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Effect of an Image Sharing Network on CT Utilization for Transferred Trauma Patients: a five-year experience at a level I trauma center

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Abstract

Objectives—To evaluate the influence of an image sharing network established between referring hospitals and a level I trauma center on CT utilization at the trauma center.

Methods—This retrospective study was approved by the local Institutional Review Board. The requirement for informed consent was waived. We linked the Harborview Medical Center's trauma registry to billing department data and obtained detailed information on all resources utilized during each patient's hospitalization. We used negative binomial regression to evaluate the body-region specific CT utilization between direct admit and transfer patients after adjustment for potential confounding variables. We paid special attention to 2005 as the year that we established Internet-based image sharing between HMC and referring hospitals.

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The authors have no conflicts of interest to declare.

Results—A total of 81,159 trauma patients were admitted to HMC (44% transfer) during the study period. The utilization of head CTs slightly increased from 1996 to 2005, with no significant difference between direct admits and transfer patients. Between 2005 and 2010, utilization remained relatively unchanged; however, we observed significantly higher utilization rates for direct admit patients.

Relatively similar pattern was observed for pelvic CTs; however, between 2005 and 2010, CT use was greater for direct admits compared to transfer patients.

Abdominal and thoracic CTs were relatively unchanged between 2005 and 2010. However, both CTs had significantly higher utilization rates for direct admits.

Conclusion—The utilization rate of different body regions CT was higher for direct admit trauma patients compared to transfer patients since 2005; however, decreasing utilization trends have been observed in recent years.

Keywords

Computed tomography; imaging; trauma; patient transfers; image sharing; information systems

Introduction

Widespread availability of Computed Tomography (CT) within the emergency department, and the short time necessary for scanning are some of the factors that have contributed to increased use of CT for management of trauma patients [1-5]. Furthermore, the development of picture archiving and communication systems (PACS) have substantially improved accessibility and sharing of all imaging modalities, including CTs [6, 7].

However, the potential long-term consequences of exposure to ionizing radiation [8] and the financial burden of high utilization rates [9, 10] have been raised as concerns in recent years. In order to minimize unnecessary imaging, patients who are reimaged most frequently should be identified. For trauma patients, transfer cases are one such group. Approximately 50% of trauma patients receive at least one CT at a referring institution prior to transfer [11], despite recommendations by the American College of Surgeons Committee on Trauma (ACS COT) that CT scanning should not delay patient transport [12]. Moreover, approximately 20% of all referred patients have at least one CT scan repeated upon admission [13]. The impact of delaying transfer for imaging purposes (performing or obtaining images) can result in delay in treatment without any realized patient benefits [14-16]. Lee et al. conducted a survey of referring physicians and found that approximately 30% of the referring physicians believed that trauma centers require pre-referral images [16]. Concerns regarding liability issues and financial interests of referring centers are among other factors that contribute to pre-referral imaging.

Recent studies have demonstrated that sending imaging files from referring centers is associated with decreased repeat CTs in trauma patients upon admission [17, 18]. Until recently, these images were often sent using compact disc (CD), which was often problematic. The CD might be lost or unreadable, the patient's images are only viewable by those with direct access to the disc, or the non-standard image viewing software may be

unfamiliar to the radiologist or other clinicians. Also, multiplanar reformats and volume rendered views are usually not possible due to relatively greater reconstruction thickness compared to reconstruction from raw data on a CT scanner [19-21]. In order to overcome the limitations of transferring images using CDs and printed films, various techniques to share images between hospitals using the Internet have been developed. The IHE consortium has released the Cross Enterprise Document Sharing (XDS) profile, a standards-based and secure profile that allows facilities to share images online, regardless of their respective PACS vendors. Another system is to develop virtual private networks (VPNs) in regional trauma networks for direct and secure transfer of images from the outside hospital's PACS or scanners to the receiving hospitals' PACS [20-23].

Harborview Medical Center (HMC) is the only level I adult and pediatric trauma center in Northwest of the United States, covering Washington State and large parts of Montana, Idaho and Alaska. Due to the large geographic area under coverage, more than half of trauma admissions are transferred to this hospital. In 2005, HMC began implementation of a VPN system that allowed participating hospitals to send and receive imaging files through a secure VPN system without compromising the quality of images. The number of hospitals participating in data sharing has increased steadily and currently more than 120 outside facilities can send images using the VPN system at HMC. Additionally, HMC supports the transfer of images from smaller facilities using a "cloud"-based online sharing system in an ad-hoc basis. A recent study from HMC demonstrated that a combination of the VPN and CD-based image transfer was associated with a significant decrease in the use of repeat imaging for transfer patients [21]. We have expanded the scope of that study to evaluate the influence of a VPN established between referring hospitals and HMC on CT utilization at HMC. We hypothesized that with the increase in availability of VPN-based image transfer, an increasing gap in overall CT use between transfer vs. direct admit patients would be observed.

