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Neuroimaging for mild traumatic brain injury in children: cross-sectional study using national claims data

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Abstract

Background—Current guidelines recommend healthcare professionals avoid routine use of neuroimaging for diagnosing mild traumatic brain injury (mTBI).

Objective—This study aimed to examine current use of CT and MRI among children and young adult patients with mTBI and factors that increase likelihood of neuroimaging in this population.

Materials and methods—Data were analyzed using the 2019 MarketScan commercial claims and encounters database for the commercially insured population for both inpatient and outpatient claims. Descriptive statistics and logistic regression models for patients ≤24 years of age who received an ICD-10-CM code indicative of a possible mTBI were analyzed.

Results—Neuroimaging was performed in 16.9% (CT; 95% CI=16.7–17.1) and 0.9% (MRI; 95% CI=0.8–0.9) of mTBI outpatient visits (including emergency department visits) among children (≤18 years old). Neuroimaging was performed in a higher percentage of outpatient visits for patients 19–24 years old (CT=47.1% [95% CI=46.5–47.6] and MRI=1.7% [95% CI= 1.5–1.8]), and children aged 15–18 years old (CT=20.9% [95% CI=20.5–21.2] and MRI=1.4% [95% CI=1.3–1.5]). Outpatient visits for males were 1.22 (95% CI=1.10–1.25) times more likely to include CT compared to females, while there were no differences by sex for MRI or among inpatient stays. Urban residents, as compared to rural, were less likely to get CT in outpatient settings (adjusted odds ratio [aOR]=0.55, 95% CI=0.53–0.57). Rural residents demonstrated a larger proportion of inpatient admissions that had a CT.

Conclusions—Despite recommendations to avoid routine use of neuroimaging for mTBI, neuroimaging remained common practice in 2019.

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Conflicts of interest None

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Keywords

Neuroimaging; mTBI; MarketScan

Introduction

Recent estimates report approximately 223,000 traumatic brain injury (TBI)-related hospitalizations in 2019 and 64,000 TBI-related deaths in the USA in 2020 [1, 2]. These estimates do not include the unknown number of patients with TBI who were treated and released from an emergency department, primary care office, or urgent care facility, or those who did not seek care. While most of these injuries are classified as mild TBIs (mTBIs), some mTBIs can have a long-lasting negative impact on patients and their families [3].

Clinical decision-making for patients with mTBI includes assessing the likelihood of a more severe brain injury and need for diagnostic neuroimaging (e.g., head computerized tomography (CT), brain magnetic resonance imaging (MRI)) [4-6]. Current guidelines from the 2018 Centers for Disease Control and Prevention (CDC)[7] and the 2008 American College of Emergency Physicians (ACEP) [8] recommend that healthcare professionals use validated decision rules to identify patients at risk for more severe intracranial injury in which neuroimaging is warranted, as there is low value in using neuroimaging to diagnose mTBI alone—in fact, it may result in harms and excess costs [7, 8]. These recommendations are driven by concerns about overuse, inconsistent use, and the potential risks (e.g., radiation) associated with head CT when applied to children [5, 9-12]. Still, neuroimaging is widely used in the USA.

The goals of this study are to (1) examine CT and MRI use among children and young adult patients diagnosed in the setting of mTBI as well as other possible mTBI (e.g., unspecified head injuries) and to (2) determine which factors are associated with use of neuroimaging in this population. While previous literature have studied some of these characteristics in youth, they are limited by several factors including evaluation of CT use only [4, 5], failure to identify factors associated with neuroimaging, sole assessment of emergency department visits [4-6], and/or analyses of older data [4-6]. This study addresses these gaps in knowledge by independently exploring imaging encounters for multiple neuroimaging modalities, various clinical settings, and identification of factors that increase neuroimaging using recent data.

