RESEARCH ARTICLE

DOI: 10.4274/AdvRadiolImaging.galenos.2024.54264
Advanced Radiology and Imaging 2024;1(1):9-12

Traumatic Brain Injury: CT Imaging and Cost-effectiveness

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Abstract

Objectives: The purpose of this study was to classify patients presenting to the emergency department with head trauma according to the Canadian Head CT Rule (CCHR) to determine the number of unnecessary computed tomography (CT) scans performed and to assess the radiation exposure and cost of unnecessary CT scans.

Methods: This single-center retrospective cohort study included patients older than 15 years with a head injury and a Glasgow Coma Scale (GCS) score of 13-15. A retrospective chart review collected demographic, clinical, radiographic, and hospital course variables. The patient files were reviewed and scored according to CCHR, unbeknownst to other researchers. The study population consisted of 150 patients. The criterion of "minor head injury" used to develop the CCHR guideline comprised "a history of loss of consciousness, amnesia, or confusion, as well as a GCS score of at least 13-15.

Results: This study included a final sample of 150 patients (85/150 men; mean age 52.0±23.9 years). All patients presented with trauma. Ten (6.6%) patients presented with GCS 13 and 39 (26.0%) patients presented with GCS 14. Two (1.3%) patients presented with suspected open or depressed skull fracture. Sixty-five (43.3%) CTs were performed in accordance with CCHR. Sixty-three (42.0%) CTs showed pathology. Two (1.3%) CTs showed no pathology. Eighty-five (56.7%) CTs were not performed in accordance with CCHR. Sixty-eight (45.3%) of these CTs showed no pathology and 17 (11.3%) CTs showed pathology.

Conclusion: We demonstrated that unneeded CTs result in wasteful radiation doses and costs. CCHR is an excellent indicator of which type of mild head trauma requires CT. In our study, approximately 57% of CTs were unnecessary and 80% of unnecessary CTs did not show pathology. In this study, the total unnecessary radiation dose was 2940 mSv, and the total unnecessary cost was 466.9 dollars.

Keywords: Traumatic brain injury, emergency medical services, tomography, unnecessary CTs, radiation exposure, cost-effectiveness analysis

Introduction

Traumatic brain injury (TBI) is a major public health concern around the world.[1] Because of the incidence of TBI, brain computed tomography (CT) scans are required. Unnecessary CT affects the economy by raising costs[1] and causes the dose to be loaded incorrectly. The New Orleans Criteria (NOC)[1,2] and the Canadian Head CT Rule (CCHR)[3] are two criteria that determine who should be diagnosed with TBI. Other criteria are the National Emergency X-Radiography use Study[4,5] and the ACR Appropriateness Criteria for Head Trauma.[6]

When compared with clinical judgment without a decision-making tool, these tools have higher sensitivity and specificity in detecting the need for neurological intervention and clinically important brain injury in emergency department patients with minor head injuries [Glasgow Coma Scale (GCS) of 15 for NOC and 13-15 for CCHR]. They result in a greater positive detection rate overall.[2,7-9]

When compared with the head trauma criteria, the CCHR contains fewer variables and more objective elements as a clinical decision-making tool. We chose CCHR to measure intracranial injury in our study population because of its high sensitivity and high spesifity.[2] The CCHR requires high risk for neurosurgical intervention GCS <15 at 2 h after injury, suspected open or depressed skull fracture, any sign of basal skull fracture, 2 or more episodes of vomiting, age 65 or older; medium risk of brain injury detection by CT, amnesia before impact of 30 min or more dangerous mechanism.[2]

In one study, brain CT characteristics were studied in elderly patients seeking emergency care according to the CCHR for minor trauma.[10] Another study was conducted in a single-centered cohort study in Ethiopia, which examined the characteristics of patients who applied for emergency service head injury compared with CCHR and NOC.[1] Studies have been conducted on the suitability of CT for people applying for head injuries to emergency services, but the results are limited. There are only a few studies on this topic, and the population is small.