Methods

In this study we linked the HMC trauma registry to the HMC billing department database from 1996-2010. Included in the trauma registry was detailed information regarding patient demographics, injury characteristics, and the trauma care process. Type and frequency of advanced imaging performed during a patient's hospitalization was obtained from the billing department data. We extracted the following variables from the linked databases: admission status (direct admit vs. transfer from another institution), age, sex, race/ethnicity, insurance status, year of admission, mechanism of injury, injury severity score, length of hospitalization, ICU admission, final disposition (dead vs. alive) and type and frequency of CTs performed during hospitalization. The study was approved by the institutional review board of the University of Washington.

We focused on CT use (including CT and CT angiography), as it is the most commonly performed advanced imaging modality in the initial workup of trauma patients due to its speed and high quality images produced. From the different body region CTs, we focused on the head, pelvis, cervical spine, abdomen, and thorax as these are the most commonly evaluated body regions in trauma patients at our institution.

To evaluate the unadjusted trend in CT usage, the average number of CTs per patient was plotted against year of admission for both transfer and direct admit patients.

We used multivariable negative binomial regression [24] to evaluate the fifteen-year trend in the use of different body region CTs between transfer and direct admit patients. In order to conduct this analysis, we created a new set of variables for the interaction between admission status (transfer or direct admission) and each of the fifteen years of the study period. This resulted in a total of 30 different categories (ie 2010-direct admit, 2010-transfer, 2009-direct admit, 2009-transfer, etc.). As a result, we compared CT utilization between different combinations of admission year and admission status, adjusting for the following covariates: age, sex, race/ethnicity, insurance status, mechanism of injury, injury severity, length of hospitalization, ICU admission and final disposition. We considered 1996-transfer patients as the baseline for all comparisons. In addition, we focused on comparison of rates pre and post 2005, as this was the year in which an internet-based image sharing system was implemented. The results are presented as incidence rate ratios (IRRs) with corresponding 95% confidence intervals (CIs). The IRR thus compares the individual-level CT usage among different combination of “referral status” and “year of admission”, considering the usage rate for directly admitted patients in 1996. In other words, an IRR of α for transfer patients in 2007 for head CTs demonstrates that transferred patients admitted to Harborview Medical Center in 2007 had a utilization rate α times that of the utilization of head CT for patients directly admitted to Harborview Medical Center in 1996. All analyses were conducted using STATA 11.1 (StataCorp, College Station, TX).

Results

There were a total of 81,159 trauma patients admitted to HMC from June 1996 to June 2010. Transferred patients comprised 44% ($n=35,638$) of the patient population. The distributions of demographic and injury characteristics of transfer versus direct admit patients are summarized in Table 1. Compared to direct admit patients, a greater proportion of transfer patients were children 0-14 years (14% vs. 9%), white (82% compared to 73%) and less likely to have a positive BAC (21% vs. 31%). Injury severity was similar between the two groups. Although the average length of hospitalization was longer and the ICU admission rate was higher in transfer patients, the fatality rate was lower in these patients compared to direct admits, 3.8 and 4.7% respectively. Over the study period, no significant changes in the distributions of these characteristics were observed for either group.

The most commonly performed CTs were head, which accounted for 46% of all CTs performed over the study period, followed by pelvis (18%), cervical spine (16%), abdomen (13%) and thorax (7%). These distributions did not significantly vary by admission status. From 1996-2010, the average number of CTs performed in trauma patients was greatest for head (1.1 per patient), followed by pelvis (0.4 per patient), cervical spine (0.4 per patient), abdomen (0.3 per patient), and thorax (0.2 per patient). The average number of body region specific CTs per patient over the study period, by referral status, is presented in Figure 1 (a-e).

As presented, head CT use was relatively constant between 1996 and 2005, with no difference between direct admits and transfer patients. Between 2005 and 2010, we observed differences in head CT use between these two groups, with a more pronounced decline in CT use for transfer patients than for direct admit patients. A similar pattern was observed for cervical spine CTs. For pelvic, abdomen and thoracic CTs, we observed increasing trends in CT use between 1996 and 2005 and a slight decline between 2005 and 2010. However, the utilization of pelvic, abdomen and thoracic CTs between 2005 and 2010 was substantially lower for the transfer patients compared to direct admits.

