Selective Use of Computed Tomography Compared With Routine Whole Body Imaging in Patients With Blunt Trauma

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Study objective: Routine pan–computed tomography (CT, including of the head, neck, chest, abdomen/pelvis) has been advocated for evaluation of patients with blunt trauma based on the belief that early detection of clinically occult injuries will improve outcomes. We sought to determine whether selective imaging could decrease scan use without missing clinically important injuries.

Methods: This was a prospective observational study of 701 patients with blunt trauma at an academic trauma center. Before scanning, the most senior emergency physician and trauma surgeon independently indicated which components of pan-CT were necessary. We calculated the proportion of scans deemed unnecessary that: (a) were abnormal and resulted in a pre-defined critical action or (b) were abnormal.

Results: Pan-CT was performed in 600 of the patients; the remaining 101 underwent limited scanning. One or both physicians indicated a willingness to omit 35% of the individual scans. An abnormality was present in 18% of scans, including 22% of desired scans and 10% of undesired scans. Among the 95 patients who had one of the 102 undesired scans with abnormal results, 3 underwent a predefined critical action. There is disagreement among the authors about the clinical significance of the abnormalities found on the 99 undesired scans that did not lead to a critical action.

Conclusion: Selective scanning could reduce the number of scans, missing some injuries but few critical ones. The clinical importance of injuries missed on undesired scans was subject to individual interpretation, which varied substantially among authors. This difference of opinion serves as a microcosm of the larger debate on appropriate use of expensive medical technologies. [Ann Emerg Med. 2011;58:407-416.]

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INTRODUCTION

Modern trauma care emphasizes the early detection and treatment of injury.[1-8] As computed tomography (CT) technology has evolved, there has been increased use of CT scans in the early evaluation of trauma patients. At our institution, trauma patients frequently receive a "pan scan," a specially designed sequence to scan the head, neck, chest, abdomen, and pelvis to rapidly identify or exclude injuries in patients with signs and symptoms or a concerning mechanism of injury. Proponents of this strategy maintain that pan-CT facilitates the immediate identification and management of almost all injuries so that delayed detection of injuries, with potential for poorer outcome and increased costs, can be avoided and a comprehensive care plan can be instituted from the outset. They also believe that pan-CT permits the safe early discharge of patients whose scan results are negative and who have no other reason for admission.[9-12]

Conversely, liberal use of CT is not without potential consequences. From 1998 to 2007, use of CT or MRI during injury-related emergency department (ED) visits increased approximately 3-fold, without a concomitant increase in the diagnosis of injury-related, life-threatening conditions or admission rates associated with these visits.[13] The foremost concern is that radiation exposure will produce 12.5 additional deaths per 10,000 scans.[14-16] Furthermore, pan-CT is expensive both directly, with a charge of $17,162 for a pan scan and its interpretation at our institution, and indirectly because occult injuries found on CT may increase the intensity of diagnostic and therapeutic activities without improving patient outcomes.[17,18] Finally, the risk of contrast-induced renal failure is estimated to be about 1%.[19]

Editor's Capsule Summary

What is already known on this topic

Pan– computed tomography (CT) scanning exposes many trauma patients to significant radiation but may aid early detection of significant injuries.

What question this study addressed

Authors determined whether CT scans that were not desired by surgeons or emergency physicians displayed clinically important injuries.

What this study adds to our knowledge

Emergency physicians would have reduced CT scans by one third, but 10% of undesired scans contained abnormalities, and 3 required a critical action. Surgeons and emergency physicians disagreed about the clinical importance of many injuries.

How this is relevant to clinical practice

Routine pan-CT scanning detects many injuries, even when thought unnecessary. Debate over finding balance between cost, radiation exposure, and important injuries continues.

Although there is little debate about the merits of CT in severely injured patients with blunt trauma, it is not yet known whether a liberal pan-CT strategy is beneficial for all patients meeting trauma activation criteria. We designed a prospective study to determine whether we could identify components of the pan-CT that could be omitted for select patients without missing clinically important injuries. We expected that the subset of patients in question would be those with a concerning mechanism but without overt signs of major cranio-cervical-truncal trauma. An interim published analysis of the first 6 months' worth of data on the subset of 284 patients who received a pan-CT demonstrated that a selective scanning policy would have omitted 27% of scans but would have missed an injury in about 17% of patients, 2 of whom underwent an immediate intervention.[20] This article presents data for all 701 patients in the completed study and examines physicians' beliefs about the importance of missed injuries that did not require an immediate intervention in greater detail.

MATERIALS AND METHODS

Study Design

We conducted a prospective observational study of patients with blunt trauma treated as a trauma activation in the ED at an academic Level I trauma center between July 1, 2007, and June 30, 2008. At our institution, each trauma activation is jointly managed by members of the emergency medicine and trauma surgery services. Before scanning, the most senior emergency physician and trauma surgeon independently indicated which components of the pan-CT they believed were necessary to obtain. The study was approved by the institutional review board, with a waiver of patient consent.

Setting

Our ED has an annual census of 45,000, including more than 1,000 trauma team activations. Los Angeles County has specific trauma triage criteria that closely match Centers for Disease Control and Prevention suggested guidelines to determine transport to a trauma center. At the time of the study, our trauma center had 2 levels of activation. The highest level, based on American College of Surgeons Committee on Trauma criteria, required emergency physicians and trauma surgeons to be present within 15 minutes of patient arrival. For all other trauma activations, the surgical attending physician could have been present or could have discussed patient management with the surgery chief resident by telephone. Attending faculty include 5 full-time trauma surgeons and 14 full-time and 17 part-time emergency medicine faculty. Our institution has residencies in both general surgery and emergency medicine.

Selection of Participants

All patients with blunt trauma treated as a trauma activation during the study period were included in the study. Patients were excluded if they died in the trauma suite, went directly to the operating room without CT, or were downgraded from trauma status before CT imaging.

Methods of Measurement

Physicians managed trauma patients in their usual fashion, with the trauma team making the final determination about which scans were performed. Standard evaluation in the trauma suite included history, physical examination, hemoglobin levels, anteroposterior chest and pelvis radiographs, and focused abdominal sonography for trauma.

After the patient received initial evaluation and stabilization but before transport for CT imaging, the emergency medicine attending physician and the most senior person on the trauma surgery team were separately surveyed to determine which components of the pan-CT (head, neck, chest, abdomen/pelvis) they wished to order (Figure E1, available online at http://www.annemergmed.com). When present, the surgery attending physician completed the form. When the surgery attending physician was absent, the senior surgery resident was asked to complete the form after discussing the case with the surgery attending physician. For the purposes of this study, a pan-CT included separate scans of the head, neck, chest, abdomen, and pelvis, followed by contrast scans of the chest, abdomen, and pelvis. Technical details are provided in Appendix E1, available online at http://www.annemergmed.com.

Primary Data Analysis

For each component of the pan-CT, the main result is the cross-tabulation of whether the scan was desired, whether the scan result was normal or abnormal, and whether patients with a positive scan result received an a priori–defined critical action. This cross-tabulation allowed us to determine the primary outcome: how often an undesired scan had abnormal findings that resulted in a critical action. Our secondary outcome was the discovery of any injury on an undesired CT regardless of whether it resulted in a critical action.

We defined an "undesired scan" as one that the emergency physician, the trauma surgeon, or both marked as unnecessary. Before beginning the study, the authors, through an informal consensus process, defined "critical actions" to include operative intervention for a finding discovered on CT, as well as the following: for head, ventriculostomy or reversal of coagulopathy in patients with intracranial bleeding; for neck, halo application; for chest, tube thoracostomy; for abdomen/pelvis, interventional radiology procedure for bleeding or transfusion of 2 or more units of packed RBCs for solid organ injury. The group could not reach consensus about whether ICU admission in the absence of the above actions was a critical action.

Scans were read preliminarily by the trauma team and by radiology residents with attending radiologist overread; the timing of the overread varied with time of day and day of week. In our analyses, we use the attending radiologist's final report. Findings reported as "possible" or "potential" were considered abnormal. For patients who had an abnormality on one or more of the scans, abstractors determined whether any of these predefined critical interventions occurred and whether the predefined interventions took place within 24 hours of presentation. Abstractors also recorded patient demographics, disposition, and hospital length of stay for admitted patients. The abstractors who classified findings on each imaging study were blinded to whether the scans were desired or undesired and whether the patient received any critical intervention. The record review was conducted in accordance with criteria proposed by Gilbert et al.[21]

Once the record abstraction results were known, there continued to be disagreement among the authors concerning the clinical relevance of injuries that would have been missed on the undesired scans. To address this issue, we asked each author to independently indicate which of the injuries identified on undesired CT scans were important to discover at the initial evaluation despite that no critical action was taken. Additional details of the methods and results of the study can be found in Appendix E1, available online at http://www.annemergmed.com.

We assessed interrater reliability for the 2 essential abstraction tasks (CT result normal versus abnormal and the presence or absence of critical interventions) by having 2 authors (M.G., D.L.S.) independently score these items for a 25-patient sample randomly selected to ensure that between 3 and 8 patients had at least 1 critical action.

