use of whole-body CT for this purpose has been supported by studies that suggest that a pan-scan identifies more injuries and leads to a change in management more often than following selective CT protocols.[18,32] In the study by Salim and colleagues,[18] 18.9% of patients had a change in management as a result of a finding on whole-body CT, including earlier discharge and procedural or surgical intervention. The study's data analysis focused on the abdominal portion of the pan-scan and found that 20.3% of patients who had a normal abdominal examination had a change in management after abdominal CT. Six of these patients required laparotomy. These

Figure 3. Pan-scan of Serious Injuries

In this 64–year-old woman who was involved in a high-speed motor vehicle crash, pan-scan identified a number of serious injuries, including spinal fracture/dislocation, grade 3 splenic laceration, and grade 5 liver injury. Image courtesy of University of Maryland School of Medicine Department of Emergency Medicine.

results suggest that CT can identify injuries in patients with normal results on the physical examination. In another study, 18 emergency physicians' clinical judgment showed relatively high sensitivity (69.9% to 100%) in excluding injuries without a pan-scan if a patient's pretest probability of injury was "very low."[33] The sensitivity of excluding injuries in specific body regions steadily decreased with higher pretest probabilities of injury, supporting the idea that the accuracy of clinician judgment worsens in the assessment of severely injured patients.

Multiple studies have failed to develop a clinical decision rule that could completely exclude all types of intra-abdominal injuries after blunt trauma without performing CT.[15,25,34] In two of these studies, the presence of abdominal pain or tenderness achieved 100% sensitivity in detecting intra-abdominal injuries requiring surgical intervention,[25,30,34] even though it missed non-surgical injuries. Because the primary outcome of these studies was identifying all injuries, the clinical decision rules were viewed as failures. This illustrates two viewpoints as to what is the most important endpoint when evaluating the use of CT in trauma. Should the endpoint be finding any injury, or should it be finding only injuries that require surgical or medical intervention? Do clinicians really need to know about an injury that does not require treatment?

Gupta and colleagues presented a study that further illustrates this debate.[35] They polled emergency physicians and trauma surgeons about which components of the pan-scan obtained for individual trauma patients they thought were necessary. All scans were ordered at the discretion of the trauma surgeon. The ED physicians would have ordered 35% fewer scans, but in doing so would have missed 10% of injuries. However, only 0.3% of these injuries would have led to a predefined critical action. This suggests that although CT is superior in identifying objective injuries that the physical examination and clinical suspicion might miss, very few of these injuries prove to be emergently dangerous. Of note, the authors had difficulty agreeing on the true importance of the abnormal findings. The emergency medicine authors thought the projected miss rate of 0.3% (the number of missed injuries that would have required predefined critical actions) supported a more selective use of CT based on physician judgment. The trauma surgeon authors pointed to the projected missed injury rate of 10% (the number of all missed injuries, regardless of requiring a critical action or not) as justification for more liberal use of CT.

Survival/Mortality. Although most of these studies have used injuries identified on CT or change in management based on CT as the primary outcome, some studies have indicated a possible decrease in the mortality rate with a liberal CT approach. Hutter et al[36] studied the effect on survival before and after the institution of a liberal pan-scan policy at a major high-volume trauma center in Germany. The study included patients who did not undergo a pan-scan due to the unavailability of the method, patients who were eligible but were not pan-scanned due to physician discretion, and eligible patients who underwent a pan-scan. Patients who actually underwent a pan-scan had a statistically significant reduction in overall mortality, with an odds ratio (OR) of 0.17 (95% CI, 0.1–0.28) and a total risk difference of 7%. The relative impact of a patient receiving a pan-scan on the mortality rate was small compared with the effect of Injury Severity Score (ISS) or neurologic function.

Huber-Wagner and associates[37] suggested that the use of whole-body CT in the management of trauma patients increased the probability of survival compared with the predicted mortality rate based on the Trauma Injury Severity Score (TRISS) and Revised Injury Severity Classification (RISC) scores. This study has been criticized because more patients in the whole-body CT group were treated at trauma centers, and it was acknowledged that the predicted mortality rate for the whole-body CT group was likely increased due to clinically insignificant findings that would in turn elevate the ISS.[38] Van Vugt et al[39] demonstrated that clinically insignificant findings found on CT do indeed elevate the ISS, artificially inflating mortality rate estimates beyond the true mortality rate, potentially altering the statistical importance of the pan-scan on survival. As overall survival in trauma generally continues to trend upward,[37] it is important to keep in mind that these observed effects are likely caused by complex systemic changes and that assigning a causal relationship to any one intervention is probably not appropriate.