Figure 2 (a-e) summarizes the adjusted IRRs for each of the different body region CTs in transfer and direct admit patients from 1996-2010, considering transfer patients in 1996 as the baseline for comparison. As presented, the utilization of head CTs slightly increased from 1996 to 2005, with no significant difference between direct admits and transfer patients. Between 2005 and 2010, utilization remained relatively unchanged; however, significantly higher utilization rates for direct admit patients relative to transfer patients were observed.

A similar pattern was observed for pelvic CTs; however, between 2005 and 2010, a significantly higher rate of CT use was observed for direct admits than for transfer patients. (Figure 2-b)

The overall CT cervical spine utilization rate from 1998 to 2005 was relatively constant. While the utilization did not change materially between 2005 and 2010 for the direct admits, we observed a declining trend in cervical spine CT use between 2005 and 2010 for transfer patients. In 2010, the utilization rate for cervical spine CT for direct admits was approximately 3 times higher than the utilization rate for transfer cases after adjustment for confounders.

Overall, rising abdomen CT use for direct admit patients began in 2000 and reached a peak utilization in 2005 (IRR: 4.53; 95% CI: 3.64-5.63) with little changes occurring thereafter. For transfer patients, abdomen CT use slightly increased to 2005, and remained relatively unchanged between 2005 and 2010. However, the utilization rate was significantly lower for the transfer patients, compared to direct admits between 2005 and 2010.

Thoracic CT demonstrated relatively the same pattern as abdominal CT. However, due to the smaller number of patients who received thoracic CTs, the confidence intervals are wider. Again, thorax CT was less common in transfer patients compared to direct admits between 2005 and 2010, while there was no difference between these two groups between 1996 and 2004.

Discussion

In this study we compared the trend in utilization of CT between transferred and directly admitted trauma patients before and after implementation of a large internet-based image transfer system between our level I trauma center and referring hospitals. We found that overall there has been a declining trend in the use of different body region CTs in more recent years in our trauma center. In addition, the declining trend in the use of CT was

greater for transfer patients compared to the directly admitted patients, even after adjustment for confounding variables that could potentially influence CT utilization. The difference in utilization rate between direct admits and transfer patients began in 2005, which is the same year we began the rollout of our VPN-based image sharing system at HMC.

Before discussing our findings, some of the limitations of the study should be reviewed. First, our study population was comprised of patients admitted to a busy single, academic level I trauma center with a very geographically large referral area. Therefore, the results may not be generalizable to other trauma centers. Second, the billing data did not include information regarding CTs performed at referring hospitals. Consequently, we were unable to determine the proportion of transfer patients receiving repeat CTs on arrival at our hospital. Third, the association between the pre-admit CTs and patients' length of hospital stay or final disposition was not evaluated in this study.

Few studies have evaluated the use of CT for transfer trauma patients [11, 17, 18, 25-28]. Liepert and Cochran (25) reported that 48% of transfer patients between 2009 and 2010 had a repeat scan of the same body region at a level I adult trauma center over a six month period. The most common reasons for repeat scans were inadequate initial scans (57%), clinical indication (12%), technical difficulties (12%), and physician preference (13%).

Similar to other studies [17, 25], head CT was the most frequently performed CT in the present investigation. We also found that the difference in CT use between direct admits and transfer patients was the least for head CTs, echoing the findings of Fenton et al. [29] that reported 83% of repeat CTs for transfer patients were of the head. Like our own, many centers perform repeat CT of the head in patients with traumatic intracranial hemorrhage to determine if intervention is necessary [30, 31]. The large number of these repeat CTs is likely to be reflected in the comparatively small reduction in head CT utilization at our hospital, especially in patients who are referred for head injury. In this study, we did not evaluate the factors that were associated with repeat CTs for transfer patients in our trauma center. However, recent investigations have found that older age, blunt trauma, injury severity, being transferred by helicopter, and institutional preference were associated with higher frequency of repeat CTs [13, 17].