Methods

Data were analyzed using the 2019 MarketScan commercial claims and encounters database for the commercially insured population for both inpatient and outpatient claims. MarketScan captures person-specific utilization and enrollment for inpatient (patients admitted to the hospital) and outpatient claims (all other patients. Examples include patients who go to the emergency department, a primary care physician, an urgent care clinic, etc.). The private health insurance database includes data from active employees, early retirees, Consolidated Omnibus Budget Reconciliation Act (COBRA) continuees, and dependents insured by employer-sponsored plans. MarketScan data are released with a delay and 2019 data were the most recent data available at the time of this study.

The International Classification of Diseases, Tenth Revision, Clinical Modifications (ICD-10-CM) codes were used to identify visits with a diagnosed or other possible mTBI. Diagnosed mTBI was defined as S02.0, S02.1, S02.91, S060.0X0, S06.0X1, S06.0X9, and other possible mTBI as S09.90; this definition was similar to Arbogast et al. [13], but was translated from ICD-9-CM to ICD-10-CM code equivalents (Supplemental Table 1). However, an important difference from that study is that the current study also examined patients diagnosed with head injury unspecified (S09.90) although this code is not included in the current CDC ICD-10-CM definition for TBI surveillance [14]. This code was included in this study, as a recent study showed a substantial percentage of patients given this diagnosis code had moderate to high evidence documented in their medical record that a TBI had occurred [15]; furthermore, it was included as imaging is conducted in some head injuries in which this diagnosis code is provided at discharge. A sensitivity analysis was performed to compare results with and without S09.90, and overall differences were minimal; thus, S09.90 was included. Herein, references to mTBI events in this study will include both diagnosed and other possible mTBI encounters. In MarketScan, a patient may have multiple visits with an mTBI, and each visit enters the dataset as a unique record. Each service date with an mTBI code was considered a visit and diagnosis codes for outpatient visits were defined by service date. Analyses were limited to mTBI visits among patients aged ≤24 years. Those who were age 18 were grouped with minors given that pediatric healthcare professionals often see patients past their 18th birthday. The 19–24-year-old age group was included in the analysis for comparison as the closest age group to children and due to greater likelihood of commonality of the behaviors (such as sports, driving).

Imaging was defined as having a head CT, head MRI, or skull radiograph during the visit with an mTBI code. Head CT was identified by a procedure group code of 210, a revenue code of 0351, or a procedure of 704.50 or 704.70. Head MRI was identified using a procedure group code of 216, a revenue code of 0611, or procedure of 705.51. Skull radiograph was identified using a procedure group code of 201 or a procedure of 702.60. A visit could have more than one of the imaging procedure and would be counted independently in each category.

Prevalence of CT, MRI, skull radiography, and no imaging (defined as not having a CT, MRI, or skull radiograph during the visit with the mTBI) was calculated overall, by age group (≤18 years as well as 0–1, 2–4, 5–9, 10–14, 15–18, and 19–24 years), sex, and urbanicity (rural and urban). Age groups were defined based on a combination of developmental milestones, Pediatric Emergency Care Applied Research Network (PECARN) decision rules for neuroimaging, and ages that represent transitions in school type (i.e., elementary/junior high/high school/post-high school). Urbanicity was assigned using the metropolitan statistical area of the primary beneficiary. Beneficiaries were classified as residing in an urban area if their county of residence was classified as a metropolitan statistical area, either micropolitan or metropolitan. Beneficiaries residing outside of a defined metropolitan statistical area were considered to reside in rural areas. Additionally, injuries were categorized by intent and mechanism of injury (motor vehicle crashes, unintentional fall, unintentional struck by or against, other unintentional injury mechanism unspecified, intentional self-harm, assault, other or no mechanisms specified, or multiple mechanisms) [16].

In addition, the five most common ICD-10-CM codes assigned to patients, other than those used for mTBI, were identified to show other diagnoses related to the mTBI visit. Logistic regression models were used to estimate the adjusted odds ratio (aOR) of visit characteristics in relation to imaging for outpatient visits, controlling for age, sex, and urban/ rural residence. Reference groups were chosen based on neuroimaging decision rules (e.g., for the variable “age”) or the level of the variable with the lower percentage. Missing data were not imputed. Records that did not include an enrollee ID (*n*=2) were excluded, as multiple claims for the same day could not be identified. Analyses were performed in Stata Version 15 (Stata Corp LP, College Station, TX) and SAS 9.4 (SAS Institute, Cary, North Carolina). This study was exempt from institutional review board review due to secondary data use.

