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Evidence-based guidelines are equivalent to a liberal computed tomography scan protocol for initial patient evaluation but are associated with decreased computed tomography scan use, cost, and radiation exposure

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Abstract

BACKGROUND—We hypothesized that trauma patient evaluations using evidence-based treatment guidelines (evidence-based group [EBG]), which include serial examinations and limited computed tomography (CT) scans in an established trauma center, would be associated with equivalent outcomes but with decreased CT scan usage, decreased cost, and less radiation exposure compared with a liberal CT scan approach (conventional group [CONV]).

METHODS—Fifteen evidence-based treatment guidelines were developed using published literature and in collaboration with other institutional departments. These were implemented on July 1, 2010. Prospectively collected data during a 4-month period were compared with a similar period in 2008 when CONV was used.

RESULTS—In 2010 (EBG), there were 611 patients compared with 612 in 2008 (CONV). Their average Injury Severity Score was 11.93 versus 8.77 ($p < 0.0001$), and the total CT scans were 757 and 1194, respectively ($p < 0.001$). The average APACHE II and hospital length of stay did not significantly vary. No missed or delayed injuries were identified. Estimated CT scan charges were \$1,842,534 versus \$2,935,024. The average number of scans per patient were 1.2 (EBG) versus 1.9 (CONV). Regarding radiation dosimetry, the estimated average computed tomography dose index (CTDI) per patient were 36.7 versus 53.31 mGy, and the estimated average dose-length product per patient were 889.91 versus 1364.11 mGy·cm.

CONCLUSION—EBG, including serial examinations, provided equivalent diagnostic data to CONV for initial workup but reduced CT scan usage, CT scan charges, and average radiation exposure per patient. This strategy may be beneficial in institutions where serial monitoring can be assiduously provided.

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AUTHORSHIP

E.M., S.A., T.D., A.G., J.A., and P.B. designed the study and implemented and the study guidelines. E.M., D.K., and A.S. managed the data collection; B.L. determined the average radiation dosages. E.M., S.A., P.B., and B.L. prepared the manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

Keywords

Guidelines; CT scan use; cost; radiation exposure

Trauma patient evaluation is very difficult even under the best of circumstances. Physical examination in patients with distracting injuries can be unreliable and warrants the use sophisticated adjunctive tests to identify clinically significant injuries. Computed tomography (CT) scan is an invaluable tool to identify all injuries. Because of this, CT scan use has become ubiquitous in trauma patient management.

More recently, fear of radiation exposure has tempered CT scan usage.¹ With the subsequent generations of CT scan imaging, there has been an incremental increase in the dose of radiation given to each organ system, which increases lifetime risk of developing a malignancy. In addition, the cost of these modalities is becoming realized. This is especially troublesome in economically threatened facilities or safety net hospitals.

The purpose of this article was to determine if a patient-centered approach on multiple evidence-based trauma guidelines could provide clinical equivalent care while reducing cost and radiation exposure compared with a liberal CT scan approach.

PATIENTS AND METHODS

Boston Medical Center, a 547-bed American College of Surgeons Committee on Trauma Level I trauma facility, is one of two safety-net health care systems in eastern Massachusetts. Annually, 2200 trauma patients are admitted, including 80% of Boston's penetrating trauma. The Boston Medical Center trauma registry has been in place since 1992 and is updated daily.

Inclusion criteria included trauma patients 16 years and older who survived more than 24 hours. Missed injuries included those that were identified after discharge. Unfortunately, a delay of diagnosis could not be determined in either group due to the trauma registry recording only the presence of an injury, but not time of discovery. The guidelines constructed included serial physical examination, meaning that the subsequent identification of injury was not considered delayed.

Normal trauma patient management includes ATLS Guidelines in the emergency room and a subsequent tertiary examination within 8 hours of presentation. Before 2009, CT scans were ordered based on trauma experience, current literature, and mechanisms of injury. Trauma sets encompassed several body regions that may have associated injuries.

In the study period, evidence-based trauma guidelines were constructed to decrease patient radiation exposure and cost. The evidence-based guidelines developed included blunt cerebrovascular injuries, electrical injuries, traumatic brain injury/blunt head injuries, blunt cervical spine injuries, penetrating extremity injuries, emergency department thoracotomies, mangled extremity, penetrating rectal injuries, hypothermia, blunt abdominal trauma, penetrating abdominal trauma, blunt splenic injury, blunt chest trauma, penetrating chest trauma, and the intoxicated trauma patient. These algorithms were constructed to serve as

guidelines based on the best available evidence; however, clinical judgment was allowed to supersede the guidelines.