Table 1. Average Adult Effective Doses of Various Radiologic Studies

Radiograph	Average Effective Dose (mSv)
Single chest	0.02
Cervical spine	0.1
Thoracic spine	1.0
Lumbar spine	1.5
Pelvis	0.6
CT	**Average Effective Dose (mSv)**
Head	2
Neck	3
Chest	7
Abdomen	8
Pelvis	6
Spine	6

Adapted from Mettler FA Jr, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: A catalog. *Radiology* 2008;248:254-263.

Potential Pitfalls of Pan-Scan

Because the rates of CT use in EDs have skyrocketed in recent years, more attention is being directed toward the weaknesses of this diagnostic modality.[6]

Contrast-Induced Nephropathy (CIN). Published reports contain significant variability regarding the effect of intravenous (IV) contrast for CT on renal function. The incidence of CIN, most commonly defined as an increase in creatinine of 0.5 mg/dL or 25% from the baseline creatinine level, has been estimated to be anywhere from 0% to 12%, depending on the study and the underlying risk factors of the patients.[40-46] Importantly, it remains unclear whether IV contrast is the actual cause of the rise in creatinine. One literature review noted that in two studies in which control groups of patients did not receive IV contrast, no association was found between IV contrast and a rise in the serum creatinine level.[47-49]

Research into the true risks of IV contrast is ongoing. Mitchell and Kline found an incidence of CIN of 11% in a population of 633 general ED patients who underwent contrast-enhanced CT.[44] Of the 70 patients in whom CIN developed, renal failure developed in 7 (1% of the overall population), defined as an increase in serum creatinine of 3 mg/dL or more. Six of those seven patients died, and in four cases it was believed that renal failure significantly contributed to death.

Unfortunately, there is not a large body of literature investigating renal failure after contrast CT in the trauma patient. However, Matsushima and colleagues[50] did find an ISS of 16 or greater to be a risk factor for contrast-induced acute kidney injury, although the dose of contrast received was not associated with an increased risk, suggesting the possibility of an association rather than causality.

Overall, although there is still controversy about CIN and the exact risks associated with acute renal failure, especially in regard to the trauma population, the consensus seems to be that there is a small but very real risk of CIN following CT with IV contrast, a point all providers should consider when ordering CT scans.

Cancer Risk. CT is responsible for more than 70% of medical radiation exposure; 16.2 million scans were ordered for ED patients in 2007.[51,52] Brenner and Hall estimated that 1.5% to 2.0% of all cancers in the United States might be attributable to ionizing radiation from CT, including many types of scans other than those done during trauma assessments. The probable death rate is much lower, at about 0.1 to 0.35%.[38,53,54] These and other estimates are not universally accepted because they are based on a linear no-threshold relationship that assumes the incidence of cancer induction is proportional to

Table 2. Intermediate Level Trauma Patients (per MIEMSS protocols)*

Category B
- Glasgow Coma Scale (GCS) score 9-14
- Paralysis or vascular compromise of limb
- Amputation proximal to wrist or ankle
- Crushed, degloved, or mangled extremity
- Penetrating injuries to extremities proximal to elbow or knee
- Combination trauma with burns

Category C
- Age < 5 years or > 55 years
- Patient with bleeding disorder or patient on anticoagulants
- Dialysis patient
- Pregnancy > 20 weeks
- EMS provider judgment
- High-risk auto crash
  - Intrusion > 12 in. occupant site; > 18 in. any site
  - Ejection (partial or complete) from vehicle
  - Death in same passenger compartment
  - Vehicle telemetry data consistent with high risk of injury
- Exposure to blast or explosion
- Falls greater than 3 times patient's height

Intermediate trauma classifications based on the trauma decision tree protocols promulgated by the Maryland Institute for Emergency Medical Services Systems. Please refer to local trauma classifications and regulations for management in other jurisdictions. Adapted from The Maryland Medical Protocols for EMS Providers. Baltimore, Maryland: MIEMSS, 2011.