RESULTS

There were 1,049 trauma activations during the study period, 869 of which were potentially eligible for the study (Figure). We failed to obtain surveys for 168 patients (19%), most of whom presented between midnight and 8 AM, when no research associate was available to cue physicians to complete the survey. Age, sex, and median Injury Severity Score (ISS) of eligible patients included in the study (5; interquartile range [IQR] 1, 13) were similar to scores of patients who were not included (5; IQR 1, 14). Of the 701 study subjects, 600 (86%) underwent pan-CT, 91 (13%) underwent selective scanning, and 10 had no scans. Head scans were performed in 97% of patients, neck scans in 97%, chest scans in 87%, and abdomen-pelvis scans in 92%. Characteristics of included patients are shown in Table 1 and Table E1, available online at http://www.annemergmed.com. Median age was 35 years and was younger than 18 years in 11% of patients and older than 65 years in 12%; 72% of patients were men; 37% of subjects had an ISS of 1 or 2 and 20% an ISS greater than 15; 90% had a Glasgow Coma Scale score of 14 or 15 and 5% of less than 9. Raters agreed on the CT findings in 97 of the 100 scans that composed the interrater reliability assessment. Two differences were recording errors; the third resulted from disagreement about whether "minimal free fluid" in the pouch of Douglas of a young female patient was an abnormal finding. There was 100% agreement between raters about whether a critical intervention had been performed in the 25-patient interrater reliability study.

Of the 2,804 scans, 992 (35%) were undesired by at least 1 physician, 794 of these (28%) were desired by the trauma surgeon but not by the emergency physician, and 187 (7%) were desired by neither the emergency physician nor trauma surgeon (Table 2). Of the 992 scans, 808 (81%) were obtained and 102 (10%) results were abnormal. Because 3 of these abnormal scan results led to a critical action, our primary outcome measure is 0.3% (3/992) (Table 3*A*). Emergency physicians indicated they would have ordered 1,823 (70%) of the 2,615 scans that were obtained, including 80% (399/501) of the scans with abnormal results and 98% (123/126) of the scans that were associated with a critical action. They would have reduced the number of pan scans by 56%, from 600 to 263. The surgeons, had they followed their indicated preferences, would have obtained 9 fewer scans than were actually obtained, missing no abnormalities while reducing the number of pan scans by 3%. When both the trauma surgery and emergency physician desired a scan, between 7% (neck) and 43% (chest) of the scan results were abnormal and between 1% (neck) and 11% (abdomen/pelvis) required a critical action. When the trauma surgeon but not the emergency physician desired a scan, between 2% (neck) and 23% (chest) of the scan results were abnormal and between 0% (neck and abdomen/pelvis) and 0.7% (head/chest) required a critical action.

There was disagreement among the authors about the clinical importance of abnormalities found on undesired scans that did

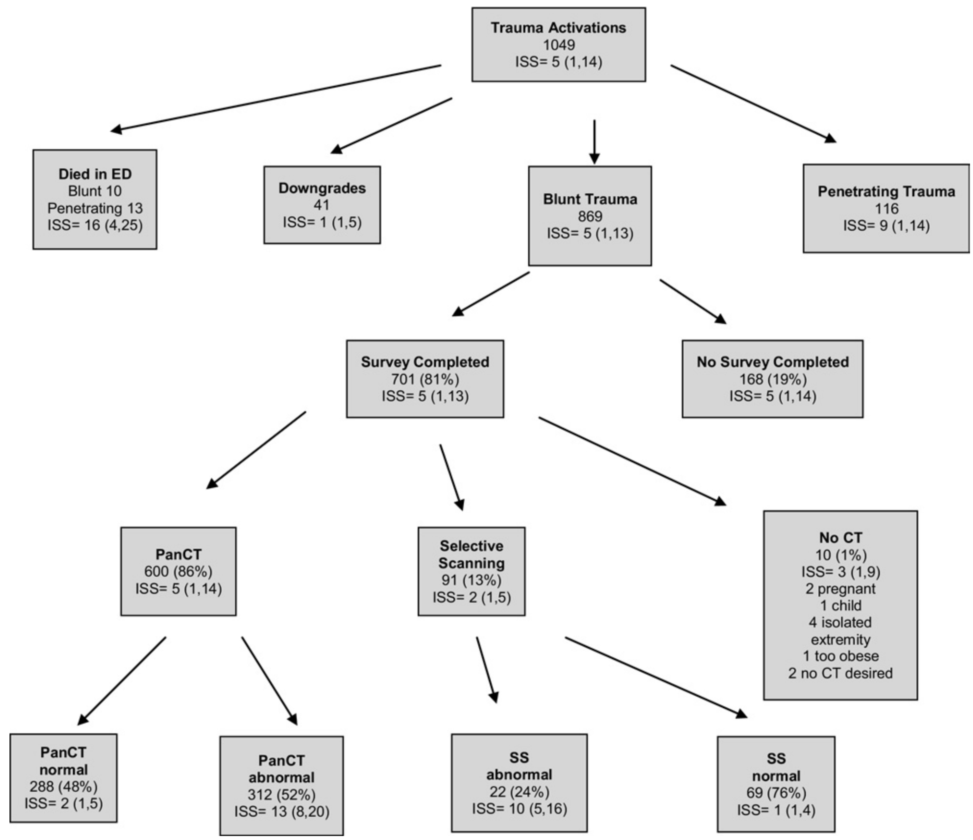

Figure. Survey and scan status of all trauma activations during the study period. *SS*, Scan status.

Table 1. Characteristics of the 701 subjects.*

Characteristics	Median	IQR
Female, %	28	
Age, y	35	23, 50
ISS[†]	5	1, 13
Glasgow Coma Scale score[‡]	15	14, 15
Pulse rate, beats/min	90	78, 102
Respiratory rate, breaths/min	20	18, 22
Systolic blood pressure, mm Hg (n=700)	138	122, 152
Diastolic blood pressure, mm Hg (n=684)	80	70, 90

*Additional details in Table E1, available online at http://www.annemergmed.com.
[†]Thirty-seven percent of study subjects were ISS 1 or 2; 20%, greater than 20.
[‡]Ninety percent were Glasgow Coma Scale score 14 or 15; 5%, less than 9.

not result in a critical action. These abnormalities, found on 99 scans from 92 patients, ranged from minor pulmonary contusions and tiny pneumothoraces to more concerning injuries to the liver, spleen, spinal column, and brain. Our 7 authors indicated that they would want to promptly know about abnormal findings in 0%, 2%, 5%, 26%, 48%, 77%, and 88% of these patients, with the 3 surgeons registering the 3 highest percentages. The author/raters were remarkably consistent; for 79 of 92 patients, their ratings were in perfect rank order according to their overall desire for CT results. For example, if 3 raters did not want a scan, they were the 3 raters with the lowest overall percentages listed above. The details of the 44 patients for whom 3 or more physicians thought early detection was important are shown in Table 3*B*. All 92 patients are shown in Table E2, available online at http://www.annemergmed.com.

None of the 5 missed head injuries that did not require a critical action demonstrated progression on follow-up head CT, and all were read as "punctate" or "tiny" hemorrhage (Tables E3 to E6, available online at http://www.annemergmed.com). The 3 neck injuries were all minor stable fractures. The most common injury on the 65 undesired chest CTs was an isolated lung contusion, and the most common finding on the 26 abnormal undesired abdominal/pelvis studies was an isolated grade 1 laceration of either the liver or spleen. Some patients had more serious injuries, including 4 patients with spleen or liver lacerations of grade 2 or higher.

There were 4 patients who were admitted to the ICU for an abnormality found on an undesired scan, 3 for very small intracerebral hematomas and 1 for a grade 3 splenic laceration associated with a decreasing hematocrit level. The last patient did not receive any blood products during his hospital stay, was transferred to the ward on hospital day 2, and was discharged on hospital day 7 after nonoperative observation of the splenic laceration and management of soft tissue injuries. Almost half (40/92) of patients who had an abnormal result on undesired

Table 2. Results of 2,804 scan decisions by body part, total.*

	Desired, % (N)	Scan Performed, % (N)	Scan Abnormal, % (N)	Critical Action, % (N)
Head				
Both	75 (523)	100 (523)	19 (101)	8 (41)
Trauma surgery only	22 (156)	99 (154)	4 (6)	0.6 (1)
Emergency physician only	0	0	—	—
Neither	3 (22)	27 (6)	0	0
Neck				
Both	76 (534)	100 (534)	7 (39)	1 (7)
Trauma surgery only	21 (148)	97 (143)	2 (3)	0
Emergency physician only	0.3 (2)	0	—	—
Neither	2 (17)	18 (3)	0	0
Chest				
Both	46 (324)	99 (322)	43 (139)	9 (28)
Trauma surgery only	40 (277)	98 (270)	23 (64)	0.7 (2)
Emergency physician only	0.9 (6)	33 (2)	0	0
Neither	13 (94)	16 (15)	3 (3)	0
Abdomen and pelvis				
Both	62 (431)	99 (428)	28 (120)	11 (47)
Trauma surgery only	30 (213)	98 (208)	12 (25)	0
Emergency physician only	0.4 (3)	0	—	—
Neither	8 (54)	13 (7)	2 (1)	0
Total				
Both	65 (1,812)	99.7 (1,807)	22 (399)	7 (123)
Trauma surgery only	28 (794)	98 (775)	12 (98)	.4 (3)
Emergency physician only	0.4 (11)	18 (2)	0	0
Neither	7 (187)	17 (31)†	2 (4)	0
Grand total	100 (2,804)	93 (2,615)	18 (501)	4 (126)‡

*The denominator for "Desired" column is 701, the number of scan decisions of each body part. The denominator for the 3 other percentages in each row is the value of the "Desired" column for that row. Implicit in this calculation is the assumption that scans that were not performed would have been normal.
†These 31 scans were performed despite both senior physicians who were present in the trauma suite indicating that they were undesired. This occurred when a surgery resident was the most senior surgeon present and the attending surgeon overrode the senior surgery resident's plan when consulted by telephone after the form was completed.
‡The 126 scans that required critical actions were performed on 102 patients. Twenty patients had 2 scans requiring a critical action and 2 patients had 3 scans requiring a critical action.

scan were discharged either from the ED or after hospital observation for less than 24 hours.

