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Original Contribution

# Utilization of chest CT for injured patients during visits to U.S. emergency departments: 2012–2015

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ABSTRACT

*Introduction:* Increased use of computed tomography (CT) during injury-related Emergency Department (ED) visits has been reported, despite increased awareness of CT radiation exposure risks. We investigated national trends in the use of chest CT during injury-related ED visits between 2012 and 2015.
*Methods:* Analyzing injury-related ED visits from the 2012–2015 United States (U.S.) National Hospital Ambulatory Medical Care Survey (NHAMCS), we determined the percentage of visits that had a chest CT and the diagnostic yield of these chest CTs for clinically-significant findings. We used survey-weighted multivariable logistic regression to determine which patient and visit characteristics were associated with chest CT use.
*Results:* Injury-related visits accounted for 30% of the 135 million yearly ED visits represented in NHAMCS. Of these visits, 817,480 (2%) received a chest CT over the study period. The diagnostic yield was 3.88%. Chest CT utilization did not change significantly from a rate of 1.73% in 2012 to a rate of 2.31% in 2015 ($p = 0.14$). Multivariate logistic regression demonstrated increased odds of chest CT for patients seen by residents versus by attendings (adjusted odds ratio [AOR] 2.08, 95% confidence interval [CI] 1.41–3.08). Patients aged 18–59 and 60+ had higher AORs (5.75, CI 3.44–9.61 and 9.81, CI 5.90–16.33, respectively) than those <18 years of receiving chest CT.
*Conclusions:* Overall chest CT utilization showed an increased trend from 2012 to 2015, but the results were not statistically significant.



## 1. Introduction

Injuries and trauma are among the most common reasons for visits to United States (U.S.) emergency departments (EDs). The use of computed tomography (CT) during visits to EDs has climbed steadily over the past 15 years. Although CT is exquisitely sensitive for detecting injury, most patients undergoing CT imaging have no clinically significant injury, leading to very low yields of current trauma CT protocols [1-3]. Increased CT use is associated with a number of problems, including greater exposure to ionizing radiation and increased healthcare costs [1,4].

Chest CT is one of the most commonly utilized CT modalities in the evaluation of patients presenting with traumatic injuries [2,5]. With the primary goal of guiding clinicians towards a paradigm of selective, rather than universal imaging, a number of clinical decision rules have been developed [5,6]. The NEXUS Chest CT decision instruments were prospectively derived and validated in cohorts consisting of over 12,500 adult patients and subsequently published in October 2013 [5]. While it will likely be years before the impact of these decision instruments is fully realized, currently, there is no baseline rate of chest CT use in trauma with which to compare this potential impact.

Up until 2012, national database information recorded CT use information only by general torso region without specific delineation of chest, abdomen and pelvis CT [1,4,7]. Examining this old data, Hussein et al. found that non-head CT use for injury-related visits significantly increased from 5.5% in 2007 to 7.3% in 2010, a relative increase of 47.3% [7]. Beginning in 2012, non-head CTs were differentiated by chest, abdomen/pelvis, and other/unknown, providing an opportunity to measure the utilization of specific imaging types. With this newer specific data, we sought to determine the baseline use of chest CT in injury-related visits nationally and to characterize trends in chest CT utilization over time. This information will help describe the magnitude of the issue of chest CT use in trauma, and gauge the potential impact of the NEXUS Chest CT decision instruments on this chest CT use.

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## 2. Methods

### 2.1. Study design, setting and population

We used data collected from the National Hospital Ambulatory Medical Care Survey (NHMACS) for the time-period between 2012 and 2015. NHAMCS is an annual, national probability sample of ambulatory visits to hospital-based EDs in the U.S. [8]. NHAMCS uses a four-stage probability sampling design, collecting a nationally representative sample of ED visits [8]. At each sampled hospital, trained hospital staff members monitored by the U.S. Census Bureau's agents complete a patient record form of each sampled visit abstracted from patient records during a randomly assigned 4-week reporting period. The study met criteria for exemption by our Institutional Review Board.

