

Quantitative Assessment of Diagnostic Radiation Doses in Adult Blunt Trauma Patients

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Study objective: Many emergency departments and trauma centers utilize extensive radiologic studies during the assessment of trauma patients. A point of concern arises about the possible biological effects of these cumulative radiation doses. The objective of this study is to determine the amount of ionizing radiation received by adult blunt trauma patients at a Level I trauma center during the first 24 hours of their care.

Methods: This nonconcurrent case series reviewed the first 100 consecutive adult blunt trauma patients who presented to a Level I trauma center in 2006. All patients met hospital standards for the less acute major triage criteria. Individual radiation dose reports calculated by the computed tomography (CT) scanner were used to determine the radiation doses from each CT procedure. Standardized tables were used to determine radiation dose for plain radiographs. The median effective dose of radiation (millisieverts) was calculated for the first 24 hours of hospitalization.

Results: A total of 100 eligible patients presented between January 1, 2006, and March 20, 2006. Eighty-six patients had complete radiologic records available. The median age was 32 years, with an intraquartile range of 23 to 46 years; the median Injury Severity Score was 14, with an intraquartile range of 9 to 29; and the median number of CT scans was 3, with an intraquartile range of 3 to 4. The median effective total dose of ionized radiation was 40.2 mSv, with an intraquartile range of 30.5 to 47.2 mSv. A dose of 40.2 mSv is the equivalent of approximately 1,005 chest radiographs.

Conclusion: Trauma patients meeting the less acute major triage criteria are exposed to clinically important radiation doses from diagnostic radiographic imaging during the first 24 hours of their care. [Ann Emerg Med. 2008;52:93-97.]

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INTRODUCTION

Background

Emergency physicians and trauma surgeons extensively use radiographic studies in the acute evaluation of seriously injured blunt trauma patients. At the study site, major trauma patients commonly receive plain radiographs of the chest and pelvis shortly after presentation to the emergency department (ED)/trauma center, followed by computed tomography (CT) of the head, neck, chest, abdomen, and pelvis. This series of studies has been informally referred to as the "pan scan." In addition,

numerous radiographs of the extremities and spine may also be performed, depending on the injuries sustained.

Importance

The radiographic studies described above use ionizing radiation, and concerns have been expressed about the potential effects of ionizing radiation in health care settings.¹ There appears to be limited information in the medical literature that quantifies the dose of ionizing radiation delivered in the acute assessment of trauma patients.²⁻⁴ There has been some trauma-specific research that has used external dosimeters to estimate the radiation dose received during a trauma evaluation.⁵

Editor’s Capsule Summary

What is already known on this topic

Computed tomography (CT) is increasingly used in the routine evaluation of trauma patients. Ionizing radiation from CT can increase lifetime cancer risk, especially in the very young.

What question this study addressed

The radiation exposure incurred during the first 24 hours by blunt trauma patients at a single trauma center.

What this study adds to our knowledge

The median number of CT scans was 3, and the median total dose was 40.2 mSv, equivalent to 1000 chest radiographs. CT of the chest-abdomen-pelvis contributed the greatest radiation doses of all scans and radiographs.

How this might change clinical practice

Although radiographic studies are an important part of the trauma evaluation, they should be used judiciously, with the goal of minimizing the patient’s exposure to ionizing radiation.

Institutional Adult Trauma Alert Criteria

Level 1

- ◆ Hypotension/Shock (includes systolic blood pressure < 90)
- ◆ Gunshot to neck, chest, abdomen, groin
- ◆ Compromise of airway or ventilation or have high potential for same (includes inability to intubate)
- ◆ Traumatic cardiac arrest

Burns

- ◆ Any burn with systolic blood pressure <90
- ◆ Any burn with threatened airway patency