It was difficult to determine the effect of scan results on the ED disposition decision because many patients had multiple injuries, others were admitted for some reason other than an abnormal scan result, and still others were discharged from the ED despite an abnormal scan result. Of the 357 patients with no abnormalities found in any of their scans, 207 (58%) were discharged from the ED, including 56% (162/288) of patients with a normal pan scan and 65% (45/69) whose selective scan results were normal (Table E7, available online at http://www.annemergmed.com). The proportion of patients who were discharged was lower when more of the scans were desired (47% of 153 patients for whom 3 or 4 scans were desired and 67% of 94 patients for whom no or 1 scan was desired. Of the 239 patients with at least 1 abnormal scan result that was desired, 11% (26) were discharged from the ED, and 8% (19) were admitted and discharged within 24 hours. Of the 95 patients with an abnormal result on undesired scan, 17 (18%) were discharged from the ED and 23% (22) were discharged within 24 hours of admission.

LIMITATIONS

The major threat to external validity is that the study was conducted at a single academic center, one that in general treats more patients with low ISS than are treated at some trauma centers.[9] It is possible that physician judgment to selectively scan patients in a more injured population would result in a larger number of critical missed injuries. In addition, the study was hypothetical. Had the trauma surgeon not ordered a pan-CT, actual scans ordered by the emergency physicians might be different from what they indicated on the data form. When forced to actually limit CT scanning, physicians might be more conservative than in this hypothetical exercise, increasing the number of scans performed and decreasing the percentage of missed injuries. The patients who were not pan scanned serve as an example of the process in action, and these decisions appear to be prudent ones. Our study demonstrated that some of the physicians have markedly different risk tolerance profiles; though further examination of these risk profiles is beyond the scope of this article. Additional limitations are that not all scans were read in real time by an attending radiologist

Table 3. Missed injuries on undesired scans deemed consequential by 3 or more authors.

Age (years), Sex	Abnormal Undesired Scan(s)	Abnormalities on the Undesired Scans	Other Injuries	Treatment, Dispo, Additional Information
***A*, Patients requiring a critical intervention**				
53, m	Chest	T8 burst fx	Hemothorax, pneumothorax, C5-disc herniation	OR for spinal injury. Pt had lower extremity paralysis in ED, and negative CXR and neck CT
77, f	Head	SAH	—	OR for extremity trauma. Empiric platelets for aspirin use. Glasgow Coma Scale score 15. No change CT #2 posttransfusion.
45, m	Chest	10 rib fxs, pulmonary contusions and lung laceration	Cerebral contusion, wrist fx	ICU. 9 fxs observed on ED CXR before CT. Chest tube hospital day 2

Age (years), Sex	Abnormal Undesired Scan(s)	Abnormalities on the Undesired Scans	Other Injuries	Dispo	No. Authors Who Thought Findings Important
***B*, Patients not requiring a critical intervention**					
3, f	Chest, AP	Grade 3–4 splenic laceration, large hemoperitoneum, pulmonary contusion	Road rash, knee laceration	Ward	6
56, f	AP	Grade 3 liver laceration	ICH, rib fxs, facial fxs	Ward	6
19, f	Neck, chest, AP	C1 arch fx, T1 TP fx, grade 3 splenic laceration, pneumothorax	Radius fx, elbow laceration	ICU	5
35, m	Neck	C6 facet fx	Bilateral hand fxs	Ward	5
15, m	AP	Grade 2 splenic laceration and hemoperitoneum	Clavicle fx	Ward	5
49, m	Chest	Vertebral body fx, 1 rib fx	Femoral neck fx	OR	4
60, m	Head	ICH	Multiple rib fxs, splenic laceration, pneumothorax	ICU	4
33, m	Head	ICH, SAH	L2 and L4 TP fxs, L5 SP fxs	ICU	4
48, m	Head, chest, AP	ICH, pneumothorax, pneumomediastinum, L2–3 TP fxs	—	ICU	4
16, m	Head	ICH, IVH	Zygomatic fx	Transfer	4
52, m	AP	T11 vertebral body fx, adrenal hematoma, L1–4 TP fxs	SDH, 40% body burn	Transfer	4
47, m	AP	Acetabular and sacral fx	Hypoglycemic coma	Ward	4
23, m	Chest	T12 vertebral body fx	—	Ward	4
47, m	Chest	L1 burst fx	Tibia-fibular fx, calcaneal fx	Ward	4
72, m	AP	Grade 1 splenic laceration and hemoperitoneum	Atrial fibrillation	Ward	4
21, m	AP	Grade 2 liver laceration	—	Ward	4
79, f	AP	Grade 1 liver laceration and hemoperitoneum	—	Ward	4
83, f	AP	Pelvic fx	SAH, SDH, complex skull fx	Ward	4
40, f	AP	Grade 1 liver laceration	Sternal fx	Ward	4
29, f	AP	Pelvic fx	—	Ward	4
80, m	Chest	T12 vertebral body fx	—	Ward	4
28, m	Chest	T10, T12 vertebral body fx	—	Home	4
84, m	Chest	6 rib fxs, pulmonary embolus	Multiple extremity fxs	OR	3
27, m	Chest	Scapula fx	EDH, SDH	OR	3
22, m	Chest	1 rib fx, pneumomediastinum	Subcutaneous air in neck	OR	3
56, m	Chest, AP	Scapula fx, L1–5 TP fxs	Extremity fxs	OR	3
91, f	Chest	7 rib fxs, T3-5 SP fxs	SAH, SDH, pelvic fx	ICU	3
82, m	Chest	Scapula fx	ICH, IVH, SAH, SDH	ICU	3
50, m	AP	Grade 1 splenic laceration	ICH, SAH, orbital and hand fxs	ICU	3
38, f	Chest	Sternal fx	L2 burst fx	ICU	3

Table 3. Continued

Age (years), Sex	Abnormal Undesired Scan(s)	Abnormalities on the Undesired Scans	Other Injuries	Dispo	No. Authors Who Thought Findings Important
21, m	AP	Colonic stranding	SAH, contusions and edema	ICU	3
62, m	Chest	3 rib fxs	ICH, cirrhosis	Ward	3
82, f	AP	Gluteal hematoma with extravasation	SDH	Ward	3
28, m	AP	Pelvic fx	—	Ward	3
30, m	Chest	3 rib fxs, pneumothorax, lung contusion, clavicle fx	Hip fx	Ward	3
24, m	AP	L1-3 TP fxs	—	Ward	3
35, f	AP	Mesenteric hematoma	—	Ward	3
53, m	Chest	Pneumothorax, 3 rib fxs	—	Ward	3
7, m	Chest	Pneumothorax, 3 rib fxs	—	Ward	3
71, m	Chest	Sternal fx	—	Ward	3
29, m	Chest	T6 small vertebral body fx, lung contusion	Road rash	Ward	3
33, m	Neck	C5 SP fx	—	Ward	3
25, f	AP	Pelvic fx	—	Home	3
43, m	Chest	T1, T3 SP fx	C7 SP fx	Home	3

m, Male; *f*, female; *fx*, fracture; *SAH*, subarachnoid hemorrhage; *AP*, abdomen/pelvis CT; *ICH*, intracranial hemorrhage; *TP*, transverse process; *SP*, spinous process; *SDH*, subdural hematoma; *EDH*, epidural hematoma.

and that we assume in our calculations that all scans that were not performed would have had normal results. Finally, the observational design precludes definitive conclusions. A larger, prospective, multicenter study will be required to address the major limitations.

DISCUSSION

The primary aim of our study was to determine whether certain components of the pan scan can be selectively omitted without missing clinically important injuries. We sought to characterize the unanticipated injuries that were found and whether those injuries changed the management of patients. Although other authors have reported that unanticipated CT scan findings led to changes in patient care in 20% to 26% of cases, these studies have substantial methodological flaws.[11,22,23] Our study sought to correct these problems by using predefined definitions of clinically important injuries and management changes. Our first important finding is that it was difficult for the authors to define what constitutes a clinically important injury.

The emergency medicine attending physicians in this study more often expressed a willingness to forgo elements of the pan scan than did the surgeons (35% versus 7% of scans). Of 992 scans (35%) that one or both physicians indicated could be omitted, 102 (10%) results were abnormal, and 3 (0.3%) of these abnormalities led to a predefined critical action. With physician judgment as the test, the negative likelihood ratio for an undesired scan having abnormal results and producing a critical action was 0.05, a value comparable to or better than that of most laboratory tests used in clinical medicine.[24] The authors had widely varying opinions about the importance of promptly detecting the abnormalities on the undesired scans at the initial evaluation (0% to 88%).