In our study, we aimed to learn about the unnecessary number of CTs taken by classifying patients over 15 years of age who apply for emergency head injuries according to CCHR and aimed to identify the radiation load and cost of unnecessary CTs.

Methods

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval and permission to participate in this study were obtained from Ankara Training and Research Hospital Research Committee (KAEK-2023-01/12.320578).

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Received: 13.03.2024 **Accepted:** 19.04.2024

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This study is a single-center retrospective cohort study conducted over 3 years.

This single-center retrospective cohort study included patients older than 15 years with a head injury and a GCS score of 13-15. A retrospective chart review collected demographic, clinical, radiographic, and hospital course variables.

The search and inclusion criteria were subjects undergoing traumatic cranial CT requested who were older than 15 years of age by the emergency department.

Individuals under 15 years of age, a history of head injury in the month prior to emergency department, known brain tumor (primary or metastatic), known hydrocephalus with ventricular shunting, intracranial hemorrhage or ischemia in the month before emergency department presentation, and those with motion and beam hardening artifacts were excluded from the study.

A total of 196 patients were evaluated in the study. Twenty-four patients aged 15 and under 15 years, 3 patients with a history of head injury in the month prior to emergency department, 5 patients with known brain tumor (primary or metastatic), 4 patients with known hydrocephalus with ventricular shunting, or 7 patients with intracranial hemorrhage or ischemia in the month before emergency department presentation, and 3 patients with motion and beam hardening artifacts were excluded. Finally, the study population consisted of 150 patients.

We included patients who underwent brain CT with and without intravenous contrast as requested by the emergency department of our institution.

Participants were selected using our image archiving system.

All patients in our hospital underwent brain CT examinations using 16-slice and 128-slice CT scanners. CT was examined using a third-generation device (Somatom Go Top, Siemens Healthineers, Erlangen, Germany). Intravenous administration of 50-60 mL iohexol (rate=4.0 mL/sec) through the antecubital vein was followed by a 40-mL saline bolus. Following the acquisition of scouts, imaging was performed in the supine position, scanning in the craniocaudal direction with the following parameters: 80/120 kVp, 60 mAs, and rotation time 0.33 s. The slice thickness was 1 mm. Image reconstruction was performed in the axial, coronal, and sagittal planes.

Radiology professionals with 1 and 11 years of experience evaluated the CTs separately and decided by consensus whether there was pathology in the CTs with discordant results.

The CCHR was established to assist clinicians in determining which patients with head injuries require head CT imaging.[4] CCHR is a highly sensitive tool that identifies five high-risk factors ("failure to reach a GCS score of 15 within 2 hours, suspected open skull fracture, any sign of basal skull fracture, vomiting ≥2 episodes, or age ≥65 years") and two medium-risk factors ("amnesia before impact >30 min and dangerous mechanism of injury"). The criterion of "minor head injury" used to develop this guideline comprised "a history of loss of consciousness, amnesia, or confusion, as well as a GCS score of at least 13-15".[10] CCHR is described in Table 1.

A different radiologist with 2 years of experience reviewed the patient files and scored them according to CCHR, unbeknown to other researchers. Patients' demographic characteristics, age, sex, etc. were collected retrospectively.

Statistical Analysis

Data were analyzed using IBM SPSS Inc.'s Statistical Package for Social Sciences (SPSS) for Windows 20 software. The Kolmogorov-Smirnov test was used to determine whether the data matched a normal distribution. Numerical variables with a normal distribution are represented as mean±standard deviation, and categorical variables as number (n) and percentage.

Results

This study included a final sample of 150 patients (85/150 men; mean age 52.0±23.9 years). Thirty-five (23.3%) patients were younger than 40 years. Seventy-four (49.3%) were 65 years and older.

