American Journal of Emergency Medicine 33 (2015) 320–325

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Original Contribution

Impact of clinical decision support on head computed tomography use in patients with mild traumatic brain injury in the ED

Ivan K. Ip, MD, MPH [a,b,c,e,*], Ali S. Raja, MD, MPH, MBA [a,b,d,e], Anurag Gupta, MD, MBA, MMSc [a,b,d,e], James Andruchow, MD [a,b,d,e], Aaron Sodickson, MD, PhD [a,b,e], Ramin Khorasani, MD, MPH [a,b,e]

[a] Center for Evidence-Based Imaging, Harvard Medical School, Boston, MA
[b] Department of Radiology, Harvard Medical School, Boston, MA
[c] Department of Medicine, Harvard Medical School, Boston, MA
[d] Department of Emergency Medicine, Harvard Medical School, Boston, MA
[e] Brigham and Women's Hospital, Harvard Medical School, Boston, MA

ARTICLE INFO

Article history:
Received 18 August 2014
Received in revised form 31 October 2014
Accepted 3 November 2014

ABSTRACT

Background: Reduction of unnecessary head computed tomographies (CTs) in patients with mild traumatic brain injury (MTBI) was recently endorsed by American College of Emergency Physicians (ACEP) in the "Choosing Wisely" campaign. We examined the impact of computerized clinical decision support (CDS) on head CT utilization in MTBI emergency department (ED) visits.
Methods: We conducted a 2-year cohort study at a level 1 trauma center and compared our results with the National Hospital Ambulatory Medical Care Survey from 2009 to 2010. All adult patients discharged from the ED with MTBI-associated diagnoses were included. After a baseline observation period at our institution, real-time CDS was implemented. Based upon the clinical history entered, low utility orders triggered an alert to clinicians, suggesting imaging studies might not adhere to evidence-based guidelines. Clinicians could cancel the order or ignore the alert. Primary outcome was intensity of head CT use in MTBI ED visits. Secondary outcomes included rates of delayed imaging and delays in diagnosing radiologically significant findings. χ^2, logistic regression, and process control chart assessed preintervention and postintervention differences.
Results: In study patients, 58.1% of MTBI-related visits resulted in head CT preintervention vs 50.3% postintervention (13.4% relative decrease, $P = .005$), a change not detected in controls (73.3% vs 76.9%, $P = .272$). Study cohort patients not receiving a head CT during their index visit were neither more nor less likely to receive one in the subsequent 7 days (6.7% preintervention vs 9.4% postintervention, $P = .231$). Rates of delayed diagnosis of radiologically significant findings were unchanged (0% vs 0%).
Conclusions: Evidence-based CDS can reduce low utility imaging for MTBI.

1. Introduction

Mild traumatic brain injuries (MTBIs) are commonly seen in US emergency departments (EDs), accounting for an estimated 1.2 million outpatient visits annually [1]. Although most patients have no clinical sequelae from their injuries, many undergo head computed tomography (CT) as part of their routine evaluation. In fact, nearly 1 million blunt trauma patients undergo head CT imaging annually in the United States, whereas fewer than 6% prove to have significant intracranial injuries that require neurosurgical intervention [2]. A number of clinical decision rules have been developed to help guide clinicians in selecting patients for whom a head CT is likely to be beneficial. These rules allow for risk stratification of patients with suspected intracranial injuries, based on clinical findings [3-5]. When used appropriately, they can help avoid unnecessary head CTs, without jeopardizing patient safety [6]. Despite their potential utility [7-10] and acceptance by professional societies [11], their clinical adoption remains scarce. It is estimated that 10% to 35% of CTs obtained in the ED for MTBI are not recommended according to the guidelines [12], and head CT utilization varies significantly both nationwide and within institutions [13,14]. Even when MTBI decision rules are used, significant interphysician variation persists [15].

In response, the reduction of unnecessary head CTs in patients with MTBI was recently endorsed by the American College of Emergency Physicians as a priority in their "Choosing Wisely" campaign that is pioneered by the American Board of Internal Medicine [16]. Cost-effectiveness analyses have demonstrated that if CTs for MTBI were performed according to decision rules, the United States could reduce health care expenditures by as much as $120 million annually [17]. Furthermore, associated reductions in both unnecessary exposure to radiation [18] and potential overdiagnosis [19] would be beneficial. However, interventions such as education and policy changes designed to reduce unnecessary imaging have yet to show significant cost saving [20].

* Corresponding author. Center for Evidence-Based Imaging, Department of Radiology and Medicine, Brigham and Women's Hospital, 20 Kent St, Second Floor, Boston, MA 02445. Tel.: +1 617 525 9713; fax: +1 617 525 9797.
E-mail address: iip@partners.org (I.K. Ip).

http://dx.doi.org/10.1016/j.ajem.2014.11.005
0735-6757/

The purpose of this study was to examine the impact of real-time computerized clinical decision support (CDS), based on published high-quality evidence, on the use of head CT in adult ED patients diagnosed with MTBI.

2. Methods

2.1. Study design and setting

The study site is an academic quaternary care, 793-bed, level 1 trauma center, with approximately 60 000 ED visits annually. The requirement to obtain informed consent was waived by our institutional review board for this Health Insurance Portability and Accountability Act (HIPAA) compliant, observational cohort study.