In the absence of an Internet-based image transfer system, image transfer can place a significant burden on hospital resources, by increasing repeat imaging and delaying treatment [13, 17]. Interestingly, Emick et al. [17] reported that CD image transfers from a referring institution did not significantly decrease treatment time compared to those patients undergoing repeat scanning. This may be attributable to problems associated with viewing and uploading CD's to the receiving hospital's PACS. In comparison, an online image transfer system allows images to be reviewed before the transfer patient arrives in the hospital. Accordingly, we have developed a system for rapid triage of some transfer patients to the OR upon arrival in our emergency department.

Flanagan et al. compared the internet and CD based image transfer system at HMC to other reported in the literature [21]. A 17% repeat CT rate during the study period was reported by

the authors, which was lower than similar studies which found 53.2% [14] and 29% [20] rate of repeat CT imaging.

Sodickson and colleagues evaluated the role of CT in the first 24 hours of patient care for transfer patients pre and post implementation of a computer system allowing the uploading of CD images into a PACS system at an adult level I trauma center [18]. The authors compared the CT use in patients in which images could be uploaded, those in which upload was unsuccessful, and in a control group prior to the implementation of the system. The authors noted an overall lower CT use in patients for which images could be uploaded compared to those in which upload was unsuccessful (2.74 CTs per patient compared to 3.30 CTs per patient). Furthermore, the number of images obtained in the ED was lowest for the group in which images could be imported (0.84 CTs per patient) compared to the historical cohort (1.18 CTs per patient) and those in which uploaded images could not be obtained (0.99 CTs per patient).

Data regarding repeat CTs for the transferred pediatric trauma patients is scarce. Hartin et al. reviewed data for patients transferred to a level I pediatric trauma center from 2000-2010 [25]. Over the study period, the authors noted increases in overall CT scanning at the referral center. Similar to other studies, the rate of repeat scanning was highest for CT of the head (21%). Eighty percent of these CT's were performed to monitor the patient status. Abdominopelvic CT was repeated in 21% of patients, and was due to lack of intravenous contrast in 50% of patients. In our study, age group did not change the association between referral status and trend in the use of different body region CTs.

In conclusion, over the study period and especially in recent years, we observed declining trends in the adjusted utilization rates of different body region CTs. In addition, we found that the CT utilization rates were lower for transfer patients compared to direct admits after 2005, the year that we began the implementation of our image sharing network at HMC.

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Take Home Points

- The utilization rate of different body regions CT was higher for direct admit trauma patients compared to transfer patients since 2005, the year in which an image sharing network was established between referring hospitals and the level I trauma center
- Internet-based sharing CT images between referring hospitals and our level I trauma center has resulted in significant decrease in the use of repeat imaging for transfer trauma patients.
- Development of virtual private networks (VPNs) in regional trauma networks for direct and secure transfer of images from the outside hospital's PACS or scanners to the receiving hospitals' PACS could prevent unnecessary repeat imaging, decrease the radiation dose and reduce the cost of imaging for transfer trauma patients.

Figure 1.
Average number of CTs per patient per year at Harborview Medical Center from 1996-2010, by referral status

Figure 2.

Negative binomial regression evaluating the trend in the use of body region specific CTs for transfer and direct admit patients (considering 1996 transfers as the baseline for comparison) at Harborview Medical Center from 1996-2010, adjusted for age, sex, race/ethnicity, insurance status, mechanism of injury, injury severity, length of hospitalization, ICU admission, and final disposition (dead vs. alive)

Table 1

Demographic and injury-related characteristics for trauma patients admitted to Harborview Medical Center from 1996-2010, by referral status

	Transfer n= 35,638	Direct admit n=45,521
<i>Demographic Characteristics</i>		
Age, y (mean)	37	38
Age, y (%)		
0-14	14	9
15-18	7	7
19-54	57	65
55+	22	19
Male (%)	71	71
Race (%)		
White	82	73
Black	6	13
Asian	5	8
Other	6	5
Insurance Status (%)		
No insurance *	12	15
Medicaid	23	20
Medicare	10	15
Other	55	50
BAC >0 (%)	21	31
<i>Injury Characteristics</i>		
Injury Severity Score (%)		
1-8	36	42
9-15	31	28
16+	32	30
Mechanism of injury (%)		
Traffic related *	21	26
Fall	27	22
Other	52	52
ICU admit (%)	34	30
Length of hospital stay, days (mean)	7	6
Died (%)	3.8	4.7

NOTE—Data may not add to 100% because of rounding. BAC= blood alcohol content.

* Includes Self pay, no insurance, and charity

† Includes motor vehicle collisions, motorcycle, bicycle, and pedestrian injuries