Compliance with the algorithms was initially assessed by a review of the care and treatment choices each patients received during scheduled morning meetings. After a total of 15 algorithms were implemented and the education process was completed, a reeducation process was performed by frequent lectures by a surgical attending (EJM) to the house officers and attending trauma surgeons. Moreover, assurances that serial examinations were being performed (as part of a treatment guideline) were additionally analyzed using impromptu evaluations and spot checks of patient care at various times during their hospital stay. If the patient did not undergo imaging, he would be admitted for observation, which included serial examinations. If the patient's condition deteriorated, appropriate CT scans would be obtained and the attending surgeon notified. Compliance with the algorithms was reviewed and recorded daily.

Trauma registry data obtained from sequential patients admitted from July 1, 2010, to October 31, 2010 (evidence-based group [EBG]), were compared with data obtained to those patients admitted from July 1, 2008, to October 31, 2008 (conventional group [CONV]). The groups were compared based on the Injury Severity Score (ISS), the APACHE II scores for patients admitted to the surgical intensive care unit (ICU), the mechanism of injury, the mortality, the number of brain, chest, and abdomen/pelvis CT scans performed, the number of ICU admissions, the ICU length of stay, the hospital length of stay, the complications, and the 30-day readmissions. Also, attending surgeons, house officers, and ancillary staff were queried as to possible barriers to the successful implementation of the guidelines.

The estimated radiation dose per patient was calculated, which equaled the percentage of brain CT scans (average brain radiation dose) plus the percentage of chest CT scans (average chest radiation dose) plus the percentage of abdomen/pelvis CT scans (average abdomen/pelvis radiation dose). The average radiation dose for each body region was obtained from the Medical Physics Division (Department of Radiology). The average radiation dose for CT scans at our institution is as follows: brain, 51.2 mGy (CTDIvol) and 872 mGy·cm (dose-length product [DLP]); chest, 15 mGy (CTDIvol) and 524 mGy·cm (DLP); and abdomen/pelvis, 15 mGy (CTDIvol) and 725 mGy·cm (DLP). These average radiation doses are 31.7% and 40% of the established guidelines of the American College of Radiology (ACR) in CT scan radiation dose for adult head (75 mGy) and abdominal examinations (25 mGy), respectively (ACR Accreditation Program Requirements, revised, 10–14–2010).

The gross charges for these CT scan of each body region were obtained and added together to be the total charge for that period. The total charges do not include CT angiogram. Moreover, actual hospital costs could not be determined because of the unpredictable fluctuations in hospital reimbursement.

RESULTS

During the 2008 study period (CONV), 612 patients were evaluated compared with 611 during the 2010 period (EBG; Table 1). The patient's are well matched based on age

(CONV, 42.08 years; 95% confidence interval [CI], 40.56–43.60 vs. EBG, 40.7 years; 95% CI, 39.24–42.26; $p = 0.19$), average APACHE II score (CONV, 8.29; 95% CI, 7.3–9.27 vs. EBG, 8.3; 95% CI, 7.38–9.27; $p = 0.97$), average hospital length of stay (CONV, 5.86; 95% CI, 5.22–6.50 vs. EBG, 5.31; 95% CI, 4.67–5.95; $p = 0.23$), ICU length of stay (CONV, 6.23; 95% CI, 5.1–7.36 vs. EBG, 6.21; 95% CI, 5.14–7.27), and number of ICU admissions (CONV, 200 vs. EBG, 197). There is a statistically significant higher ISS of patients in the EBG compared with the CONV group (CONV, 8.77; 95% CI, 8.07–9.47 vs. EBG, 11.93; 95% CI, 10.99–12.87; $p < 0.0001$). There was no statistically significant difference in the mortality between the two groups (CONV, 4.41% vs. EBG, 5.73%; $p = 0.29$).

The total number of CT scans is listed in Table 2. There was a statistically significant reduction for CT scans in the EBG compared with the CONV group. Overall, there is a decrease in the average number of scans per patient; specifically, there were 1.2 CT scans per patient (EBG) versus 1.9 CT scans per patient (CONV). The estimated total radiation exposure per patient of the CONV group was 53.31 mGy (CTDI) and 1364.11 mGy·cm (DLP) versus 36.7 mGy (CTDI) and 889.11 mGy·cm (DLP) in the EBG group. This represents an estimated 33% reduction in total radiation exposure per patient and a 37% reduction in the EBG compared with the CONV group (Table 3).