### 2.2. Study protocol

We restricted our analysis to visits that were related to an injury due to trauma, a variable that became available in NHAMCS starting in 2012. NHAMCS defined an injury-related visit based on the reason for visit, diagnosis, and cause of trauma. We abstracted several patient characteristics from NHAMCS including patient age (<18, 18–59, and >59 years), sex, race, insurance status, region, and provider type. Insured was defined as having private health insurance coverage, Medicare, Medicaid, or worker's compensation. Uninsured was defined as self-pay, no charge, charity, other, or unknown. Provider type was categorized as having been seen by an attending physician, resident physician (defined as intern or resident), or an advanced practice provider (physician assistant or nurse practitioner).

#### 2.2.1. Objective measures

We investigated national trends in the use of chest CT during injury-related visits to the ED during a 4-year period (2012–2015) with utilization rate as the primary objective. As secondary objectives, we determined diagnostic yield, defined as the proportion of injury-related visits in which patients receiving a chest CT had a significant chest injury diagnosis, and whether patient or visit characteristics were independently associated with chest CT use.

We defined "significant chest injury" diagnoses according to the International Classification of Diseases, 9th Revision (ICD-9) codes including: Closed fracture of three or more ribs (807.03–807.09), open fracture of rib(s) (807.10–807.19), open fracture of the sternum (807.3), fracture of flail chest (807.4), traumatic pneumothorax and hemothorax (860.xx), injury to heart and lung (861.xx), injury to other and unspecified intrathoracic organs (862.xx), injury to blood vessels of thorax (901.xx), and crushing injury of trunk (926.xx).

### 2.3. Data analysis

We calculated unweighted raw number of ED visits along with weighted national representative size and proportions. We assessed the yearly trends of chest CT utilization for injury-related visits. We used survey-weighted chi-square tests to assess for differences in the proportion of visits receiving chest CT across categories, and performed a survey-weighted multivariable logistic regression to assess whether patient or visit characteristics, such as age, were independently associated with chest CT use for injury-related visits.

We conducted all analyses using SAS 9.4 (Cary, NC) and incorporated NHAMCS complex survey design features including cluster, strata, and probability weights to produce nationally representative estimates. As recommended, we only provided estimates and analyzed data in which the cell sizes were equal to or exceeded 30 samples per cell [9]. A $p$-value < 0.05 was considered statistically significant.

## 3. Results

### 3.1. Study cohort

From 2012 to 2015, the NHAMCS included an unweighted total of 99,135 ED visits, representing a weighted sample of 135 million yearly ED visits. Of these, 40,242,437 yearly visits were injury-related. Overall, in the years 2012 to 2015, 817,480 (2%) of injury-related patient visits included at least one chest CT. Patient and visit characteristics are reported in Table 1.

### 3.2. Chest CT utilization and yield

Chest CT utilization for injury-related ED visits showed an increased trend during the study period (2012: 1.73%, confidence interval [CI] 1.17–2.30, 2015: 2.31%, CI 1.73–2.91, $p = 0.14$), but the results were not statistically significant (Fig. 1).

The diagnostic yield of chest CT for a significant chest injury diagnosis over the 4-year period was 3.88%. Because the number of significant chest injuries in each year had cell sizes <30 samples, we did not calculate yields for individual years.

### 3.3. Characteristics associated with chest CT

Several factors were significantly associated with an increased adjusted odds ratio (AOR) of a patient receiving a chest CT, including increasing age. Patients 18–59 years of age and 60 years and older had a higher AOR of receiving chest CT than patients <18 years of age (AOR 5.75, CI 3.44–9.61 and AOR 9.81, CI 5.90–16.33, respectively) of receiving a chest CT. In addition, patients seen by residents also had a higher odds ratio than patients seen primarily by an attending of receiving a chest CT (AOR 2.08, CI 1.41–3.08).