The electronic request and emergency department discharge summary were reported on the same day in all cases. All cases were non-contrast CT scans because no contrast CT scan was performed between admissions.

All patients presented with trauma. Ten (6.6%) patients presented with GCS 13 and 39 (26.0%) patients presented with GCS 14 at least 2 h after trauma. Others (67.3%) presented with GCS 15.

Two (1.3%) patients presented with suspected open or depressed skull fracture. None of the patients presented with racoon eyes, hemotympanum, otorrhea/rhinorrhea, or Battle's sign. The number of people admitted with 2 or more episodes of vomiting was 9 (6.0%). The number of people admitted with pedestrian struck by vehicle is 13 (8.7%). The number of people admitted with an occupant ejected from a motor vehicle is 18 (12.0%). The number of people admitted with fall from an elevation of 1 m or 5 stairs more is 23 (15.3%). The number of people admitted with others is 85 (56.7%). Examples of cases in our clinic are shown in Figure 1.

The 3 most common reasons for admission are others is, fall from elevation of 1 meter or 5 stairs more 23 (15.3%) patients, occupant ejected from motor vehicle 21 (14.0%) patients, The rarest reason for admission is suspected open or depressed skull fracture 3 (2.0%) patients. Other reasons are shown in Table 2.

Sixty-five (43.3%) CTs were performed in accordance with CCHR. Sixty-three (42.0%) CTs showed pathology. Two CTs showed no pathology. Eighty-five (56.7%) CTs were performed not in accordance with CCHR.

Table 1. Canadian head computed tomography rule

High risk of neurosurgical intervention:
Glasgow Coma Scale <15 in 2 h after injury
Suspected open or depressed skull fracture
Sign of basal skull fracture*
Two or more episodes of vomiting
Age 65 years or older
Medium risk of brain injury detection by computed tomography:
Amnesia before impact of 30 min more
Dangerous mechanism**
***Signs of basal skull fracture**
Hemotympanum, "racoon" eyes, cerebrospinal fluid otorrhea/rhinorrhea, Battle's sign
****Dangerous mechanism**
Pedestrian struck by vehicle
Occupant ejected from the motor vehicle
Fall from elevation of 1 meter or 5 stairs more

Sixty-eight of these CTs showed no pathology and 17 CTs showed pathology. The classification of CT scans is shown in Tables 3 and 4.

A brain CT scan contains a radiation dose of 42 milliSieverts (mSv). The cost of a brain CT scan is $6.67. According to the CCHR, there are 70 CT scans with discordant results that are unnecessary. This corresponds to a total unnecessary radiation dose of 2940 mSv. The total unnecessary cost is $466.9 dollars.

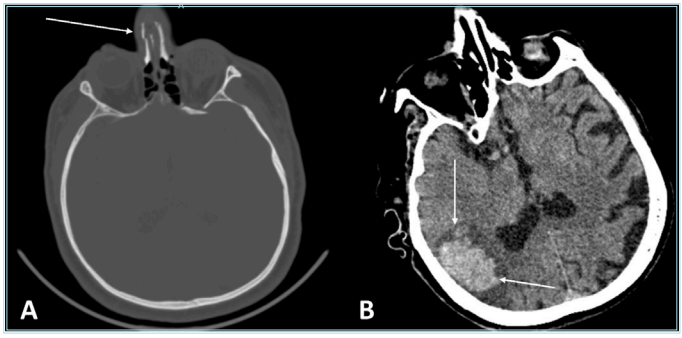

Figure 1. Nasal fracture and intraparenchymal hemorrhage. A) The image on the left is an axial CT scan of a patient admitted to our hospital with beatings and punishments. The image shows a nasal fracture (arrow). B) The image on the right is a CT scan of a patient admitted with the occupant ejected from the motor vehicle. The image shows intraparenchymal hemorrhage (arrows) and edema