Tables 4 and 5 list the complications and the 30-day readmissions for each cohort, respectively. There are significantly more complications and 30-day readmissions in the EBG group. The “other miscellaneous” complications in Table 4 include patient readmissions for headache, nausea and vomiting, dizziness of unclear cause, repeat fall at home, return to the hospital after leaving against medical advice, pain, poor oral intake, failure to thrive, wound infection, and persistent pleural effusion.

There were no missed injuries identified in either group. The perceived barriers to implementing the trauma guidelines are listed in Table 6.

DISCUSSION

Our data demonstrate that an evidence-based approach to direct the use of CT scan has clinical equivalency to a system of liberal CT scan usage, improving cost efficacy and reducing radiation exposure despite treating patients more injured than the historical controls (CONV). Likely, the increased attending involvement, and other advances in trauma care, contributes to these findings.

Missed injuries remain a significant concern when excluding liberal CT scan usage. Self et al² evaluated 650 patients undergoing cranial CT scans after blunt trauma and examined associated intrathoracic, abdominal, or pelvic injuries. They found that 173 patients had unexpected findings in the chest, abdomen, or pelvis. We think, however, that their true number of missed injuries is not adequately described. Anecdotal usage of CT scan by physicians also precludes study clarity. Perhaps a protocolized system would have minimized their radiographic examination as well.

Salim et al³ performed a retrospective review to determine the efficacy of a liberal whole body imaging. Five hundred ninety-two whole body scans were performed on the basis of

the mechanism of injury, and an additional 408 whole body scans were performed because of a depressed level of consciousness. They reported that clinically significant abnormalities were found in 3.5% of the head CT scans, 5.1% of the cervical spine CT scans, 19.6% of the chest CT scans, and 7.1% of the abdominal CT scans, resulting in treatment changes in 18.9% of patients. These researchers concluded that the use of whole body scan based on mechanism is warranted because clinically significant abnormalities were not uncommon. However, they also found that 96.5% of CAT scans of the head, 94.9% of cervical spine, 80.4% of the chest, and 92.9% of abdominal CT scans would be normal. Therefore, it seems that many patients will need to be burdened with the exposure and cost of a CT scan to identify the minority of patient with injuries. From the retrospective nature of this research, one cannot conclude that this would be superior to a selective EBGs approach. Given our findings, we think that a selective approach, which includes serial physical examinations as well as a tertiary survey, will identify all clinically significant injuries.

Publications from the Netherlands have also supported the routine use of CT scans in the evaluation of blunt trauma patients. Their research states that the routine use of CT scan is superior to a selective approach in identifying injuries of the abdomen, pelvis, lumbar spine,⁴ chest,⁵ and thoracoabdominal regions.⁶ However, in each of these studies, no true selective treatment group was ever developed. The conclusions were based on injuries that would have been missed if a theoretical selective approach would have been used. Therefore, it is unclear how many of the detected injuries would have been identified if a selective CT scan algorithm was used. Interestingly, these authors have developed a diagnostic algorithm for the selective use of CT scan of the abdomen.⁷ These authors admit that “evidence-based guidelines that reduce medical costs and unnecessary radiation exposure are required to improve trauma care.” We agree with this assessment.

Greishop et al⁸ performed a retrospective review of 1096 blunt trauma patients to determine if there were any identifiable conditions other than an abnormal abdominal examination that were associated with occult intra-abdominal injury and therefore warrant abdominal CT scans. Only two risk factors, chest injury and gross hematuria, were associated with a statistically significant increased risk of intra-abdominal injury. Therefore, the authors concluded that CT scanning is warranted in patients with an abnormal abdominal examination or either chest injury or gross hematuria after blunt trauma but not in patients with a normal examination and neither of the risk factors.

Kokabi et al⁹ retrospectively evaluated 106 patients who underwent CT scans of the cervical spine to determine if fewer scans could have been performed if published clinical guidelines were followed. They concluded that 57 scans could have been avoided without any detrimental effects. In a comparably designed study, Garber et al¹⁰ published similar findings.

No missed injuries were found in either the CONV or the EBG during our study. This is likely due to the study design. We had attempted to capture any potential missed injuries by evaluating the overall complication rate as well as the 30-day readmissions for each group. There were significantly more complications and readmissions in the EBG group compared with the CONV group (see Tables 4 and 5). We think that the increased complication rates

and the 30-day readmissions are based on two factors. First in 2009, we expanded to the types of complications captured within the trauma registry. In addition, we think that there has been a Hawthorne effect in that we have increased the capture of complications and the 30-day readmissions from our registry during the study. It is possible, nonetheless, that some patients did experience missed injuries, but they were subsequently evaluated at another facility.