## 4. Discussion

In this analysis of national survey data, we delineated baseline chest CT use for the years 2012 to 2015, finding that 817,480 (2%) of injury-

**Table 1**
Relationship between patient and visit characteristics and chest computed tomography use during injury-related Emergency Department (ED) visits.

| | Unweighted ED visits | Weighted ED visits (thousands) | Adjusted odds ratio (95% CI) |
|---|---|---|---|
| Age | | | |
| <18 years | 7072 | 9591 | Reference |
| 18–59 | 18,934 | 25,187 | 5.75 (3.44–9.61) |
| >59 | 4152 | 5462 | 9.81 (5.89–16.33) |
| Sex | | | |
| Male | 15,881 | 20,775 | Reference |
| Female | 14,277 | 19,467 | 0.93 (0.69–1.24) |
| Race | | | |
| Non-Hispanic White | 18,900 | 25,245 | Reference |
| Non-Hispanic Black | 5726 | 7722 | 0.91 (0.63–1.31) |
| Other | 5532 | 7274 | 1.02 (0.72–1.44) |
| Insurance | | | |
| Uninsured | 7759 | 10,459 | Reference |
| Insured | 22,399 | 29,782 | 1.18 (0.85–1.65) |
| Provider | | | |
| Attending | 20,302 | 27,433 | Reference |
| Resident/intern | 2619 | 2990 | 2.08 (1.41–3.08) |
| PA/NP | 6479 | 8842 | 1.06 (0.71–1.59) |
| Region | | | |
| Northeast | 6403 | 7402 | Reference |
| Midwest | 7365 | 9526 | 0.74 (0.44–1.27) |
| South | 9986 | 14,244 | 1.06 (0.62–1.80) |
| West | 6404 | 9069 | 1.43 (0.82–2.51) |
| Total | 30,158 | 40,242 | |

PA = physician assistant; NP = nurse practitioner.

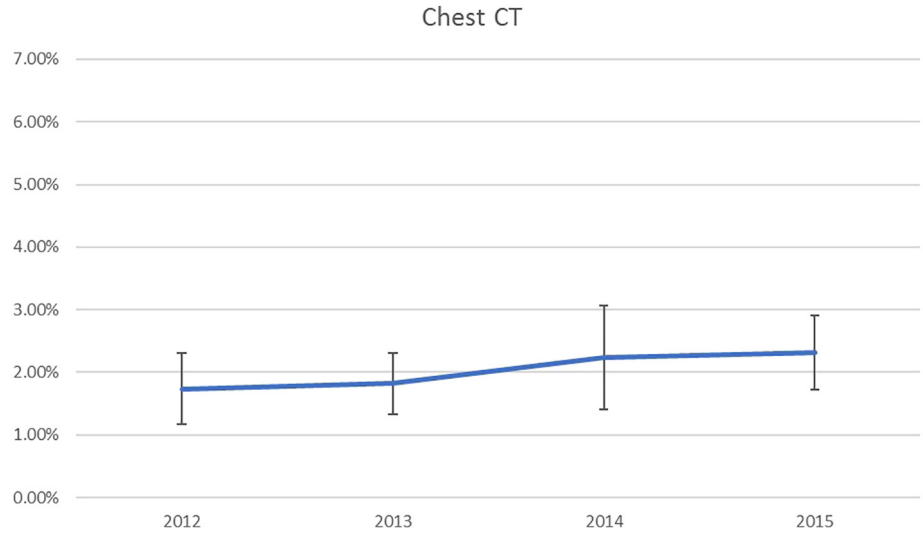


**Fig. 1.** Yearly computed tomography (CT) utilization for injury-related visits to Emergency Departments from 2012 through 2015 with 95% confidence intervals.

related visits included chest CT. We also found that there was no statistically significant increase in chest CT utilization for injury-related ED visits from 2012 compared to 2015, which was different than the increased rate of non-head CT use described in previous years [1,7].