exposure, which some argue is not congruent with biological and animal data.[55] Most models are based on data extrapolated from atomic bomb survivors, but there has been debate about the level of radiation that leads to an increased cancer risk. A full explanation of this debate is beyond the scope of this article, but some have concluded that there is no significant carcinogenic risk with a dose up to 150 to 200 millisieverts (mSv) to normal tissues,[55,56] while others estimate that the safe dose is less than 100 mSv.[53] The sievert (Sv) is a measure of the effective dose of radiation on biological tissues based on the stochastic effect of ionizing radiation. The average underlying exposure from everyday background radiation is about 3 mSv per year.[54] Most patients receive an effective dose of about 20 to 50 mSv from a single pan-scan,[54,57] depending on the scanner power and scan technique. Table 1 includes a list of the average effective doses from individual radiologic studies.[58]

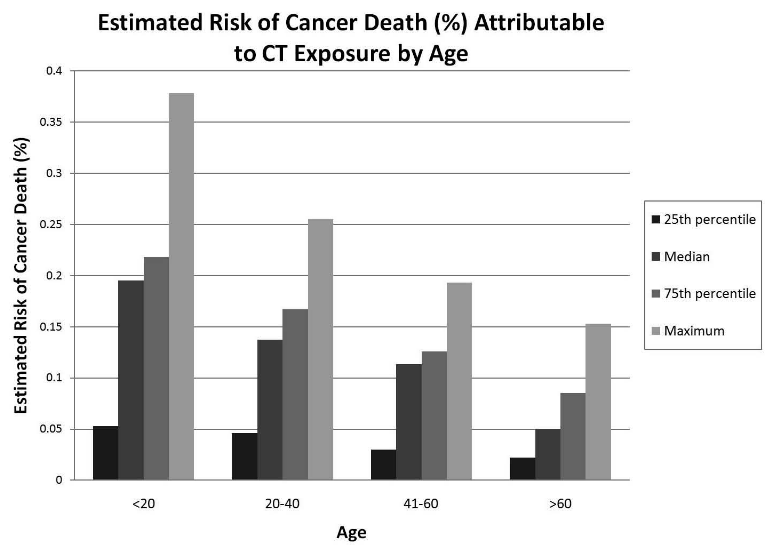
The risk of death from severe trauma has been estimated to be 50 to 100 times higher than the risk of a cancer death from CT-related radiation exposure.[59,60] In the trauma population, use of whole-body CT is usually not questioned because of the significant risk-benefit ratio. The population of particular interest and debate, however, has intermediate-level trauma, such as category B or C patients (*see Table 2*) or priority II patients; in other words, those who have potentially life-threatening, but not immediately life-endangering injuries. In this subset of patients, which has not been well-studied, trauma-related mortality is still a real concern, estimated between 0.6% and 2%,[38,57] but there is a larger proportion without serious injuries. In a recent study of 642 adult intermediate-level trauma patients, Laack and colleagues estimated that the risk of trauma-related mortality was six times greater than the cancer risk.[38] Trauma-related mortality was highest in older patients, and the risk of cancer death was inversely proportional to age; therefore, the youngest patients have the most potential danger from radiation — patients younger than 20 years have four times the estimated risk of those older than 60 years. (*See Figure 4.*) It is notable that no one younger than 80 died in Laack's study, and all deaths were caused by head injuries. The mortality rate and median ISS were relatively low compared with the findings in a smaller study by Winslow and associates, who examined the amount of radiation to which intermediate trauma patients were exposed.[57]

Pediatrics. Because children are more susceptible to the carcinogenic effects of ionizing radiation, efforts to reduce unnecessary radiation exposure are paramount. CT remains the diagnostic test of choice for evaluation of blunt trauma in children, but the risk of inducible cancer is much higher than in adults. Mueller et al[61] showed that the effective radiation dose during CT is on par with adults, but doses to organs such as the thyroid gland fell within the range of radiation doses historically correlated with increased cancer risk. Based on a model by Berrington de Gonzalez and associates, the mean lifetime cancer risk after whole-body CT in 3-year-old boys and girls is 1 in 133 and 1 in 166, respectively.[62] At 15 years of age, the risks were estimated at 1 in 250 for girls and 1 in 500 for boys.