It is possible that, if we went back to evaluate the complications in the CONV with the expanded complication profile, we might see a greater number of complications in this group. However, our current limitations in resources and personnel preclude such a review. Therefore, we must use the trauma registry data at our disposal. Moreover, although we cannot demonstrate causality between the higher ISS and the higher complication rate in the EBG group, we think that there seems to be an association between these two factors. Moreover, we have carefully reviewed each of the cases of the EBG group in which patients had complications or were readmitted. In no case did we identify any injuries that were missed during the trauma evaluation or subsequent workup. As is demonstrated in Table 5, the reason for readmission is infectious in most cases, with the remainder representing common syndromes that occur after a significant injury.

The use of a liberal CAT scanning protocol, however, does not itself guarantee that there will be no missed injuries. Lawson et al¹¹ had previously demonstrated that even with a protocol of a “trauma scan” for blunt trauma, there was a delay of diagnosis in 1.84% of patients, including one death. The authors concluded that trauma scans were “an effective way evaluating the trauma patients but that a high index of suspicion and a tertiary survey must remain a mainstay of therapy.” During our study, all patients in the EBG group who did not have an indication for a CT scan at the time of initial evaluation were admitted for close monitoring, which included serial examinations as well as a thorough tertiary survey to assess for any occult injuries.

Other researchers have also demonstrated that liberal CT scan policy may not avoid missed injuries. At the AAST conference in 2010, Dr Karina McArthur from the Washington Hospital Center presented their results of a retrospective review of 3223 patients who were treated with a selective protocol.¹² These researchers identified 23 patients with missed injuries, of whom 16 patients (69%) had appropriate CT scans performed.

Recently, there has been increasing concern about the long-term health effects of radiation from the CT scans. Whereas in 1991 only 0.4% of all cancers in the United States could be attributed to radiation from CT scans, today the estimate is 1.5% to 2.0%.¹ Although multifactorial, this increase is partly due to the dramatic increase in the use of CT scan during this period as well as the increase doses of radiation associated with newer generations of CT scans. In 1991, Gray et al^{13,14} from ACR estimated the risk of cancer death as 12.5/10,000 for each CT scan of the abdomen. More recently, Brenner and Hall¹ estimated that the risk is much lower, with the risk of death from lung cancer of a 40-year-old patient exposed to 10 mGy of radiation to be 175/1,000,000 (0.0175%) and from colon cancer as 100/1,000,000. However, these risks increase dramatically in younger patients. Smith-Bindman et al¹⁵ estimated the risk of developing cancer in a 20-year-old woman

undergoing a coronary CT angiogram to be approximately 1 in 150. Other researchers¹⁶ have estimated that the overall risk to be approximately 1 in 2000. This is sobering information given the fact that we performed approximately 3700 CT scans for trauma in 2008. This was reduced to approximately 1800 in 2010. Our results reveal an estimated 33% reduction in radiation exposure in the EBG compared with the CONV group. Moreover, these results are supported by Deunk et al⁷ who estimated a 26% reduction in radiation exposure using a selective diagnostic algorithm.

Several investigators have attempted to include the hospital charges from radiographic studies as part of their evaluation. In their presentation at the AAST in 2010, McArthur¹² demonstrated that by using a selective CT scan approach over a pan-scan approach, there was an estimated savings of \$1,004,702 during a 26-month period. Furthermore, Deunk et al⁷ thought that their facility would realize a 44% reduction in radiological costs with a selective CT scan approach to the abdomen. Contrary to this, Lawson et al¹¹ found that a “trauma-scan” approach would save approximately \$1593 per patient compared with a selective model based on charge “bundling.” We think this estimation may not be valid, however, because the patients in the selective group may require fewer studies and therefore fewer charges.

Using an evident-based selective CT scan model, we found a 37% reduction in the hospital charges compared with the CONV group. We acknowledge that CT scan charge reduction is not a succinct, clear measure of cost savings. However, the ability to directly compare the hospital costs between the two groups and to determine what effect, if any, this one intervention had on overall costs was not feasible. Therefore, we decided to compare hospital charges because this has been used as a surrogate marker by other investigators^{17,18}

Multiple barriers against the implementation of the EBG method, whether real or perceived, were identified during the study. Overall, one must have trust in the system in which one is practicing. The EBG method may not be right for each individual facility. Our study was conducted in a well-developed Level I trauma system. Other centers may think that the liberal, “trauma-scan” approach is more appropriate in their facility because it does not have all these capabilities. Each practitioner must be able to make a risk/benefit assessment for his patient in their specific environment to determine which method to employ.