2.2. Selection of participants

The study cohort included all adult ED patient visits with a discharge diagnosis of MTBI between January 1, 2009, and December 31, 2010. We selected this period to allow direct comparison with a nationwide control cohort, for which data from this timeframe have been recently published and were readily available. To identify eligible visits, we queried our institutional billing database for all visits of patients aged 18 years or older with an associated primary (or top 2 secondary) discharge diagnosis of MTBI, using *International Classification of Diseases*, *Ninth Revision* (*ICD-9*) codes for concussion (850.0, 850.1, 850.11, 850.12, 850.2, 850.3, 850.4, 850.5, and 850.9) and head injury not otherwise specified (959.01) as codes previously determined to represent minor traumatic brain injury [1].

To account for secular differences, we selected a control cohort consisting of ED patients diagnosed with MTBI captured from the most recent publicly available National Hospital Ambulatory Medical Care Survey (NHAMCS) during our study period. The NHAMCS was designed to be representative of emergency medical care delivered in the United States and includes data on patient demographics, medications listed, laboratory and imaging studies ordered, and up to 3 discharge diagnoses derived from *ICD-9* codes. We included only visits of adult patients aged 18 years or older and used *ICD-9* diagnosis (primary or secondary) to identify MTBI-related visits using the same codes as for our study cohort.

2.3. Intervention

After gathering baseline data for 1 year, we implemented real-time computerized CDS into our institutional imaging computerized physician order entry (CPOE) system during the last quarter of 2009. Details of the implementation have been described previously [21,22]. The CDS enables iterative interaction with the ordering clinician to provide automated, actionable, and real-time feedback to optimize the ordering decision (Fig. 1). The CDS launched, when a head CT was ordered for the indication of "trauma." Based on clinical data entered by the requesting clinician, the CDS indicated when head CT might be of low utility. The CDS logic was derived from 3 large, multiinstitutional, well-validated trials of high-quality evidence (the New Orleans Criteria [5], the Canadian CT Head Rule [3], and the CT in Head Injury Patients Prediction Rule [4]) for the use of head CT in patients with MTBI. The combination of these 3 high-quality prediction models allows us to capture most MTBI patients at our institution (eg, Canadian CT Head Rule excludes patients who had no loss of consciousness, whereas it is not an exclusion criterion in the CT in Head Injury Patients Prediction Rule). The CDS logic was created, reviewed, and approved collaboratively by clinical leadership in radiology and emergency medicine, including final approval from respective department chairs. Details of the logic have been described previously [22]. If a head CT order is classified as "low utility" based on the above rules, the provider is shown a CDS screen informing him/her of such, with direct links to the corresponding supporting evidence [22]. Ordering clinicians could either ignore the advice and proceed with imaging or cancel the order as recommended by the CDS. Because of our focus on MTBI, orders of scans for multiple body parts (eg, head CTs ordered together with maxillofacial or cervical spine CT or head through pelvis "pan scans" in multisystem trauma patients) were not included to minimize unnecessary physician interactions with CDS for MTBI and help reduce alert fatigue [23].

2.4. Methods and measurements

Patient demographics in the study cohort were collected from electronic health records. Imaging data were identified using the radiology information system and CPOE system. The use of any head CT in the study cohort, performed on either the day of the ED visit or within the subsequent 7 days at our institution, was recorded, along with the results of that head CT to search for delayed diagnoses of radiologically significant findings. For the control cohort, similar patient demographic and head CT utilization data were collected from the NHAMCS database. Because of the design of NHAMCS, data regarding imaging studies ordered subsequent to the ED visit and delayed diagnosis of radiologically significant findings were not available for the control cohort.

2.5. Outcomes

Our primary outcome measure was the head CT utilization rate, defined as the number of head CTs ordered per the number of ED visits for MTBI. Head CT use in the preintervention period was compared with that postintervention. Change in head CT use between the preintervention and postintervention periods in the study cohort was compared with the control cohort to account for secular confounders. Secondary outcome measures in the study cohort included the rate of delayed imaging and the rate of delayed diagnosis of a radiologically significant finding on imaging. *Delayed imaging* was defined as cases in which a head CT was not performed during the initial ED visit but subsequently performed during a follow-up ED, inpatient, or outpatient visit at our institution within 7 days. Radiologically significant findings on imaging included the presence of an acute traumatic intracranial lesion (subdural, epidural, or parenchymal hematoma; subarachnoid hemorrhage; cerebral contusion; or depressed skull fracture) [5] as defined in previous studies [5,3].

2.6. Analysis

Analyses were performed using Microsoft Excel 2003 (Microsoft, Redmond, WA) and JMP 10 (SAS Institute, Cary, NC). χ^2 and logistic regression were used to assess preintervention and postintervention differences. A 2-tailed P value of $< .05$ was defined as statistically significant. As a secondary analysis, for the study cohort, we also evaluated trend using statistical process control chart from 2008 to 2011, based on 3 δ and p subtype. Statistical process control analysis allows one to distinguish "noise" from "signal [24]." The extended period for the secondary analysis was chosen to allow for 8 data points (grouped quarterly) before and after the intervention [24].

3. Results

3.1. Characteristic of cohorts

Between January 2009 and December 2010, there were 116 009 unique ED visits at the study site and 53 477 visits in the control cohort, which were representative of nearly 20 million ED visits captured nationally through the NHAMCS. Overall, MTBI represented 1.2% of all ED visits (1.12% at the study site and 1.28% from NHAMCS). Of the 1988 combined MTBI visits identified, 50.8% were for female patients, and the average age of all patients was 46.2 years. The study cohort (n = 1302) was more diverse ethnically and contained a greater proportion of women than