Although the FAST exam is well-established in adult trauma, its utility as a screening exam in pediatric trauma is not universally supported.[7,26,63] CT has been shown to be sensitive for identification of injuries in children, similar to adults. An important consideration for pediatric trauma, however, is that solid organ injuries in children are being treated increasingly non-operatively,[64,65] so discovery of these injuries in hemodynamically stable children does not automatically lead to surgical intervention.[66] On the other hand, a review of three prospective studies looking at intra-abdominal injury determined that the negative predictive value (NPV) of abdominal CT was 99.8%, suggesting that routine admission and serial exams after a normal abdominal CT and a normal physical exam may not be necessary.[68]

Clinical decision rules for obtaining a CT scan have been successful for pediatric head injury[68,69] and C-spine injury,[70] and are being investigated for abdominal trauma.[66] Unfortunately, just as with adults, there is no clinical decision rule for using pan-scan in the pediatric trauma population. Use of a pan-scan is not routinely recommended in stable children without abnormal physical exam findings or a mechanism that induces concern for significant injury. Selective scanning of body areas, rather than whole-body scanning, results in a statistically significant decrease in all organ doses and total effective dose.[61]

Figure 4. Risk of Death and CT Exposure



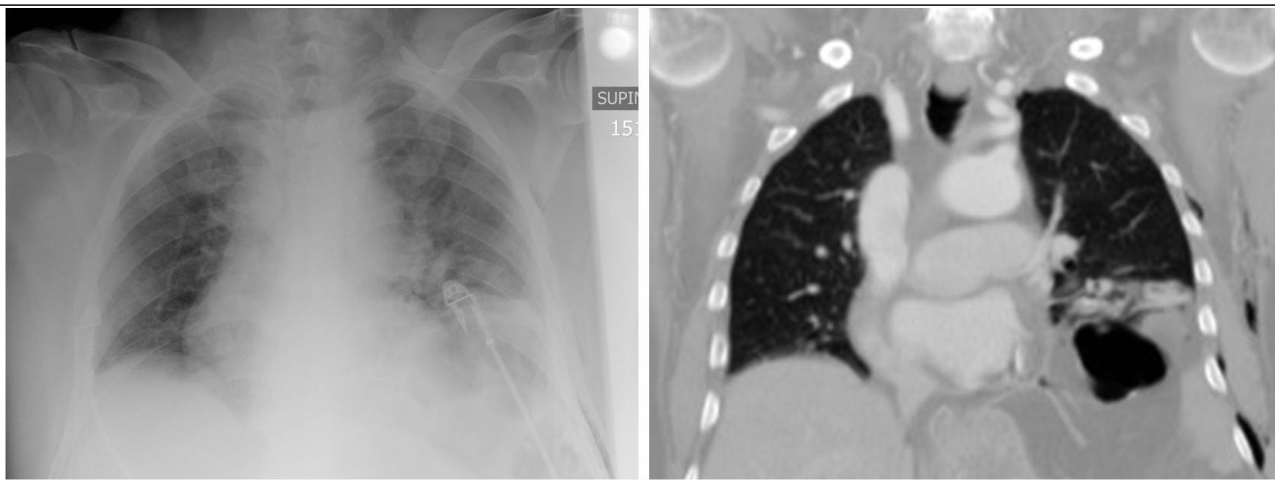
Estimated risk of death attributable to CT exposure by age. Adapted from: Laack TA, Thompson KM, Kofler JM, et al. Comparison of trauma mortality and estimated cancer mortality from computed tomography during initial evaluation of intermediate-risk trauma patients. *J Trauma* 2011;70:1362-1365.

Other Considerations

An Imperfect Test. While CT has been shown to have generally superior ability to identify injuries, it is not a perfect test. Alone, CT has demonstrated insufficient sensitivity to rule out diaphragm injury, although its positive predictive value appears to be very good.[71] (*See Figure 5.*) Similar concern has been expressed for other radiographically occult injuries such as diffuse axonal injury, hollow viscus injuries, and mesenteric injuries, but Tan showed that patients with surgically confirmed hollow viscus and mesenteric injuries were very likely to have had an abnormal CT scan.[72] Positive trauma scans are conclusive, but negative results require subsequent confirmation.[17] Injuries initially missed on CT are uncommon; while these falsely negative scans can sometimes delay management, they have not yet been shown to affect the mortality rate.[73] In that vein, second readings are advocated to avoid missed injuries not seen on the initial preliminary "hot read,"[74] at least in patients with intermediate to high pretest probability for injury.