Results

Outpatient visits

In 2019, there were 166,473 outpatient visits captured among patients 0–24 years of age who had an mTBI during the year. Among these visits, 37,630 (22.6%) had a CT, 2,205 (1.3%) had a skull radiograph and 1,790 (1.1%) had an MRI. Most outpatient visits (*n*=125,531; 75.4%) did not have imaging (Table 1). Neuroimaging was ordered in 16.9% (95% CI=16.7–17.1; CT), 1.4% (95% CI=1.4–1.5; skull radiograph), and 0.9% (95% CI=0.8–0.9; MRI) of outpatient visits among children (≤18 years). Outpatient visits among patients aged 19–24 years had the highest percentage of imaging among all age groups for CT and MRI (CT=47.1%, 95% CI=46.5–47.6 and MRI=1.7%, 95% CI=1.5–1.8). Among children, those 15–18 years of age had the highest percentage of CT and MRI imaging (CT=20.9%, 95% CI=20.5–21.2 and MRI=1.4%, 95% CI=1.3–1.5) during outpatient visits for mTBI. There appeared to be similar percentages of imaging by sex as 23.2% (95% CI=22.9–23.4) of outpatient visits among males included a CT scan and 22.0% (95% CI=21.7–22.3) of visits among females included a CT scan. This pattern was similar for outpatient visits by sex for skull radiography and MRI.

The most common secondary diagnosis for outpatient visits with an mTBI was headache (Table 2). Headache was diagnosed in 30.9% (11,610/37,630) and 29.6% (529/1790) of visits in which CT and MRI were utilized, respectively. Secondary diagnosis codes were more varied for visits with skull radiography or no imaging.

Among visits for children ≤18 years old who received CT imaging with an mTBI, unintentional falls and unintentional struck by or against were the most common mechanism of injuries (Supplemental Table 2). However, for visits among patients 19–24 years old who received CT imaging, motor vehicle crashes and unintentional falls were the most common mechanism of injury.

Outpatient visits—imaging by demographic characteristics

Patients aged 15–18 years and 19–24 years were more likely to have CT during an outpatient visit for mTBI than those aged 0–1 years (15–18: aOR=1.49, 95% CI=1.41–1.57; 19–24: aOR=5.12, 95% CI=4.87–5.39) (Table 3). Visits with patients for all age groups (2–24 years old) were less likely than those aged 0–1 years to have a skull radiograph during the visit for mTBI (aORs<1.00, 95% CI<1.00). For MRI, visits with patients aged 2–4 years were less likely than those aged 0–1 years to have an MRI during the visit for mTBI (aOR=0.63, 95% CI=0.43–0.90). However, visits with patients aged 10–24 years were more likely to have an MRI than those aged 0–1 years (aOR=1.84–3.24). Outpatient visits among males were 1.22 (95% CI=1.10–1.25) times more likely to have a CT and 1.13 (95% CI=1.03–1.23) times more likely to have a skull radiograph compared to females; for MRI, there was no significant difference by sex. Visits for rural residents were more likely to have a CT (aOR=1.81, 95% CI=1.74–1.87) or skull radiograph (aOR=1.31, 95% CI=1.15–1.50) compared to urban residents, while there was no significant difference for MRI (aOR=0.99, 95% CI=0.85–1.16).