Level 2

- ◆ Significant neurologic injury (Glasgow coma score < 10) and potential for multisystem injury (motor vehicle accident or fall >15 feet)
- ◆ Intubated interhospital transport
- ◆ Flail chest
- ◆ Stab to torso
- ◆ Spinal injury
- ◆ History of hypotension but normal blood pressure at present
- ◆ Gunshot wound to proximal extremity (excluding groin)
- ◆ Crush injury to pelvis
- ◆ Amputation proximal to wrist or ankle
- ◆ Auto versus pedestrian
- ◆ Ejection from vehicle
- ◆ Neurovascular compromise of limb
- ◆ Two or more long bone fractures
- ◆ Patients who initially do not meet criteria for a trauma alert who decompensate after emergency department arrival

Burns

- ◆ >10% total body surface area, age >60 years
- ◆ >15% total body surface area, all others
- ◆ Burn patient intubated prior to arrival
- ◆ Burn patient with obvious, non-thermal injuries

Figure 1. Institutional adult trauma criteria.

A frame of reference for radiation exposure is important to better discuss this issue. The average person living in the United States receives approximately 3 mSv annually of background radiation.⁶ A person will typically receive 0.04 mSv during a chest radiograph and 0.02 mSv during a dental radiograph.⁷ The average radiation exposure for astronauts on the international space station is 174 mSv during a year.¹

Goals of This Investigation

The purpose of this study is to estimate the dose of radiation delivered to trauma patients during their initial evaluation. In contrast to previous studies, we used estimated radiation doses calculated by the CT scanner for each patient at the imaging procedure.

MATERIALS AND METHODS

Study Design and Setting

This study is a nonconcurrent case series. It was reviewed and approved by the institutional review board. The study site is a Level I trauma center based at an academic medical facility that treats 3,200 trauma patients a year. It has a multistate referral base and an air medical unit. The hospital ED has an annual census of more than 80,000 patients.

Selection of Participants

Patients were identified through the hospital trauma registry. Only adult patients were entered into the study. The study site uses a 2-tiered trauma triage system to triage patients with major trauma into severe criteria (Level I) or less severe criteria (Level II), according to out-of-hospital information. Both types of

patients are likely to have serious injuries. Patients who meet Level I trauma criteria often have more acute injuries than the patients triaged to the lower level and are more likely to leave directly for the operating room after a truncated evaluation. At the site studied, approximately 75% of trauma activations are Level II and 25% were Level I. The mechanistic and physiologic criteria used to define blunt trauma and Level II trauma are similar to those recommended by the American College of Surgeons and widely used at trauma centers throughout the country (Figure 1).

If the patient was an adult and was a Level II trauma victim with a blunt mechanism, then he or she was entered into the

study. If patients were younger than 18 years, Level I trauma victims, were victims of penetrating trauma, or did not meet Level II trauma activation criteria, then they were excluded from the study.

Methods of Measurement

In this study the effective dose for the entire body is measured in millisieverts, which is the unit commonly used to compare radiation exposure received during different procedures. For CT scans, this information was calculated with CT dose indexes calculated by the CT scanner for each scan. Calculations of the effective dose from plain film radiographs were achieved with the medical procedure radiation dose calculator and consent language.⁷ The medical procedure radiation dose calculator does not take into account the need for repeated exposures to secure a good image.

Data Collection and Processing

A single abstractor collected the data. The abstractor was trained in the data collection process by the principal investigators. The inclusion criteria are described above in the "Selection of Participants" section. The data were entered directly into a standardized spreadsheet. If there were dose reports on any procedures missing, then that subject was not included in the study. The principal investigators met with the abstractor several times throughout the study to ensure uniformity throughout the process. In addition, all CT scans that had radiation exposures near the extremes of the range were reviewed by the principal investigator. The abstractor was not blinded to the purpose of the study.

Data obtained from the trauma registry included demographics, date of admission, mechanism of injury, Injury Severity Score, and initial disposition from the ED/trauma center (including ICU, step-down unit, floor, home, morgue, and operating room). The radiographic studies included in the study were CT scans and plain radiographs. At the center studied, the trauma chest, abdomen, and pelvis protocols were considered a single study according to institutional practice. Fluoroscopy was not included because there were insufficient data in the medical record. A 24-hour period was chosen because the investigators were interested in the immediate postinjury evaluation. The investigators chose not to follow the patient for the entire hospitalization because there is likely a wide range in injury severity, comorbidities, and lengths of stay, which would confound the data. Also the types of studies carried out during a patient's initial assessment are likely to be less variable during the first 24 hours versus an entire hospitalization.