To this end, every clinician must determine what is his or her tolerance toward diagnostic uncertainty or not identifying every injury. Given that none of the complications or 30-day readmission was due to a missed injury in the EBG cohort, we think that we have identified all the clinically significant injuries. Undoubtedly, there may have been additional injuries identified if we were able to subsequently performed whole body scans on all the patients in the EBG group. However, we also think that this additional injury would have a negligible effect on the overall patient care.

In conclusion, the EBG approach was clinically equal to the CONV group for the identification of injuries but at a reduced radiation risk to the patient and a reduction in hospital charges. As stated in the “green book” of the American College of Surgeons, *Resources for Optimal Care of the Injured Patient, 2006*, “For, in the era of health care

reform, we not only must strive for optimal care but we also must try to provide this optimal care in a cost effective manner.”¹⁹

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TABLE 1

Overview of Patients

	CONV	EBG
Total no. admissions	612	611
Average age	42.08	40.7
Average ISS	8.77	11.93 ($p < 0.001$)
Average APACHE	8.29	8.3
Average hospital length of stay (days)	5.86	5.31
ICU admissions	200	197
Injuries		
Penetrating, %	21.1	21.28
Blunt, %	78.9	78.72
Average mortality, %	4.41	5.73
Complications (number)	42	75

TABLE 2

Imaging

Imaging	CONV	EBG	No. Absolute Difference	Reduction, %
Brain CT scan	414	309	105	25 [*]
Chest CT scan	365	189	176	48 [*]
Abdomen/pelvis CT scan	386	239	147	38 [*]
CT angiogram	29	20	9	31
Total	1194	757	437	37 [*]

^{*}
 $p < 0.001$.

TABLE 3

Average Hospital Charge of CT Scan

Study	Hospital Charge per Scan, \$	CONV, \$	EBG, \$	Absolute Difference, \$	Reduction, %
Brain	1720	712,080	531,489	180,591	25
Chest	1766	644,590	333,774	310,816	48
Abdomen/pelvis	4089	1,578,354	977,271	601,083	38
Total		2,935,024	1,842,534	1,092,490	37

TABLE 4

Complications

Complication	CONV, n = 42	EBG, n = 75
Stroke/CVA	2	1
Respiratory failure/SOB/PNA	15	20
UTI	3	3
Pneumothorax/hemothorax	4	1
MI/cardiac arrest/arrhythmia	4	8
Coagulopathy	1	2
DVT	2	2
Acute renal failure	1	3
Empyema	—	1
Bleeding	1	1
Maxillary artery pseudoaneurysm	—	1
Seizure	1	1
Other neurologic	1	1
Mandible abscess	—	1
Intra-abdominal abscess	—	3
Abdominal compartment syndrome	—	2
Extremity compartment syndrome	—	2
Drug withdrawal	—	13
Tracheoesophageal fistula	—	1
Pulmonary embolism	—	3
Other miscellaneous	7	17

CVA, cerebrovascular accident; SOB, shortness of breath; PNA, pneumonia; DVT, deep vein thrombosis.

TABLE 5**30-Day Readmissions**

CONV	
Patient	Indications
1	Wound infection
2	Poor oral intake, pain, urinary tract infection
3	Persistent pneumothorax
4	SOB, respiratory failure with pleural effusion 21 days after MVA
5	SOB, respiratory failure with pleural effusion 9 days after SW to chest
EBG	
Patient	
1	Intra-abdominal abscess after penetrating bowel injury
2	Intra-abdominal abscess 2 weeks after penetrating bowel injury
3	Headache 1 month after assault, SDH Dx at time of assault
4	Nausea and vomiting after injury day 3
5	Fall at home
6	UTI, tracheoesophageal fistula after surgical repair for penetrating injury
7	Pneumonia, alcohol withdrawal after leaving AMA
8	Mandible space abscess
9	Maxillary artery pseudoaneurysm 27 days after GSW to face
10	Empyema
11	Dizziness with normal ct brain
12	Hemothorax/pneumothorax after injury day 7
13	Intra-abdominal abscess
14	Pulmonary embolism

MVA, motor vehicle accident; SW, stab wound; SDH Dx, subdural hematoma diagnosis; AMA, against medical advice.

TABLE 6**Possible Barriers to Implementation of EBGs**

Clinician tolerance toward diagnostic uncertainty
Trust in system
Concern about medical-legal implications
Emergency department throughput
Fixed costs in capital investments

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