Inpatient visits

In 2019, there were 2,249 inpatient visits captured among patients 0–24 years of age who had an mTBI (Table 4). Among these visits, 528 (23.48%) admissions did not receive imaging, while 1,666 (74.08%) inpatient admissions had an associated CT, and 148 (6.58%) visits had an associated MRI. Data for visits that only included skull radiography were not shown in Table 4 due to the low prevalence of use. Among admissions, 78.6% (95% CI=75.9–81.2) of 19–24-year-olds and 73.3% (95% CI=69.3–77.0) of 15–18-year-olds received a CT; 15.4% (95% CI=11.3–20.7) of 0–1-year-olds and 11.8% (95% CI=7.3–18.4) of 2–4-year-olds who were admitted received an MRI. Among MRI, CT, and no imaging, the proportion of females and males was similar. Among visits for rural residents, 77.2% (95% CI=72.2–81.6) had a CT, 4.6% (95% CI=2.8–7.7) had an MRI, and 20.8% (95% CI=16.6–25.7) received no imaging, compared to 73.6% (95% CI=71.6–75.5) for CT, 6.9% (95% CI=5.8–8.1) for MRI, and 23.9% (95% CI=22.1–25.8) among urban residents. Among those admissions that had a CT, the proportion varied with a high among those with a length of stay between >48 h and 7 days (76.4%, 95% CI=73.1–79.4) compared to durations of other lengths. Comparatively, for admissions that had an MRI, there was a high percentage among those with a stay ≤48 h (7.5%, 95% CI=6.1–9.1) compared to durations of other lengths.

Among those admissions with a CT for mTBI, unspecified injury of the neck was the most common secondary diagnosis with 24.2% (403/1666) of admissions having that code (Table 5). Among those admissions with an MRI for mTBI, three secondary diagnoses were found in 18.9% (28/148) of the records: traumatic subdural hemorrhage with loss of consciousness of unspecified duration, headache, and unspecified convulsions. The secondary diagnosis codes for no imaging were more varied with the most common code (major depressive disorder, single episode, unspecified) only found in 8.5% (45/528) of the records.

Discussion

This study of encounters from a large health database demonstrated that use of CT, skull radiography, and MRI varied by patient age and urban/rural residence. The largest proportions of neuroimaging for outpatient visits were among adolescents and young adults for CT and MRI, while for inpatient visits, young adults and children aged 1 year and younger were the age groups that received the largest proportion of CTs and MRIs, respectively. Additionally, there was a high proportion of visits among rural residents that included a CT, for both outpatient and inpatient visits. Incidence of skull radiography was very low, in accordance with national guidelines [7] recommending avoidance of radiographs in the diagnosis of TBI given that skull radiographs cannot diagnose intracranial injury and are not the best imaging modality to diagnose skull fracture. These findings suggest that specific populations have a higher likelihood of neuroimaging for mTBI. Recent studies suggest that healthcare professional education and the implementation of clinical decision support tools improve adherence to TBI guidelines [17-20].

The skew towards higher percentages of neuroimaging for young adults and in rural settings presented in this dataset largely confirms previously suggested trends. Specifically, the results demonstrate that while adolescents 15–18 years have the highest percentage (20.9%) of CT use among children for outpatient visits, there was much higher use of CT among young adults (47.1%); this pattern was not seen with MRI or skull radiography within outpatient visits. This result is consistent with data demonstrating that young adults are more likely to be seen in the ED for injuries related to motor vehicle collisions [21, 22], interpersonal violence [23], and assault [24], and may present obtunded from ingestions or intoxications [25-27]. This may also reflect young adults, and some older children, receiving care at adult-focused healthcare facilities, as opposed to dedicated pediatric facilities. Regardless, this highlights the need for targeted protocols to reduce unnecessary neuroimaging in young adults [28]. The higher levels of CT use among rural versus urban resident outpatient visits, including ED visits, may be linked to interhospital transfer protocols and variations in guideline adherence [29-31]. Specifically, evaluation for clinically important TBI at rural and community hospitals without resources to manage pediatric trauma patients may result in overtriage (the unintentional prioritization of a patient’s care without significant injuries over other patients with a greater urgency of need), neuroimaging, and further consideration for interhospital transfer for numerous reasons (e.g., clinician experience, hospital resources, parental concern, medicolegal implications) [32, 33]. Notably, images obtained in referring institutions have been associated with a 9–13% discordance rate in findings compared to assessment of the same images at tertiary care centers, which raises concerns about unnecessary interhospital transfers of pediatric patients [34, 35]. Similarly, while the proportion of visits among rural residents that had a CT scan was higher, this was consistent with other studies [29-31] that report that CT use may be higher in rural areas secondary to interhospital transfer protocols related to prognostication of stability in transfer and transfer hospital preparedness. More specifically, a recent study [36] found that a higher proportion of children with minor head injury received head CT in transferring facilities when compared to pediatric emergency department among low-risk (28.9% vs 15.8%) and intermediate-risk groups (42.8% vs 29.4%). Reported domains that increase the likelihood of CT following pediatric head injury include ED-related practice constraints, clinician and caregiver preference or anxieties, modes of establishing trust, and patient expectations [36, 37]. Transport times and concerns about patient stability during transport may also drive the decision for neuroimaging prior to transfer to another facility. Additionally, MRI may be less available in rural hospitals and thus used less often for inpatient visits [38].

