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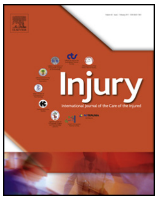

Consequences of increased use of computed tomography imaging for trauma patients in rural referring hospitals prior to transfer to a regional trauma centre

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ABSTRACT

Background: Computed tomography (CT) plays an integral role in the evaluation and management of trauma patients. As the number of referring hospital (RH)-based CT scanners increased, so has their utilization in trauma patients before transfer. We hypothesized that this has resulted in increased time at RH, image duplication, and radiation dose.
Methods: A retrospective chart review was completed for trauma activations transferred to an ACS-verified Level II Trauma Centre (TC) during two time periods: 2002–2004 (Group 1) and 2006–2008 (Group 2). 2005 data were excluded as this marked the transition period for acquisition of hospital-based CT scanners in RH. Statistical analysis included t test and χ^2 analysis. $P < 0.05$ was considered significant.
Results: 1017 patients met study criteria: 503 in group 1 and 514 in group 2. Mean age was greater in group 2 compared to group 1 (40.3 versus 37.4, respectively; $P = 0.028$). There were 115 patients in group 1 versus 202 patients in group 2 who underwent CT imaging at RH ($P < 0.001$). Conversely, 326 patients in group 1 had CT scans performed at the TC versus 258 patients in group 2 ($P < 0.001$). Mean time at the RH was similar between the groups (117.1 and 112.3 min for group 1 and 2, respectively; $P = 0.561$). However, when comparing patients with and without a pretransfer CT at the RH, the median time at RH was 140 versus 67 min, respectively ($P < 0.001$). The number of patients with duplicate CT imaging ($n = 34$ in group 1 and $n = 42$ in group 2) was not significantly different between the two time periods ($P = 0.392$). Head CTs comprised the majority of duplicate CT imaging in both time periods (82.4% in group 1 and 90.5% in group 2). Mean total estimated radiation dose per patient was not significantly different between the two groups (group 1 = 8.4 mSv versus group 2 = 7.8 mSv; $P = 0.192$).
Conclusions: A significant increase in CT imaging at the RH prior to transfer to the TC was observed over the study periods. No associated increases in mean time at the RH, image duplication at TC, total estimated radiation dose per patient, and mortality rate were observed.

Introduction

Computed tomography (CT) plays an integral role in the evaluation and management of trauma patients. The initial care of the trauma patient, according to Advanced Trauma Life Support (ATLS) guidelines, emphasizes early stabilization and expedited transfer to a definitive trauma centre based on severity of injury. The American College of Surgeons Committee on Trauma has guidelines on criteria for the immediate transfer of moderately to severely injured patients to Level I/II Trauma Centres [1]. Criteria for immediate transfer of trauma patients to a higher level of care include altered mental status, respiratory failure requiring mechanical ventilation, hemodynamic instability, and penetrating trauma. These guidelines rely on information primarily obtained from history, physical examination, chest X-ray and pelvis X-ray. Furthermore, these guidelines advocate against the acquisition of pretransfer CT in this patient population.

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Prior to 2005, most of the referring hospitals (RH) in our area had only limited access to mobile-based CT scanners. However, after 2005, the number of hospital-based CT scanners at these facilities increased dramatically. We hypothesized that the widespread acquisition of hospital-based CT scanners at RH resulted in increased utilization of CT prior to transfer, increased time at the RH, more duplicate CT imaging, and increased overall radiation dose per patient.

Materials and methods

Our health system is an integrated healthcare organization serving 19 counties in western Wisconsin, southeast Minnesota, and northeast Iowa. The institution includes an American College of Surgeons (ACS) verified Level II Trauma Centre (TC). A retrospective review of our TC's entries in the National Trauma Registry of the American College of Surgeons (NTRACS) was performed to identify all trauma patients admitted to the TC from January 1, 2002 to December 31, 2008. All patients meeting trauma activation criteria who were transferred from the 35 RH in our referral area to the TC during two defined study periods were included. Group 1 consisted of those patients transferred from January 1, 2002 to December 31, 2004. Group 2 consisted of those patients transferred from January 1, 2006 to December 31, 2008. The 2005 data were excluded as this marked the transition period for the widespread acquisition of hospital-based CT scanners at RH in our region. By the beginning of 2006, all of the RH in our region were using hospital-based CT scanners. During the early years of the study period, CT images were frequently sent on a compact disc with the patient. After 2006, electronic transfer of images was increasingly used. Transfer agreements between our institution and the RH remained the same throughout the entire study period.