All CT scans were performed with a General Electric Light Speed VCT 64 slice scanner (General Electric Company, Fairfield, CT). Individual dose reports from each CT procedure were retrieved and reviewed. The dose report displays the dose length product index, which represents the integrated radiation dose for a specific CT examination. The CT scanner used was calibrated by a certified medical physicist using a phantom

Table. Median effective doses for specific CT studies.

Type of CT	Total Studies, No.	Median Effective Dose, mSv	25th To 75th Quintiles	Range, mSv
Head	87	3.0	2.8–3.2	0.9–6.1
Cervical spine	82	4.9	4.6–5.3	3.5–16
Chest/abdomen/pelvis*	84	26.1	18–31	8.2–52.7
Facial	22	1.4	1.3–2.0	1.1–5.1
CT neck angiography	11	2.9	2.8–6.5	2.3–29

*At the institution studied, all scans of the abdomen/pelvis for trauma included the chest.

model to ensure that the dose reports given by the scanner were correct. The dose length product was multiplied by conversion factors for specific areas of the body to determine the effective dose in millisieverts to the entire body.^{8,9}

Primary Data Analysis

The primary outcome of this study was the median effective dose of radiation received during the first 24 hours. Data were compiled into a spreadsheet (Microsoft Office Excel 2003; Microsoft Corporation, Redmond, WA), and descriptive analysis was performed using statistical software (GraphPad InStat version 3.06; GraphPad Software, San Diego, CA).

RESULTS

Eighty-six of these 100 patients had complete records available for review. The remaining 14 patients had incomplete or missing dose reports and were excluded. There were 68 men and 18 women. The median age was 32 years (range 18 to 86 years), and the median Injury Severity Score was 14 (range 1 to 48). Mechanisms of injury included 49 (58%) from motor vehicle crash; 11 (13%) from motorcycle, all terrain vehicle, or bicycle; 9 (10%) from fall; 8 (9%) from pedestrian versus automobile; and 9 (10%) from other. Disposition locations from the ED included 32 (37%) to the ICU, 26 (30%) to the floor, 21 (24%) to the operating room, 2 (2%) to the step-down unit, 3 (3%) to home, and 2 (2%) to the morgue.

Seventy-nine (92%) of the 86 patients had a full trauma "pan scan," which included CT of the head, cervical spine, and chest/abdomen/pelvis. The median number of CT scans performed was 3 (range 2 to 10). Median dose equivalents for individual CT protocols ranged from 3 mSv for a head CT to 26 mSv for a chest/abdomen/pelvis CT. See the Table for a listing of effective radiation dose per individual type of CT study. The median number of plain radiograph studies performed was 9.5 (range 2 to 64), with a median total radiation exposure of 7.4 mSv. Three patients received repeated head CTs, and 1 patient received a total of 3 head CTs. Another patient received 2 chest/abdomen/pelvis CTs. The median effective total dose of ionized radiation was 40.2 mSv, with an intraquartile range of 30.5 to 47.2 (Figure 2).

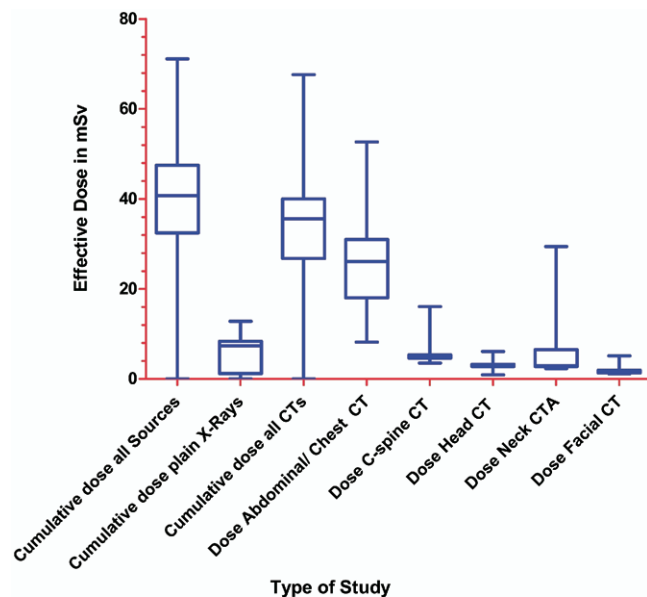


Figure 2. Box and whisker plot with median, 25th and 50th percentiles, and ranges for effective doses during first 24 hours (n=86 patients).