Although we agree on the validity of the numbers presented in this study, we disagree on their meaning. We offer 2 perspectives on the meaning of our findings.

Surgeon Authors' Perspective

From the surgeon-authors' perspective, the CT scan is a valuable tool that has markedly improved our ability to provide optimal care to the injured patient. Our current management of traumatic brain injury, solid organ injury, transection of the thoracic aorta, and pelvic fracture hemorrhage, to name a few, has evolved because of advances in CT technology. Many of these potentially life-threatening injuries are occult, with minimal physical findings to suggest their presence. These injuries also are relatively infrequent. To find them, we know that we will be subjecting many patients to a scan.

The first important finding of our study was that a large number of injuries were found in the various scans that were ordered by the trauma surgeons and believed to be unnecessary by the emergency physicians; abnormalities were found in 20% of scans that were thought to be necessary by emergency physicians and 10% of scans that were believed to be unnecessary. Our data would not support modifying our current approach because of the number of injuries that would potentially have been missed. However, we could still justify modifying our approach if the majority of the injuries found were trivial and of no significant clinical consequence.

Our second important finding was that it is difficult to determine the clinical significance of an injury identified on a CT scan, particularly if a patient has more than 1 injury. Several articles have used the significance criterion that the scan led to a change in management, but we found that we were unable to agree on the significance of an injury when we used this approach.[1,11,22,23] The trauma surgeons believe that aspects of care such as admission to the hospital, admission to the ICU, invasive monitoring, and other modalities used to provide appropriate care of an identified injury should be considered clinically significant.

Using our current strategy, we believe that we have maximized our rapid identification of injuries and, equally important, have excluded important injuries, allowing for the rapid development of a management plan with excellent patient outcomes. In our opinion, the data from this study do not justify a change in that approach. We do agree that there were fewer critical procedures required for the injuries found in the emergency physicians' undesired scans compared with the desired scans and that many of the injuries identified on both the desired and undesired scans were of minimal clinical significance. However, 3 critical procedures were required and should not be trivialized. In addition, the trauma surgeons believe that all 45 injuries listed in Table 3*B* are clinically significant and that their identification and characterization were important in developing an optimal care plan for the patient.

We believe that definition of all injuries at presentation remains a standard of care until a prospective evaluation determines which of these injuries are indeed innocuous. The noncritical injuries in this study could be judged so only in retrospect. As an example, the 5 patients with brain injuries that would have been missed without performing the undesired scans were admitted to the ICU and treated according to our traumatic brain injury protocol. None of the patients progressed to require a critical intervention but certainly might have. The trauma team and neurosurgical consultants used the information from the undesired scan to develop a care plan that resulted in an excellent outcome.

We do not believe that the data in this study indicate that our current use of CT scan represents overuse or lack of value. Further, we believe that these data show that an attempt to reduce the use of CT scans in this patient population according to intuition would miss a significant number of clinically important injuries and reduce the quality of care. We support further efforts to improve CT scan technology and reduce the radiation dose required to provide important information for high-quality patient care rather than limit the availability of that information.

Emergency Physician Authors' Perspective

As evidenced by the relatively low median ISS scores in our sample, out-of-hospital trauma triage guidelines are sensitive but not specific to ensure that all patients with serious injuries are transported to a trauma center. Consequently, many trauma patients are not seriously injured, and physicians must make clinical judgments about the need for imaging. Although we acknowledge our surgery colleagues' desire to detect all injuries as soon as possible, this desire must be balanced by consideration of the potential harms of an automatic pan-CT approach that undervalues careful examination, serial examination, and clinical judgment. We do not think it necessary that a pan-CT be obtained for every patient with blunt trauma to ensure that no injury goes undetected. In general, such a no-risk approach subjects patients to excessive testing that may result in unnecessary additional testing or interventions, additional costs, and delays in the treatment of other patients.

It is likely that the 3 missed injuries that resulted in critical actions in this study could have been managed without an initial CT. There is no evidence that the provision of platelets to a patient receiving aspirin who has a small intracranial bleed improves outcome, the thoracic spine injury would have been detected in the ED shortly after the cervical spine CT images were completed and failed to identify the clinically suspected spinal fracture, and the lung laceration and contusions would have been detected by serial radiographic examinations once the patient had been admitted.

Resumption of Joint Discussion

As demonstrated by these contrasting perspectives, this study's relevance extends beyond trauma care because it illustrates the difficulties encountered when attempting to define appropriate medical use of an expensive, potentially harmful technology such as CT. We work side by side daily yet have different interpretations of the meaning of these data. Because we do not dispute the data's accuracy, the disparity arises from divergent beliefs about the extent to which diagnostic certainty is necessary and the relative values of the accompanying tradeoffs.

In a 1989 article, Kassirer[25] listed a number of potential drivers of suboptimal overtesting, including fear of malpractice, demands of patients, pressure from peers and supervisors, and convenience of testing. He further opined that physicians' quest for diagnostic certainty was an important, neglected factor in testing, driven in part by near-virtual freedom to order tests.

Certainly, CT use in trauma care amplifies many of the above drivers of testing, with its high-risk subset of patients, combined with a readily accessible technology that can rapidly eliminate almost all uncertainty. CT use in trauma care also demonstrates the extent to which the appropriate amount of diagnostic certainty remains a subjective declaration, driven both by the particularities of physician specialty and by the individual risk profiles of physicians within each specialty. In our study, individual emergency physicians thought that as few as 0% and as many as 26% of scan findings were important; individual surgeons, as few as 48% and as many as 88%. Possible reasons, in addition to those described above, why surgeons may desire more diagnostic certainty than emergency physicians include (1) a discomfort with the possibility, however remote, that any delay in diagnosis will lead to an adverse outcome and they will be held accountable; (2) combined with the first point, the fact that it is the surgeon who is ultimately responsible for the patient; (3) a case-mix bias whereby surgeons care for the sickest trauma patients and are less involved with the minor trauma patients treated by emergency physicians, who do well without extensive testing; and (4) the anxieties inherent in relying on ancillary staff (including residents and nurses) to perform serial examinations on patients scattered throughout the hospital. Emergency physicians, on the other hand, may be more comfortable with more diagnostic uncertainty in patients with blunt trauma because of extensive experience with patients with minor trauma, an awareness that resources are limited in the ED and that unnecessary scanning of trauma patients may delay other more necessary scans, and a larger focus on public health in the context of resource use and negative consequences of testing from a population perspective.

In addition to the effect that one's clinical specialty has on testing in trauma patients, individual risk profiles likely also factor in. Though few data exist on how surgeons' decisionmaking behaviors are linked to their tolerance for uncertainty and risk-taking profiles, studies examining other specialties have shown a positive correlation.[26] For example, one study demonstrated a positive correlation between emergency physicians' malpractice fears and their intensity of evaluation for patients with low-risk chest pain.[27] A similar trend in testing has been observed among family practice physicians.[28] In this study, trauma surgeons exhibited a nearly 2-fold difference in the number of scans with nonintervention injuries they believed were important to find (Table 3*B*), whereas emergency physicians exhibited similar individual risk tolerance.

Finally, the author differences in defining what level of diagnostic uncertainty is deemed appropriate must be situated within a shifting, larger cultural context in which our patient populations may have very different goals and opinions of what defines appropriate.

Our study begins to address some of the above questions as they pertain to patients with blunt trauma. At the same time, our study highlights many of the systemic questions that will need to be addressed for other high-cost technologies and clinical scenarios if we are to reduce burgeoning health care costs while providing optimal health care, as defined in a way acceptable to all stakeholders.

Selective CT scanning of patients with blunt trauma based on physician judgment could substantially reduce the number of scans while missing a very small number of injuries that result in a critical action. Roughly 10% of undesired scans had abnormalities, and there exists disagreement among us about the clinical importance of detecting these injuries during the initial evaluation. The balance between the benefits of early detection and the harms from ionizing radiation and contrast remains unclear, as does the economic balance between the costs of pan-CT and the potential savings from early discharge of patients with negative scan results.

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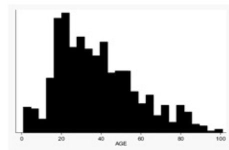
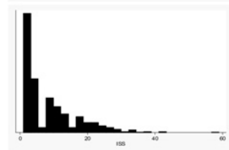
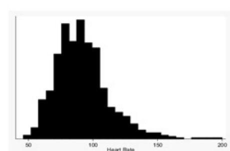
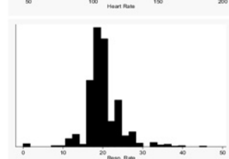
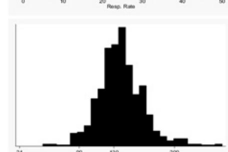
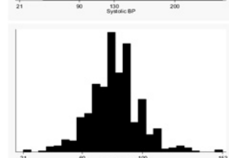
Supplementary Table 1. Study Subject Characteristics.