Variables reviewed included demographics (age and gender), mechanism of injury, injury severity score (ISS), and abbreviated injury scale (AIS). We reviewed the number of patients who underwent CT at a RH, at the TC, and overall. CT scans were subcategorized into the total number of CTs by anatomic location (head, chest, abdomen/pelvis) at a RH, at the TC, and overall. Finally, we reviewed the time at the RH, based on arrival and discharge times at the RH, estimated radiation dose per patient, length of hospital stay at the TC (LOS), and 30-day mortality.

Actual radiation dose per patient was difficult to accurately determine. Individual patient volume CT dose index ($\mathrm{CTDI_{vol}}$) and dose length product (DLP) were not routinely recorded for all CT exams at the TC until 2007 and not at the RH until 2008–2010. Effective radiation dose for trauma patients in group 1 was derived from a Food & Drug Administration report of a Conference of Radiation Control Program Directors (CRCPD) Nationwide Evaluation of X-Ray Trends (NEXT) survey publication [2]. Effective radiation dose for trauma patients in group 2 was derived from National Council on Radiation Protection and Measurements (NCRP) Report number 160 [3]. These derivations are summarized in Table 1. The reason for using two different sources for estimation of effective dose was because significant advances in CT technology affecting patient dose occurred during the study periods. Higher power generators and more robust X-ray tubes capable of scanning at greater kVp and mAs values were implemented. Use of volume scanning with spiral CT became standard, as did wider detectors for multi-row, multi-slice scanning, enabling faster scanning and acquisition of thinner slices. Cone beam CT, dual source CT, and dose reduction strategies such as tube current modulation were developed [4]. Effective dose values from the CRCPD NEXT publication and NCRP Report No. 160 were from the years 2000 and 2006, respectively, and were thus appropriate for technology in use during each study period.

Table 1
Effective radiation dose calculations by exam type.

Study group	Effective dose (mSv)
Group 1	
Head CT	2.0[a]
Chest CT	9.1[a]
Abdomen/pelvis CT	12.1[a]
Group 2	
Head CT	2.0[b]
Chest CT	7.0[b]
Abdomen/pelvis CT	10.0[b]

CT = computed tomography.
[a] CRCPD 2000 NEXT CT Survey, Tables 1.3, 1.24, and 1.30[2].
[b] NCRP Report No 160, Table 4.2[3].

Statistical analysis consisted of *t* test, Wilcoxon Rank Sum, and chi square analysis. Continuity adjustment was used in 2 × 2 tables. Statistical significance was defined as a *P* value <0.05.

Results

One thousand seventeen patients met study inclusion criteria; 503 patients in group 1 and 514 patients in group 2. Demographic comparison revealed a significant difference in mean age between the two groups with group 1 being younger (Table 2). There was no significant difference in gender between the two groups. Mechanism of injury was primarily blunt (Table 2). The overwhelming majority of blunt trauma involved motor vehicle collisions and falls.

Median injury severity score (ISS) was 14 in group 1 and 11 in group 2 ($P < 0.001$). Overall, the number of patients with abbreviated injury scale (AIS) ≥3 was not significantly different between the groups. However, when stratified by anatomic location, chest AIS ≥3 ($n = 157$ for group 1 and $n = 120$ for group 2; $P = 0.006$) and extremity AIS ≥3 ($n = 151$ for group 1 and $n = 98$ for group 2; $P < 0.001$) were more frequent in group 1. No significant differences were found for face, head, or abdomen AIS ≥3 between the two groups.

As depicted in Table 3, there were 115 patients in group 1 versus 202 patients in group 2 who underwent CT imaging at RH ($P < 0.001$). Conversely, 326 patients in group 1 had CT scans performed at the TC versus 258 patients in group 2 ($P < 0.001$). The overall number of patients who had CT scans performed was not

Table 2
Patient characteristics.

Variable	Group 1	Group 2	*P* value
	(2002–2004)	(2006–2008)	
N	503	514	–
Age, mean (SD); years	37.4 (20.5)	40.3 (21.4)	0.028
Sex, *n* (%)			0.081
Female	156 (31)	133 (26)	
Male	347 (69)	381 (74)	
Mechanism of injury, *n* (%)			0.175
Blunt	483 (96)	483 (94)	
Penetrating	20 (4)	31 (6)	
ISS, median (IQR)	14 (19–25)	11 (6–19)	<0.001
AIS ≥3, *n* (%)			
Face	11 (2)	4 (1)	0.109
Head	177 (35)	166 (32)	0.363
Chest	157 (31)	120 (23)	0.006
Abdomen	57 (11)	47 (9)	0.295
Extremity	151 (30)	98 (19)	<0.001
Any region	363 (72)	344 (67)	0.081
30-Day mortality, *n* (%)	28 (5.6)	36 (7.0)	0.415

SD = standard deviation; ISS = injury severity score; IQR = interquartile range (25th–75th percentile); AIS = abbreviated injury score.