In addition to updating prior studies, this work's strengths include its assessment of an expansive dataset that allowed for comparisons among demographic groups and examined multiple imaging modalities and settings. Commonly used neuroimaging modalities that reflect historical practice patterns (skull radiography), gold standard imaging (head CT), and more newly adopted imaging (MRI) were examined. Of particular interest is whether imaging has decreased following the proliferation of guidelines focused on pediatric mTBI. These guidelines recommend that imaging not be used for diagnosing mTBI and instead should be reserved for patients who meet the criteria laid out in validated clinical decision rules. These data represent a snapshot in time that future studies can use to compare and identify whether imaging use, and particular types of imaging, are increasing or decreasing.

There were multiple limitations to the study. First, neuroimaging use was limited to visits with a diagnosed or other possible mTBI. More severe forms of TBI were not examined as they would almost always warrant neuroimaging. Second, while a strength of this study is that the dataset is very large and covers a large proportion of all US healthcare visits, the data are not wholly representative of the US population as it only reflects those with commercial insurance coverage. Prior research [39] has found that neuroimaging and payer status are associated, while those without commercial insurance more likely to be imaged. The results presented in this study are likely a lower bound given previous research. Third, the data represent medical visits and not individual patients. Therefore, patients could have been imaged multiple times for the same injury on different days and multiple types of imaging could have been performed in the same encounter. Finally, the data do not allow for coding of positive or negative imaging findings, or for assessing of whether imaging was indicated based on validated clinical decision rules for pediatric imaging. Future studies might examine how the proportion of positive imaging findings varies by age group and other patient characteristics; alternatively, future studies could examine the proportion of head imaging meeting the criteria laid out in established clinical decision rules, and how this varies by age and other patient characteristics.

Conclusion

In conclusion, neuroimaging-associated visits for mild TBI varied significantly by patient age and resident location in a large healthcare dataset. The outcomes of this study serve to support targets for current and future guideline implementation strategies. Further research is needed to determine trends in neuroimaging over time for mild TBI, appropriateness of imaging ordering, and whether adoption of guideline recommendations may have impacted trends.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Frequency of imaging for mild TBI[a] among outpatient visits by demographics and health characteristics, MarketScan[b] private health insurance, USA, 2019