			All	Age 0-14	Age 15-64	Age 65+
Number of subjects		701		51	569	81
Female (%)		28%		37%	25%	44%
Age						
	median	35				
	IQR	23, 50				
	range	1, 101				
Injury severity score						
	median	5		2	5	9
	IQR	1, 13		1, 9	1, 13	2, 18
	range	1, 59		1, 20	1, 59	1, 43
	1 or 2	37		51	37	33
	>15	20		2	19	35
Glasgow coma score						
	median	15		15	15	15
	IQR	14, 15		15, 15	15, 15	14, 15
	range	3, 15		10, 15	3, 15	3, 15
	14 or 15 (%)	90		98	91	83
	<9 (%)	5		0	5	12
Heart rate						
	median	90		116	88	86
	IQR	78, 102		99, 138	78, 100	73, 99
	range	46, 200		61, 200	50, 186	46, 151
Respiratory rate						
	median	20		24	18	18
	IQR	18, 22		20, 28	18, 20	16,20
	range	0, 46		14, 46	0, 36	0, 28
Systolic BP						
	median	138		123	138	148
	IQR	122, 152		113, 137	122, 151	125, 170
	range	48, 255		48, 181	58, 255	53, 228
	(N)*	700		50	569	81
Diastolic BP						
	median	80		70	80	86
	IQR	70, 90		63, 78	72, 90	76, 98
	range	21, 153		21, 92	34, 153	23, 125
	(N)*	684		49	556	79

Supplementary Table 2. Treatment of 95 patients with injuries on 102 undesired scans.

Age, sex	Scan Decision and Completion Status H	N	C	AP	Abnormalities on the undesired scans	Other injuries	Treatment and Disposition
Patients requiring a critical action							
53m	D	D	U	U	T8 burst fx	Hemothorax, pneumothorax, C5-disc herniation	OR for spinal injury, ICU
77f	U	U	U	U	SAH	-	OR for extremity trauma
45m	D	D	U	U	10 rib fxs, pulmonary contusions and lung laceration	Cerebral contusion, Wrist fx	ICU, chest tube (day2)
Patients not requiring a critical action							
21m	D	D	U	D	Pulmonary aspiration, contusion	SDH, SAH, midline shift	OR
37m	U	U	U	D	2 rib fxs, lung contusion	Grade 3 liver and splenic injury, extremity fxs	OR
84m	D	D	U	D	6 rib fxs, pulmonary embolus	Multiple extremity fxs	OR
18f	U	U	U	D	Pneumothorax	L3 burst fx	OR
37m	U	D	U	U	Lung contusion	C1-C2 fxs	OR
27m	D	D	U	D	Scapula fx	EDH, SDH	OR
41f	D	D	U	U	L1 TP fxs	Ankle fx	OR
49m	D	D	U	D	Vertebral body fx, 1 rib fx	Femoral neck fx	OR
22m	D	D	U	U	1 Rib fx, pneumomediastinum	Subcutaneous air in neck	OR
37m	U	U	U	D	Lung contusion	Pelvic fx, multiple extremity fxs	OR
56m	u	u	U	U	Scapula fx, L1-5 TP fxs	Extremity fxs	OR
19f	D	U	U	U	C1 arch fx, T1 TP fx, grade 3 splenic laceration, pneumothorax	Radius fx, elbow laceration	ICU
33f	U	U	U	D	Pneumothorax, 2 rib fxs, lung contusion	Grade 3 splenic injury, pelvic fx	ICU
49m	U	D	U	U	Pulmonary contusion, pneumomediastinum, aspiration	Hangman's fx, C3-4 SP fxs	ICU
60m	U	D	D	D	ICH	Multiple rib fxs, splenic laceration, pneumothorax	ICU
34m	U	D	U	D	ICH, SAH	L2 and L4 TP fxs, L5 SP fxs	ICU
64m	D	D	U	U	Renal contusion, pulmonary contusion	Central cord syndrome	ICU
91f	D	D	U	D	7 rib fxs, T3-5 SP fxs	SAH, SDH, pelvic fx	ICU
82m	D	D	U	U	Scapua fx	ICH, IVH, SAH, SDH	ICU
21m	D	D	U	D	Clavicle fx	SAH	ICU
50m	D	D	U	U	Grade 1 splenic laceration	ICH, SAH, orbital and hand fxs	ICU
23m	D	D	U	D	Pneumothorax, peumomediastinum, pulmonary contusion, sternal fx	Renal Hemorrhage, SAH overread as normal by atttending radiologist in AM	ICU
44m	D	D	U	D	Lung contusion	SAH	ICU
47m	D	U	U	D	5 rib fxs	SAH, kidney injury	ICU

48m	U	U	U	U	ICH, pneumothorax, pneumomediastium, L2-3 TP fxs	-	ICU
37m	D	D	U	D	Mediastinal hematoma	Nasopharyngeal bruising and edema	ICU
38f	U	U	U	D	Sternal fx	L2 burst fx	ICU
21m	D	D	U	U	Colonic stranding	SAH, contusions and edema	ICU
52m	D	D	U	U	1 rib fx	-	Transfer
16m	U	U	U	D	ICH, IVH	Zygomatic fx	Transfer
44m	U	U	U	U	Mesenteric Hematoma, 1 rib fx	Ankle fx	Transfer
52m	D	D	D	U	T11 vertebral body fx, adrenal hematoma, L1-4 TP fxs	SDH, 40% body burn	Transfer
36f	U	U	U	D	Pneumothorax	Kidney laceration, L5 TP fx	Ward
7m	D	U	U	U	Bilateral pulmonary contusions	-	Ward
21m	U	U	U	U	3 rib fxs, clavicle fx	-	Ward
31m	D	D	U	D	Clavicle fx	Scalp laceration	Ward
62m	D	D	U	U	3 rib fxs	ICH, cirrhosis	Ward
3f	D	D	U	U	Grade 3-4 splenic laceration, large hemoperitoneum, pulmonary contusion	Road rash, knee laceration	Ward
33m	u	u	U	U	4 rib fxs, pneumothorax	Road rash	Ward
47m	U	U	D	U	Acetablular and sacral fx	Hypoglycemic coma	Ward
23m	D	D	U	D	T12 vertebral body fx	-	Ward
53f	D	U	U	U	T11 TP fx, kidney contusion, adrenal hematoma	-	Ward
47m	U	U	U	D	L1 burst fx	Tibial-fibular fx, calcaneal fx	Ward
72m	U	U	U	U	Grade 1 splenic laceration and hemoperitoneum	Atrial fibrillation	Ward
37m	U	U	U	U	1 rib fx, lung contusion, scapula fx	-	Ward
21m	D	D	U	U	Grade 2 liver laceration	-	Ward
82f	D	D	U	U	Gluteal hematoma with extravasation	SDH	Ward
79f	D	D	D	U	Grade 1 liver laceration and hemoperitoneum	-	Ward
83f	D	D	U	U	Pelvic fx	SAH, SDH, complex skull fx	Ward
28m	U	U	U	U	Pelvic fx	-	Ward
30m	D	U	U	U	3 rib fxs, pneumothorax, lung contusion, clavicle fx	Hip fx	Ward
24m	U	U	U	U	L1-3 TP fxs	-	Ward
29m	D	D	U	D	Pulmonary contusion	Calcaneous, L2-4 fxs	Ward
35m	U	U	U	U	C6 facet fx	Bilateral hand fxs	Ward
35f	D	D	U	U	Mesenteric hematoma	-	Ward
56f	D	U	D	U	Grade 3 liver laceration	ICH, rib fxs, facial fxs	Ward
40f	U	U	D	U	Grade 1 liver laceration	Sternal fx	Ward
29f	D	D	D	U	Pelvic fx	-	Ward
22m	D	D	U	D	Pneumothorax	Pelvic fx, hip dislocation, tibia fx	Ward
25m	D	D	U	U	Lung contusion	-	Ward
8f	U	U	U	U	Lung contusion	-	Ward
53m	D	D	U	D	Pneumothorax, 3 rib fxs	-	Ward
35m	D	D	U	D	Pneumothorax, 4 rib fxs	Pelvic fx	Ward
23m	U	U	U	U	Clavicle fx	-	Ward
44f	U	U	U	D	1 rib fx	Femur fx	Ward

13m	U	U	U	D	Lung contusion, clavicle fx	-	Ward
13m	U	U	U	D	Lung contusion	Adrenal hematoma	Ward
7m	D	D	U	U	Pneumothorax, 3 rib fxs	-	Ward
41m	U	U	U	U	Lung contusion	-	Ward
32m	U	U	U	D	Lung contusion, 3 rib fxs	L3-L4 TP fxs	Ward
71m	U	D	U	U	Sternal fx	-	Ward
29m	D	D	U	U	T6 small vertebral body fx, lung contusion	Road rash	Ward
15m	D	D	D	U	Grade 2 splenic laceration and hemoperitoneum	Clavicle fx	Ward
80m	D	D	U	D	T12 vertebral body fx	-	Ward
33m	D	U	U	U	C5 SP fx	-	Ward
62m	D	D	U	D	1 rib fx	-	Home
29m	U	U	U	U	Pnemothorax	Road rash	Home
54f	U	U	U	U	1 rib fx	-	Home
22m	D	D	U	U	Lung contusion	-	Home
57m	D	D	U	U	Grade 1 liver laceration	Orbital and nasal fxs	Home
50f	U	D	u	U	L4 TP fx	-	Home
23m	D	D	U	U	Lung contusion, lung laceration, peumomediastinum	-	Home
43m	D	D	U	D	T1, T3 SP fx	C7 SP fx	Home
51m	U	U	U	U	Humeral fx	-	Home
28m	D	U	U	U	Lung contusion	Road rash	Home
28m	U	D	U	U	T10, T12 vertebral body fx	-	Home
40m	D	D	U	U	Scapula fx	Road rash	Home
22m	U	U	U	U	Lung contusion	Road rash	Home
18m	D	D	U	U	Clavicle fx	-	Home
25f	U	U	U	U	Cerebral contusion	-	Home
25f	U	U	U	U	Pelvic fx	-	Home
27m	U	U	U	U	2 rib fxs, pulmonary contusion	-	Home

Abbreviations: Shaded cells = abnormal scans. D = desired/done, U = undesired/done, u = undesired/not done, AP = Abdomen/Pelvis CT, EDH = epidural hematoma, SAH = subarachnoid hemorrhage, ICH = intracranial hemorrhage, SDH = subdural hematoma, TP = transverse process fracture, SP = spinous process fracture, fx = fracture.