LIMITATIONS

Retrospective studies have limitations about missing data and the possibility of errors in data abstraction. This study includes data from only a single trauma center. Practice patterns may vary at other centers; however, this study provides an estimate of the radiation doses received by trauma patients undergoing each component of the scanning protocol used at our center. A multicenter study is needed to account for practice patterns at other institutions.

An additional limitation is that there are many variables that can affect the radiation exposure. The most important variable is the beam current, measured in milliamperes. This is, in effect, the amount of energy the machine is using during the scan, with higher beam current resulting in higher resolutions. Variables such as beam current can change between machines and among centers, limiting extrapolation of these findings.

The data presented may underestimate the total radiation exposure per patient because it does not include radiation dose for referring hospitals or radiation received from fluoroscopy. Further, we evaluated only those radiologic studies performed during the first 24 hours of care. Unstable trauma patients, who are more common among the Level I trauma patient population, often require immediate operative management. These patients may have lower levels of radiation exposure because of truncated initial evaluations and were not studied. Last, the determination of radiation dose equivalent was based on CT dose index estimations. It is possible that other techniques allow a better estimation of radiation exposure for each organ and the whole body.

DISCUSSION

The study data clearly demonstrate that blunt trauma patients are exposed to significant amounts of radiation during their initial evaluation. The median radiation exposure of the patients in the study was 40.2 mSv, or 1005 chest radiograph equivalents. This demonstrates that the radiographic evaluations performed at many EDs and trauma centers expose trauma patients to a significant amount of ionizing radiation compared with the normal background effective radiation dose of 3.0 mSv received by an individual in a year.⁶ The median effective radiation dose in our study was higher than the doses observed in the external dosimeter study mentioned in the Introduction. It is difficult to compare these 2 studies because external dosimeters estimate only surface exposure. The CT dose index method is likely better able to estimate internal and external exposures.

The National Academies seventh report on biologic effects of ionizing radiation states that of 100,000 people exposed to a dose of 100 mSv, there would be an additional 800 cases of cancer.⁶ This risk is linear, suggesting that the median dose of 40.2 mSv observed in this study would contribute to an additional 322 cancer cases per 100,000 subjects exposed. Age is an additional variable because the younger the person, the greater the chance that radiation exposure could lead to malignancies.

It is widely accepted that multitrauma patients are at high risk of life-threatening injuries, and this clearly justifies aggressive investigation to identify and intervene in such injuries, even if the investigation entails some risk. Our data contribute an initial assessment of the amount of ionizing radiation exposure occurring among trauma patients at one large academic center. If our data are confirmed at other centers, approaches should be designed to minimize the risks as much as possible. Approaches to decreasing ionizing radiation exposure may include reducing repeated imaging studies, using lower-dose radiologic imaging techniques, using alternative imaging methods that do not use ionizing radiation (ultrasonography, magnetic resonance imaging), and returning to an increased reliance on clinical examinations.

Trauma patients are exposed to significant radiation doses from diagnostic radiographic imaging. Physicians should consider the risks and benefits of exposure to these levels of ionizing radiation.

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Author contributions: JEW and JWH initially developed the idea for the project and developed the methods. JEW also oversaw the entire project and contributed greatly to the article. WPB helped mentor the project and better develop research methods and contributed to writing the article. MJH contributed throughout the process, collected the data, helped analyze the data, and helped write the article. RCW was extremely important in providing the physics background needed for this project and was also important in maintaining the accuracy of our methods and reviewing our work. All authors contributed to the final article. JEW takes responsibility for the paper as a whole.

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