Imaging Prior to Transfer. Emergency medicine practitioners who do not work at designated trauma centers will certainly be responsible for the occasional trauma patient, and if the patient meets criteria for transfer to a trauma center, the question of whether to obtain imaging prior to transfer may arise. From a practical standpoint, the role of the practitioner is to stabilize the patient to the best of his or her abilities and to facilitate transport to the receiving facility for definitive management as soon as possible. As noted previously, CT is sensitive for diagnosing life-threatening injuries and can be used as a tool for determining disposition after trauma.[18] In a stable trauma patient with clinically suspected injuries based on mechanism or examination, CT might elucidate the need for further specialized management or it can obviate the need for admission or transfer. If a patient meets criteria for transfer prior to imaging, it is important to communicate with the receiving facility regarding the expectation of, or necessity for, imaging at the referring center. However, if a patient clinically requires transfer to a trauma center, sophisticated diagnostic studies may help with eventual management but should not delay transfer. Between 53% and 58% of transferred patients receive repeat imaging upon arrival at the receiving trauma center.[35,75] The reasons for repeating studies are varied, including change of clinical status during transfer, inadequate original technique, software incompatibility, and even simple human error such as misplacing or forgetting to send the original scans. It is notable that patients who received repeat imaging tended to be more severely injured

Figure 5. Pan-scan Showing Rib Fractures, Left Hemidiaphragm Injury, and Large Flank Hematoma



Following a motor vehicle crash, a clinically stable 84-year-old man complained of mild left flank pain. His wife died as a result of the crash. Pan-scan revealed a number of rib fractures, a left hemidiaphragm injury, and large flank hematoma, which were not evident on plain radiograph and FAST examination. Images courtesy of University of Maryland School of Medicine Department of Emergency Medicine.

but also suffered longer delays[75] as well as additional radiation and financial charges. Lastly, incidental findings are found in up to one-third of trauma patients,[39] and trauma patients are notoriously often lost to follow-up,[76] which begs the question of who will arrange follow-up on these patients if incidental abnormalities are found during a formal over read after transfer.

Recommendations

Unfortunately, there is no universally accepted algorithm regarding routine whole-body CT compared with selective CT. A hospital could benefit from the development of a standardized CT protocol. Standardizing the radiologic workup of trauma patients needs to balance the risks of complications, cost, and incidental findings from CT versus the risk of missed injuries, repeat imaging, and delay in disposition or treatment.

Pan-scan is a noninvasive and effective method of injury determination in the hemodynamically stable trauma population, but it must be used with an awareness of its associated problems. Indiscriminate use without proper clinical evaluation or concern is inappropriate. Efforts to reduce radiation exposure should be focused toward younger patients and those with obviously minor injuries or trauma mechanisms. Pan-scanning may reduce but does not eliminate the incidence of missed injuries and is not a substitute for a thorough clinical evaluation, appropriate repeat examinations, and follow-up. Single-pass pan-scans reduce scan time and radiation compared with conventional sequential imaging. Comprehensive secondary reading of a scan after a preliminary read may lower the rate of missed injuries.

Further research is needed. Currently in progress is the REACT-2 trial, a prospective, multicenter, multi-national study investigating the effects of immediate pan-scan CT during the primary survey on clinical outcomes compared with the use of conventional imaging and selective CT. The intervention group undergoes immediate whole-body CT, completely eliminating plain radiographs and the FAST exam. This is a novel approach and is focusing on the primary outcome of in-hospital mortality as well as secondary endpoints such as effects on morbidity, radiation exposure, and cost-effectiveness. It is hoped that this study, and those to follow, will delineate an appropriately balanced diagnostic approach for trauma patients.

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CME/CNE Questions

1. Of the following, what is the most appropriate choice for a 48-year-old pedestrian who was struck by a motor vehicle with a moderate impact, is hemodynamically stable, and has no major physical exam findings except chest wall tenderness and a Glasgow Coma Scale (GCS) score of 13?
   A. separate head and chest CT scans
   B. head CT scan and chest radiograph only
   C. single-pass pan-scan
   D. no imaging; observation only

2. Which of these patients would most benefit from a pan-scan?
   A. any blunt trauma patient, regardless of mechanism
   B. a hemodynamically stable patient injured in a motor vehicle crash, with no obvious physical findings, whose passenger died on scene
   C. a hemodynamically stable 8-year-old boy with no physical findings after falling from a 5-foot ladder
   D. a hemodynamically stable pedestrian struck at 10 mph with right knee and hip pain

3. Which of the following statements regarding contrast-induced nephropathy (CIN) in patients undergoing enhanced CT after trauma is correct?
   A. The incidence may be as high as 12%, although this may be an associative rather than causative effect.
   B. CIN is defined as an increase of 25% or 0.5 mg/dL in creatinine from baseline.
   C. An Injury Severity Score of 16 or higher may be a risk factor for CIN.
   D. The higher the dose of contrast administered, the higher the risk of CIN.
   E. All of the above
   F. Only A, B, and C are correct.