Supplementary Table 3. Missed injuries without critical intervention on undesired scans.

HEAD (5)

Age, Sex	**Injury**	**Change in CT#2**	**Disposition**
16 M	Intracranial hemorrhage, intraventicular hemorrhage	No	Transferred to outside facility, no intervention
60 M	Intracranial hemorrhage	No	Admitted for multiple thoraco-abdominal injuries
25 F	Contusion	Not done	Discharged from ED
33M	Intracranial hemorrhage, Subarachnoid hemorrhage	No	Admitted for thoraco-lumbar and extremity fractures
48M	Intracranial hemorrhage	No	Admitted for weakness from neck injury

NECK (3)

Age, Sex	**Injury**	**Abnormal C-spine Plain Film?**	**Disposition**
33M	Spinous process fracture	Not done	Discharged hospital day 2
19F	Transverse process fracture, C1 arch fracture	Yes	Admit, multiple other injuries
35M	C6 facet fracture	No	Discharged hospital day 3

CHEST (65)

Injury	**Patients**	**Abnormal CXR**	**Discharged from ED**	**Discharged by hospital day 2**
Isolated vertebral body fracture	4	0	1	1
Isolated rib fracture	8	1	1	0
Isolated lung contusion	15	2	3	4
Isolated pneumothorax, hemothorax or pneumomediastinum	5	0	1	0
Isolated SP or TP fracture	3	0	2	1
Isolated clavicle, scapula or sternum fracture	8	4	2	4
Rib fracture and lung contusion only	3	1	1	1
Rib fracture and pneumothorax, hemothorax or sternal fracture	5	2	0	2
Other*	14	5	2	5
Total	65	15	13	18

* Combinations of above injuries. Also includes one patient with a lung laceration and one patient with a mediastinal hematoma

ABDOMEN/PELVIS (26)

Injury	**Patients**	**Discharged from ED**	**Discharged by hospital day 2**
Isolated Liver/Spleen Grade 1-2	8	1	3
Liver/Spleen Grade 3-5	2	0	0
Isolated Pelvic Fracture	5	1	0
Isolated SP or TP Fracture	3	1	0
Isolated Kidney Injury	1	0	0
Other*	7	0	2
Total	26	3	5

* Combinations of above injuries. Also includes one patient with colonic stranding and one with mesenteric stranding

Supplementary Table 4. Injuries and critical actions by body part. *TS*, Trauma surgeon.

	Desired by:		
	Neither	**TS Only**	**Both**
Head	22	156	523
Abnormal Scans	0	6	101
No intervention	-	5	59
Total Interventions	-	1	56
Immediate Intervention	-	1	53
OR/Ventriculostomy/Blood Product	-	0/0/1	13/11/29
Delayed Intervention	-	0	3
OR/Ventriculostomy/Blood Product	-	-	0/2/1
Neck	17	148	534
Abnormal Scans	0	3	39
No intervention	-	3	32
Total Interventions	-	-	7
Immediate Intervention	-	-	5
OR/Halo	-	-	2/3
Delayed Intervention	-	-	2
OR/Halo	-	-	2/0
Chest	94	277	324
Abnormal Scans	3	64	139
No intervention	3	62	111
Total Interventions	-	2	32
Immediate Intervention	-	1	24
OR/Thoracostamy	-	1/0	5/19
Delayed Intervention	-	1	8
OR/Thoracostamy	-	0/1	4/4
Abdomen/Pelvis	54	213	431
Abnormal Scans	1	25	120
No intervention	1	25	77
Total Interventions	-	-	78
Immediate Intervention	-	-	47
OR/Interventional Radiology or Blood Product	-	-	20/27
Delayed Intervention	-	-	31
OR/Interventional Radiology or Blood Product	-	-	10/21
Totals			
Total Interventions	0	3	173
Immediate Interventions	-	2	129
Delayed Interventions	-	1	44

Supplementary Table 5. Detailed CT findings by body part.

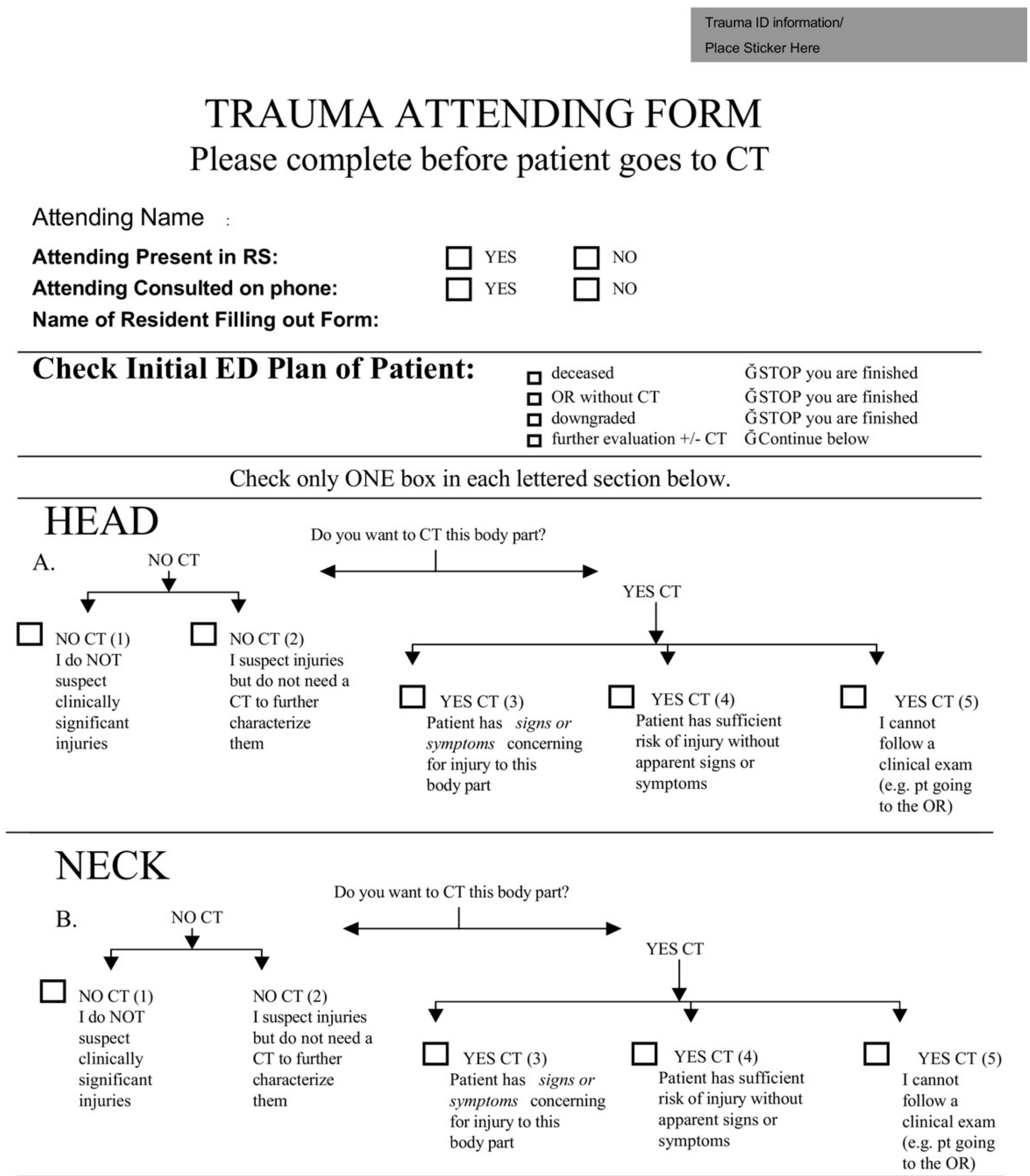
		Desired by: Neither		TS Only		Both		Total	
		N	%	N	%	N	%	N	%
Head	Normal scan	6	100%	148	96%	422	81%	576	84%
	Abnormal scan	0	0	6	4%	101	19%	107	16%
	Intracerebral Hemorrhage or Contusion	0	-	4	3%	26	5%	30	4%
	Intraventricular or Subarachnoid Hemorrhage	0	-	3	2%	63	12%	66	10%
	Epidural	0	-	0	0%	7	1%	7	1%
	Subdural	0	-	0	0%	42	8%	42	6%
	Other	0	-	1	1%	59	11%	60	9%
	Total injuries	0	-	8		197		205	
Neck	Normal scan	3	100%	140	98%	495	93%	638	94%
	Abnormal scan	0	0	3	2%	39	7%	42	6%
	Transverse or Spinous Process Fracture	0	-	2	1%	19	4%	21	3%
	Vertebral Fracture	0	-	1	1%	4	1%	5	1%
	Subluxation	0	-	0	0%	2	0%	2	0%
	Other	0	-	1	1%	27	5%	28	4%
	Total injuries	0	-	4		52		56	
Chest	Normal scan	12	80%	206	76%	183	57%	403	66%
	Abnormal scan	3	25%	64	24%	139	43%	206	34%
	Lung Contusion or laceration	2	17%	28	10%	71	22%	101	17%
	Rib Fracture	0	0%	24	9%	86	27%	110	18%
	Hemothorax, Pneumothorax	0	0%	13	5%	61	19%	74	12%
	Clavicle or Scapula Fracture	0	0%	12	4%	30	9%	42	7%
	Transverse or Spinous Process Fracture	1	8%	3	1%	12	4%	16	3%
	Vertebral Fracture	1	8%	7	3%	11	3%	19	3%
	Suspected aortic Injury	0	0%	0	0%	3	1%	3	0%
	Other	0	0%	7	3%	38	12%	45	7%
	Total injuries	4		94		312		411	
Abdomen-pelvis	Normal scan	6	86%	183	88%	308	72%	499	77%
	Abnormal scan	1	14%	25	12%	120	28%	146	23%
	Splenic Laceration	0	0%	5	2%	26	6%	31	5%
	Liver Laceration	0	0%	5	2%	18	4%	23	4%
	Kidney Injury	0	0%	1	0%	13	3%	14	2%
	Possible Small Bowel Injury	0	0%	0	0%	8	2%	8	1%
	Pelvic fractures	1	14%	4	2%	45	11%	50	8%
	Transverse or Spinous Process Fracture	0	0%	4	2%	40	9%	44	7%
	Vertebral Fracture	0	0%	1	0%	11	3%	12	2%
	Other	0	0%	6	3%	25	6%	31	5%
	Total injuries	1		26		186		213	