CT: Computed tomography

Table 2. The number of people admitted for other reasons

Reason	Number (%)
Fall from height less than 1 m	26 (17.3)
Beatings and punishments	37 (24.7)
Hitting your head against a hard object at a slow speed	22 (14.7)

Table 3. Pathology rates

CTs	Number of people with pathology	Number of people without pathology
CCHR-eligible shots	63	2
Shootings not in accordance with the CCHR	17	68

CT: Computed tomography, CCHR: Canadian Head CT Rule

Table 4. Pathologies of CTs

Pathologies	Number	
	CCHR: Eligible shots	Shootings not in accordance with the CCHR
Subarachnoid hemorrhage	7	1
Subdural hematoma	13	4
Epidural hematoma	9	2
Le-Fort fracture	3	
Aneurysm rupture	1	
Nasal fracture	5	10
Blow out fracture	8	
Contusion: Intraparenchymal hemorrhage	14	
Pneumocephaly	1	
Coup-contra coup lesion	2	

CT: Computed tomography, CCHR: Canadian Head CT Rule

Discussion

In this study, we hope to learn about the needless number of CTs performed by categorizing patients over the age of 15 who apply for emergency head injuries based on CCHR and determining the radiation burden and cost of unneeded CTs. We demonstrated that unneeded CTs result in wasteful radiation doses and costs. CCHR is an excellent indicator of which type of mild head trauma requires CT.

There is an increasing use of CT in emergency departments in daily practice because of reasons such as increased patient density, fear of malpractise and the desire to reach a diagnosis quickly. As a result, there is an exponential increase in patients' radiation exposure. There are many studies in the literature showing that there is an increasing use of CT in studies on this subject.[3,11] In addition to radiation exposure, unnecessary CT examination may cause an increase in the time the patient spends in the hospital, unnecessary costs, and side effects due to the iodinated contrast material used.[12-14] It is known that most patients with minor head trauma who frequently visit emergency departments receive CT scans in emergency departments.[15]

The CCHR was created in 2001 as a guideline to help clinicians determine which patients with minor head traumas should receive head CTs. The CCHR is a clinical decision-making tool designed to assist emergency physicians in ordering appropriate head CTs for adult patients with minor head traumas. The CCHR has been proven to be the most effective clinical decision rule for limiting testing and preventing missed injuries in people with mild head injuries. Żyluk's[16] 2015 comprehensive review found that the CCHR has 100% sensitivity and 48-77% specificity. CCHR has been verified in hospitals worldwide. Despite the adoption of the CCHR in hospital systems, research has revealed that it is not regularly followed in practice.[17]

Studies have shown that unnecessary CTs cause cost and radiation burden.

Karavas et al.[18] in their study, inadvertent exposure to high amounts of ionizing radiation can cause short-term damage such as burns and hair loss. Exposure to such dosages directly in the eyes increases the chance of cataracts. Fatihoglu et al.[19] In their study, younger patients undergoing CT were more vulnerable to the potential neoplastic effects of ionizing radiation. Gökharman et al.[20] In their study, calculated the cost of unnecessary CTs performed in the emergency department.

Study Limitations

Our study has some limitations, such as the low number of participants and the fact that it is a single-center and retrospective study.

Conclusion

In conclusion, in our study, approximately 57% of CTs were unnecessary and 80% of unnecessary CTs did not show pathology. The total unnecessary radiation dose was 2940 mSv. The total unnecessary cost is $466.9 dollars. We demonstrated that unneeded CTs result in wasteful radiation doses and costs, and CCHR is an excellent indicator of which type of mild head trauma requires CT.

Ethics

Ethics Committee Approval: Ethical approval was obtained from Ankara Training and Research Hospital Research Committee (KAEK-2023-01/12.320578).

Informed Consent: Since the study was a retrospective study, informed consent was not required by the ethics committee.

Authorship Contributions

Surgical and Medical Practices - Concept - Design - Data Collection or Processing - Analysis or Interpretation - Literature Search - Writing: A.G., F.D.G.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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