4. You are a physician at a community hospital and have just placed a chest tube to stabilize a woman who was injured in a motor vehicle collision. She arrived with a pneumothorax caused by multiple rib fractures. The FAST exam is positive, and you have to transfer her to the nearest trauma center for surgery. What is the most appropriate approach to imaging?
   A. The patient is stable, so send her to CT for pan-scan.
   B. The patient is stable, but imaging should not delay definitive management; transfer her immediately.
   C. Scan the chest and abdomen, then transfer with accompanying images.
   D. Send the patient to CT, because the receiving facility will probably want a scan.

5. Regarding pediatric blunt trauma patients, which of the following is true?
   A. Children can be unreliable during history and physical, so they should be pan-scanned.
   B. The FAST exam is a reliable way to rule out surgical abdominal injuries in stable children without abdominal pain.
   C. Children receive the same effective radiation doses from CT as adults, but these doses carry a higher risk of secondary cancer.
   D. Pan-scan is a good way to rule out surgical injuries for all pediatric trauma patients.

6. Which of the following statements about lifetime cancer risk associated with pan-scan is true?
   A. The risk of trauma-related mortality is approximately six times that

of CT-related cancer mortality in all-comer intermediate-level trauma patients.
B. Age is a factor in CT-related cancer risk, and the risk is proportional to age.
C. The mean lifetime cancer risk after whole body CT in 3-year-old boys is 1 in 133 (0.75%) and 1 in 166 (0.60%) in girls.
D. The background radiation received on a yearly basis in an urban environment is almost as much as a single pan-scan.
E. B and D are correct.
F. A and C are correct.

7. Incidental findings are detected in approximately what percentage of trauma patients undergoing CT?
A. 1%
B. 10%
C. 33%
D. 50%

8. In a recent poll of emergency physicians and trauma surgeons about the components of the pan-scan obtained for individual trauma patients the physicians thought were necessary, which of the following is true?
A. The ED physicians and trauma surgeons always agreed on which scans were necessary.
B. ED physicians desired 35% fewer scans, and < 1% of these undesired scans would have led to a predefined "critical action."
C. The trauma surgeons desired fewer scans than the ED physicians.
D. All scans were ordered at the discretion of the ED physician.

9. Which of the following statements regarding clinician ability to rule out injury based on physical exam is true?
A. The sensitivity of ruling out injuries in specific body regions steadily decreases with higher pretest probabilities of injury.
B. Multiple studies have shown that physical exam is superior to CT scan for ruling out injuries.
C. All patients with abdominal injuries found on CT will have abdominal tenderness.
D. Ruling out injury based on physical exam findings is reliable in patients with altered mental status.

10. Which of the follow statements about the use of CT is true?
A. The use of CT in EDs declined between 1998 and 2007.
B. A typical "pan-scan" is a non-contrast CT of the head, followed by contrast-enhanced scans of the neck, chest, abdomen, and pelvis.
C. A typical "pan-scan" is a non-contrast CT of the head, followed by contrast-enhanced scans of the neck, chest, abdomen, and pelvis and CT angiography of the extremities.
D. CT accounts for approximately 70% of radiation exposure in medical populations.
E. B and D are true.

CNE/CME Objectives

Upon completing this program, the participants will be able to:
- discuss conditions that should increase suspicion for traumatic injuries;
- describe the various modalities used to identify different traumatic conditions;
- cite methods of quickly stabilizing and managing patients; and
- identify possible complications that may occur with traumatic injuries.

CNE/CME Instructions

HERE ARE THE STEPS YOU NEED TO TAKE TO EARN CREDIT FOR THIS ACTIVITY:

1. Read and study the activity, using the provided references for further research.
2. Log on to **www.cmecity.com** to take a post-test; tests can be taken after each issue or collectively at the end of the semester. *First-time users will have to register on the site using the 8-digit subscriber number printed on their mailing label, invoice, or renewal notice.*
3. Pass the online tests with a score of 100%; you will be allowed to answer the questions as many times as needed to achieve a score of 100%.
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