The fact that we examined all injury-related visits and not just trauma activations explains the relatively low rate of chest CT use. Chest CT use may be plateauing due to several factors. Clinicians may be more aware of the costs and risks of CT imaging, especially the concerns related to radiation exposure. Clinicians may be incorporating a decision rule, such as the NEXUS Chest, to reduce unnecessary chest imaging in patients who suffered trauma [5]. In addition, even in severe trauma, there is research interest in determining which patients would benefit from selective CT scanning rather than whole body CT scanning in order to reduce radiation exposure [10,11].

The diagnostic yield of chest CT was 3.88% during the study period. Prior studies had shown increased utilization in advanced imaging with little to no change in diagnostic yield for certain disease processes [1,4,7]. However, our study shows that chest CT utilization has remained steady. The chest CT diagnostic yield was similar to another study which found a diagnostic yield for non-head CTs of 3.3–6.4% [7]. These relatively low diagnostic yields are in contrast to the higher yields (28.8%) of injury found in the NEXUS Chest study [5]. These differences likely arise from the different definitions of injury in the two studies, and spectrum bias in that the NEXUS Chest study cohort was primarily trauma activations – a more injured population. We were unable to compare trends in diagnostic yield of chest CTs from year to year due to small unweighted cell sizes for each year. However, this is the first analysis of nationally representative data which specifically looked at the diagnostic yield for chest CT among injury-related ED visits.

While insurance, race, and sex did not significantly effect chest CT utilization, patients seen by residents were more likely to receive a chest CT than patients seen primarily by an attending physician. While residents are supervised by attendings, residents may order more initial tests such as imaging than would attending physicians [12]. Other studies have also found that residents were associated with increased CT imaging utilization [1,7]. One potential explanation for this finding is that residents are primarily located in teaching hospitals.

Older patients had a higher AOR of receiving a chest CT than younger patients. This could be due to a lower threshold for ordering imaging by clinicians as older patients have limited cardiovascular reserve and more comorbidities, placing them at higher risk for complications associated with trauma [13]. Cancer risk due to radiation exposure is also of lessor concern for older patients. Finally, many decision rules use an age cutoff criteria [5,14,15]. The NEXUS Chest noted that a patient older than 60 years cannot be designated by the decision instrument as having very low risk for intrathoracic injury.

### *4.1. Limitations*

Our analysis is subject to the limitations intrinsic to data derived from the NHAMCS database, which provides visit-level data without the specific clinical characteristics necessary to adjust for severity of illness. As a result, we were unable to estimate only those trauma cases involving the chest. Although chest CT use may have been underreported, the rigor of the NHAMCS sampling framework makes this unlikely. In addition, it is unclear how many of these traumatic diagnoses could have been diagnosed by chest x-ray alone. It is also possible that clinically significant injuries discovered later during the hospital course and not recorded may have caused us to underestimate the diagnostic yield of chest CT. Despite these limitations, NHAMCS provides the best available data source to analyze practice variations and trends at a national level.

## 5. Conclusions

We have established a baseline use of chest CT in injury-related visits in the NHAMCS database of 2.0%. In contrast to statistically significant increases in general utilization of CT imaging during the time-period of 2007–2010 [1,7], chest CT use among injury-related ED visits has not significantly increased between 2012 and 2015. The diagnostic yield of chest CT for finding clinically significant injury was 3.88%.

**Summary conflict of interest statement**

No conflicts exist for BJY, RMR, AMP, DAP, DEB, or ASR.

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None.

**Prior abstract publication/presentation**

None.

## References


[1] Korley FK, Pham JC, Kirsch TD. Use of advanced radiology during visits to US emergency departments for injury-related conditions, 1998–2007. JAMA - J Am Med Assoc [Internet] 2010;304(13):1465–71 Available from: https://doi.org/10.1001/jama.2010.1408.