Supplementary Table 6. Injuries and critical actions by body part.

	Desired by:		
	Neither	**TS Only**	**Both**
Head	22	156	523
Abnormal Scans	0	6	101
No intervention	-	5	59
Total Interventions	-	1	56
Immediate Intervention	-	1	53
OR/Ventriculostomy/Blood Product	-	0/0/1	13/11/29
Delayed Intervention	-	0	3
OR/Ventriculostomy/Blood Product	-	-	0/2/1
Neck	17	148	534
Abnormal Scans	0	3	39
No intervention	-	3	32
Total Interventions	-	-	7
Immediate Intervention	-	-	5
OR/Halo	-	-	2/3
Delayed Intervention	-	-	2
OR/Halo	-	-	2/0
Chest	94	277	324
Abnormal Scans	3	64	139
No intervention	3	62	111
Total Interventions	-	2	32
Immediate Intervention	-	1	24
OR/Thoracostamy	-	1/0	5/19
Delayed Intervention	-	1	8
OR/Thoracostamy	-	0/1	4/4
Abdomen/Pelvis	54	213	431
Abnormal Scans	1	25	120
No intervention	1	25	77
Total Interventions	-	-	78
Immediate Intervention	-	-	47
OR/Interventional Radiology or Blood Product	-	-	20/27
Delayed Intervention	-	-	31
OR/Interventional Radiology or Blood Product	-	-	10/21
Totals			
Total Interventions	0	3	173
Immediate Interventions	-	2	129
Delayed Interventions	-	1	44

Supplementary Table 7. Patients sent home from the ED by number of scans performed and scan results.

	Percentage of Patients Discharged from ED (fraction)				
	Number of scans obtained				**Total**
	1	2	3	4 (Pan-scan)	
Patients with no abnormal scans	67% (4/6)	62% (21/34)	69% (20/29)	56% (162/288)	58% (207/357)
Patients for whom all abnormal scans were desired	- (0/0)	0% (0/10)	17% (1/6)	11% (25/223)	11% (26/239)
Patients with at least 1 undesired abnormal scan	- (0/0)	0% (0/2)	25% (1/4)	18% (16/89)	18% (17/95)



Trauma ID information/
Place Sticker Here

TRAUMA ATTENDING FORM
Please complete before patient goes to CT

Attending Name :

Attending Present in RS: ☐ YES ☐ NO
Attending Consulted on phone: ☐ YES ☐ NO
Name of Resident Filling out Form:

Check Initial ED Plan of Patient:

☐ deceased ĞSTOP you are finished
☐ OR without CT ĞSTOP you are finished
☐ downgraded ĞSTOP you are finished
☐ further evaluation +/- CT ĞContinue below

Check only ONE box in each lettered section below.

HEAD

A.

Do you want to CT this body part?

NO CT

☐ NO CT (1) I do NOT suspect clinically significant injuries

☐ NO CT (2) I suspect injuries but do not need a CT to further characterize them

YES CT

☐ YES CT (3) Patient has *signs or symptoms* concerning for injury to this body part

☐ YES CT (4) Patient has sufficient risk of injury without apparent signs or symptoms

☐ YES CT (5) I cannot follow a clinical exam (e.g. pt going to the OR)

NECK

B.

Do you want to CT this body part?

NO CT

☐ NO CT (1) I do NOT suspect clinically significant injuries

NO CT (2) I suspect injuries but do not need a CT to further characterize them

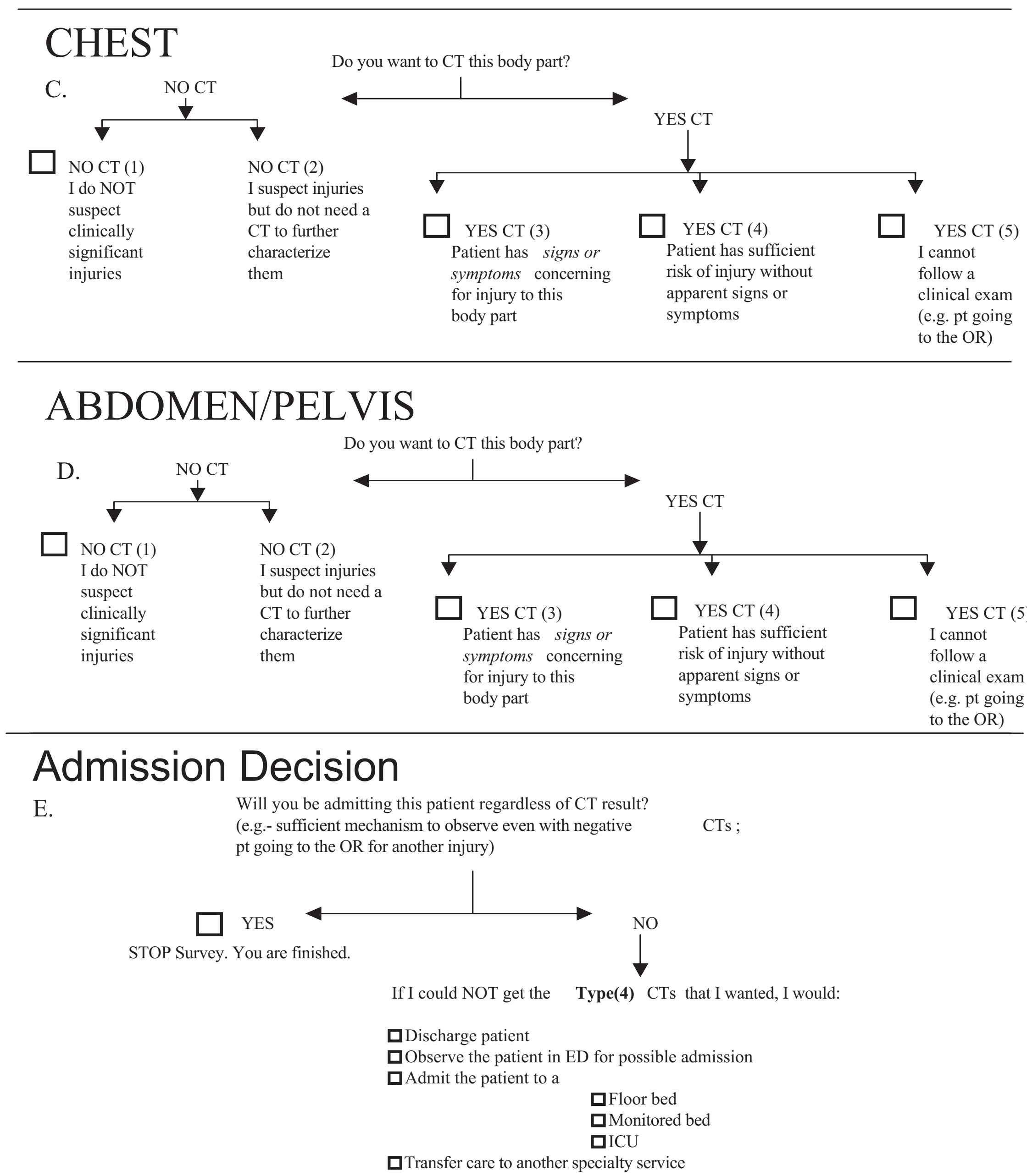
YES CT

☐ YES CT (3) Patient has *signs or symptoms* concerning for injury to this body part

☐ YES CT (4) Patient has sufficient risk of injury without apparent signs or symptoms

☐ YES CT (5) I cannot follow a clinical exam (e.g. pt going to the OR)

Supplementary Figure 1. Trauma attending survey form completed after patient evaluation but prior to completion of CT.