[2] Rodriguez RM, Baumann BM, Raja AS, Langdorf MI, Anglin D, Bradley RN, et al. Diagnostic yields, charges, and radiation dose of chest imaging in blunt trauma evaluations. Acad Emerg Med 2014;21(6):644–50.

[3] Murphy SP, Hawthorne N, Haase D, Chiku C, Wen J, Rodriguez RM. Low yield of clinically significant injury with head-to-pelvis computed tomography in blunt trauma evaluation. J Emerg Med 2017;53(6):865–70 [Internet]. Available from https://doi.org/10.1016/j.jemermed.2017.08.036.

[4] Venkatesh AK, Agha L, Abaluck J, Rothenberg C, Kabrhel C, Raja AS. Trends and variation in the utilization and diagnostic yield of chest imaging for medicare patients with suspected pulmonary embolism in the emergency department. Am J Roentgenol 2018 Jan;24:1–6 [Internet]. Available from https://doi.org/10.2214/AJR.17.18586.

[5] Rodriguez RM, Anglin D, Langdorf MI, Baumann BM, Hendey GW, Bradley RN, et al. Validation of a decision instrument for selective chest imaging in blunt trauma. JAMA Surg 2013;148(10):940–6.

[6] Stephens CQ, Boulos MC, Connelly CR, Gee A, Jafri M, Krishnaswami S. Limiting thoracic CT: a rule for use during initial pediatric trauma evaluation. J Pediatr Surg 2017;52(12):2031–7 E [Internet]. Available from https://doi.org/10.1016/j.jpedsurg.2017.08.039.

[7] Hussein W, Mullins PM, Alghamdi K, Sarani B, Pines JM. Trends in advanced computed tomography use for injured patients in United States emergency departments: 2007–2010. Acad Emerg Med 2015;22(6):663–9.

[8] Centers for Disease Control and Prevention. NAMCS/NHAMCS. About the Ambulatory Health Care Surveys [Internet]. [cited. Feb 19]. Available from https://www.cdc.gov/nchs/ahcd/about_ahcd.htm; 2018.

[9] McCaig LF, Burt CW. Understanding and interpreting the national hospital ambulatory medical care survey: key questions and answers. Ann Emerg Med 2012;60(6):716–721.e1 Dec.

[10] Caputo ND, Stahmer C, Lim G, Shah K. Whole-body computed tomographic scanning leads to better survival as opposed to selective scanning in trauma patients: a systematic review and meta-analysis. J Trauma Acute Care Surg 2014;77(4):534–9.

[11] Sierink JC, Treskes K, Edwards MJR, Beuker BJA, den Hartog D, Hohmann J, et al. Immediate total-body CT scanning versus conventional imaging and selective CT scanning in patients with severe trauma (REACT-2): a randomised controlled trial. Lancet [Internet] 2016;388(10045):673–83 Available from: https://doi.org/10.1016/S0140-6736(16)30932-1.

[12] Charlson ME, Karnik J, Wong M, McCulloch CE, Hollenberg JP. Does experience matter? A comparison of the practice of attendings and residents. J Gen Intern Med 2005;20(6):497–503.

[13] Calland JF, Ingraham AM, Martin N, Marshall GT, Schulman CI, Stapleton T, et al. Evaluation and management of geriatric trauma: an eastern association for the surgery of trauma practice management guideline. J Trauma Acute Care Surg 2012;73(5):345–50 SUPPL.4.

[14] Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, Deblieux PMC. Indications for computed tomography in patients with minor head injury. N Engl J Med [Internet] 2000 Jul 13;343(2):100–5 Available from: https://doi.org/10.1056/NEJM200007133430204.

[15] Stiell IG, Wells GA, Vandemheen K, Clement C, Lesiuk H, Laupacis A, et al. The Canadian CT Head Rule for patients with minor head injury. Lancet 2001;357(9266):1391–6.