Supplementary Figure 1. Continued.

APPENDIX

This appendix contains supplementary methods, results and tables about secondary stratified analyses that were part of the study protocol but could not be fitted into the main paper. The supplementary methods also describe details about the radiological techniques used in our CT protocols.

Supplementary Methods

a) Radiographic methods

The non-contrast scans were performed with the following collimation: head (1.2 mm), neck (6 mm), and chest, abdomen and pelvis in continuity (1.2mm). CT angiography of the chest (0.6mm) and abdomen and pelvis (1.2 mm) were performed using non-ionic intravenous contrast. All scans were completed on a 16 slice helical scanner. Routine coronal and sagittal reconstructions of the cervical spine and CTA of the chest were performed as were sagittal-oblique reconstructions of the chest CTA, and coronal reconstructions of the contrast abdomen/pelvis CT.

b) Stratified analyses

i. Stratifying variables

As explained in the main paper, the senior physicians for each service completed a form (Supplementary Figure 1) designed to determine whether each scan was "desired" or "undesired." For each desired scan, each physician indicated whether the desire was based on symptoms and physical findings, mechanism alone, or inability to adequately monitor the patient (eg, getting a head CT on a patient about to undergo lengthy anesthesia for an orthopedic procedure). When a scan was deemed "undesired" the physician indicated whether this was because there was little or no chance of finding a clinically important injury, or because suspected injuries could be adequately assessed by other means (eg, a chest x-ray was sufficient to evaluate any injuries to the thorax).

ii. Stratified analyses

We examine the frequency of abnormal scans and resulting critical actions stratified by the reason that the scan was desired or undesired, whether the patient was pan- or selectively scanned, and whether the scan was desired by the emergency physician, the trauma surgeon, or both.

c) Supplementary Results

For both the emergency physicians and trauma surgeons the percentage of abnormal scans was higher when the scan was ordered for "signs and symptoms" (EM = 31% TS = 31%) than for "mechanism only" (EM = 15% TS = 14%) (Supplementary Table 7). Emergency physicians and trauma surgeons each rated a similar number of scans as "desirable" based on signs and symptoms (822 vs. 806), but the former were far less likely to consider a scan "desirable" based on mechanism only (961 vs. 1759). A critical action was also more common following a scan that was desired because of signs and symptoms (7%) than a scan desired for mechanism of injury (4%).

Abnormal scans and resulting critical actions were more common in patients who were pan-scanned (52%, 17%) than in patients who were scanned selectively (22%, 3%) (Supplementary Table 8). Six of the 101 (6%) patients who were selectively scanned had an abnormal undesired scan, none of which led to a critical action. In contrast, 89 (15%) of the 600 pan-scanned patients had an abnormal undesired scan including the 3 (.3%) that led to a critical action. Finally, there were only 3 critical actions in the 101 patients who were not pan-scanned. All three resulted from desired head CTs that showed intracranial bleeding in elderly patients.

d) Supplementary Comment

These stratified analyses provide evidence of the content validity of our study and the reasonableness of the hypothetical decisions made by the treating physicians. As would be expected, abnormal scans were more common in patients with signs and symptoms of injury than in those scanned only for mechanism (Supplementary Table 7). Furthermore, these findings provide some insight into the physicians' actual ability to risk-stratify patients as patients who were not pan-scanned had fewer injuries, fewer critical actions, fewer abnormal undesired scans, and no critical actions resulting from an undesired scan. Said another way, in their decision not to obtain a pan-scan the doctors demonstrated their ability to identify a group of patients at much lower risk for injury.

Supplementary Table 8. Abnormal scans and critical actions by ordering decision.

A. Emergency Physicians			
Scan desired?	N	Abnormal* N (%)	Critical Action N (%)
HEAD			
No, not clinically indicated	171	6 (4)	1 (1)
No, can get information without CT	7	0	0
Yes, for signs/symptoms	371	93 (25)	39 (11)
Yes, bad mechanism	149	8 (5)	2 (1)
Yes, patient cannot be monitored	3	0	0
* 75% (4 of 6) of abnormal undesired scans were considered important			
NECK			
No, not clinically indicated	153	3 (2)	0
No, can get information without CT	12	0	0
Yes, for signs/symptoms	150	17 (11)	6 (4)
Yes, bad mechanism	376	22 (6)	1 (0)
Yes, patient cannot be monitored	10	0	0
* 100% (3 of 3) of abnormal undesired scans were considered important			
CHEST			
No, not clinically indicated	356	60 (17)	2 (1)
No, can get information without CT	15	7 (47)	0
Yes, for signs/symptoms	133	75 (56)	19 (14)
Yes, bad mechanism	188	63 (34)	9 (5)
Yes, patient cannot be monitored	9	1 (11)	0
* 31% (21 of 67) of abnormal undesired scans were considered important			
ABDOMEN/PELVIS			
No, not clinically indicated	258	25 (10)	0
No, can get information without CT	9	1 (11)	0
Yes, for signs/symptoms	168	66 (39)	23 (14)
Yes, bad mechanism	248	52 (21)	24 (10)
Yes, patient cannot be monitored	18	2 (11)	0
* 81% (21 of 26) of abnormal undesired scans were considered important			
TOTAL			
No, not clinically indicated	938	94 (10)	3 (0.3)
No, can get information without CT	43	8 (19)	0
Yes, for signs/symptoms	822	251 (31)	87 (7)
Yes, bad mechanism	961	145 (15)	36 (4)
Yes, patient cannot be monitored	40	3 (8)	0
* 48% (49 of 102) of abnormal undesired scans were considered important			

B. Trauma Surgeons			
Scan desired?	N	Abnormal* N (%)	Critical Action N (%)
HEAD			
No, not clinically indicated	21	0	0
No, can get information without CT	1	0	0
Yes, for signs/symptoms	339	92 (27)	39 (12)
Yes, bad mechanism	337	13 (4)	2 (1)
Yes, patient cannot be monitored	3	0	1 (33)
NECK			
No, not clinically indicated	18	0	0
No, can get information without CT	1	0	0
Yes, for signs/symptoms	180	18 (10)	7 (4)
Yes, bad mechanism	496	24 (5)	0
Yes, patient cannot be monitored	6	0	0
CHEST			
No, not clinically indicated	96	3 (3)	0
No, can get information without CT	4	0	0
Yes, for signs/symptoms	132	73 (55)	16 (12)
Yes, bad mechanism	455	130 (29)	14 (3)
Yes, patient cannot be monitored	14	0	0
*33 % (1 of 3) of abnormal undesired scans was considered important			
ABDOMEN/PELVIS			
No, not clinically indicated	54	1 (2)	0
No, can get information without CT	3	0	0
Yes, for signs/symptoms	155	67 (43)	24 (16)
Yes, bad mechanism	471	75 (16)	23 (5)
Yes, patient cannot be monitored	18	3 (17)	0
* 100% (1 of 1) of abnormal undesired scans were considered important			
TOTAL			
No, not clinically indicated	189	4 (2)	0
No, can get information without CT	9	0	0
Yes, for signs/symptoms	806	250 (31)	86 (7)
Yes, bad mechanism	1759	242 (14)	39 (4)
Yes, patient cannot be monitored	41	3 (7)	1
* 50 % (2of 4) of abnormal undesired scans were considered important			

Supplementary Table 9. Abnormal scans and critical actions in pan- and selectively scanned patients.

A. Scans completed, N

	Head	Neck	Chest	Abdomen/Pelvis	Total scans
Pan-scan	600	600	600	600	2,400
Selective	83	80	9	43	215
Total	683	680	609	643	2,615

B. Abnormal scans: pan vs. selective scanning, by scan, N, (%)

	Head	Neck	Chest	Abdomen/Pelvis	Total
Pan-scan	96 (16)	38 (6)	203 (34)	138 (23)	475 (20)
Selective	11 (13)	4 (5)	3 (33)	8 (19)	26 (12)

C. Critical actions: pan vs. selective scanning, by scan, N, (%)

	Head	Neck	Chest	Abdomen/Pelvis	Total
Pan-scan	39 (7)	7 (1)	30 (5)	47 (8)	123 (5)
Selective	3 (4)	0	0	0	3 (1)

D. Abnormal scans and critical actions: pan vs. selective scanning, by person, N, (%)

	Abnormal scans	Critical Actions
Pan-scan	312 (52)	99 (17)
Selective	22 (22)	3 (3)

E. Abnormal scans and critical actions in undesired scans: pan vs. selective scanning, by person, N, (%)

	Abnormal scans	Critical Actions
Pan-scan	89 (15)	18 (20)
Selective	6 (6)	0