	CT		Skull radiograph		MRI		No imaging[c]	
	n	**% (95% CI)**	***n***	**% (95% CI)**	***n***	**% (95% CI)**	***n***	**% (95% CI)**
Age								
≤18	22,807	16.9 (16.7–17.1)	1912	1.4 (1.4–1.5)	1263	0.9 (0.8–0.9)	109,456	81.1 (80.9–81.3)
0–1	2211	14.9 (14.3–15.5)	400	2.7 (2.4–3.0)	78	0.5 (0.4–0.7)	12,212	82.3 (81.7–82.9)
2–4	2132	15.3 (14.7–15.9)	306	2.2 (2.0–2.5)	46	0.3 (0.2–0.4)	11,463	82.4 (81.7–83.0)
5–9	3119	15.6 (15.1–16.1)	343	1.7 (1.5–1.9)	114	0.6 (0.5–0.7)	16,440	82.3 (81.8–82.9)
10–14	5815	14.3 (14.0–14.7)	436	1.1 (1.0–1.2)	391	1.0 (0.9–1.1)	34,085	83.9 (83.6–84.3)
15–18	9530	20.9 (20.5–21.2)	427	0.9 (0.9–1.0)	634	1.4 (1.3–1.5)	35,256	77.2 (76.8–77.6)
19–24	14,823	47.1 (46.5–47.6)	293	0.9 (0.8–1.0)	527	1.7 (1.5–1.8)	160,75	51.1 (50.5–51.6)
Sex								
Male	20,423	23.2 (22.9–23.4)	1266	1.4 (1.4–1.5)	927	1.1 (1.0–1.1)	65,968	74.8 (74.5–75.1)
Female	17,207	22.0 (21.7–22.3)	939	1.2 (1.1–1.3)	863	1.1 (1.0–1.2)	59,563	76.1 (75.8–76.4)
Rural/urban residence								
Rural	5160	33.2 (32.5–34.0)	247	1.6 (1.4–1.8)	175	1.1 (1.0–1.3)	10,024	64.5 (63.8–65.3)
Urban	32,470	21.5 (21.3–21.7)	1958	1.3 (1.2–1.4)	1615	1.1 (1.0–1.1)	115,507	76.5 (76.3–76.7)
Total	37,630		2205		1790		125,531	

[a] Mild TBI cases were identified using ICD-10-CM codes S02.0, S02.1, S02.91, S060.0X0, S06.0X1, S06.0X9, and other possible mTBI were identified using ICD-10-CM code S09.90

[b] IBM Watson Health and MarketScan are trademarks of IBM Corporation in the USA, other counties, or both

[c] No Imaging is defined as not receiving a CT, MRI, or skull radiograph during the claim

ICD-10-CM indicates International Classification of Diseases 10th Revision, Clinical Modification

Table 2

Frequency of imaging for the top five other diagnoses related to the mild TBI[a] encounter among outpatient visits, MarketScan[b] private health insurance, USA, 2019

	CT		Skull radiograph		MRI		No imaging[c]	
Other diagnoses related to the encounter[d]	**ICD-10-CM**	***n* (%)**	**ICD-10-CM**	***n* (%)**	**ICD-10-CM**	***n* (%)**	**ICD-10-CM**	***n* (%)**
1	R51 (headache)	11,610 (30.9)	S0083XA (contusion of other part of head)	338 (15.3)	R51 (headache)	529 (29.6)	R51 (headache)	9715 (7.7)
2	S199XXA (unspecified injury of neck)	6458 (17.2)	R51 (headache)	335 (15.2)	M542 (cervicalgia)	265 (14.8)	M542 (cervicalgia)	4074 (3.2)
3	M542 (cervicalgia)	5768 (15.3)	S0993XA (unspecified injury of face)	299 (13.6)	S199XXA (unspecified injury of neck)	172 (9.6)	S0181XA (laceration without foreign body of other part of head)	4021 (3.2)
4	S0083XA (contusion of other part of head)	3151 (8.4)	S0992XA (unspecified injury of nose)	251 (11.4)	R42 (dizziness and giddiness)	146 (8.2)	S0083XA (contusion of other part of head)	3839 (3.1)
5	R55 (syncope and collapse)	3034 (8.1)	S0033XA (contusion of nose)	189 (8.6)	R55 (syncope and collapse)	126 (7.0)	R42 (dizziness and giddiness)	3491 (2.8)

[a] Mild TBI cases were identified using ICD-10-CM codes S02.0, S02.1, S02.91, S060.0X0, S06.0X1, S06.0X9 and other possible mTBI were identified using ICD-10-CM code S09.90

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[c] No Imaging is defined as not receiving a CT, MRI, or Skull radiograph during the claim

[d] The top 5 diagnosis codes will not sum to 100% as claims have multiple associated codes

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Table 3

Imaging for mild TBI[a] outpatient visits by demographics, MarketScan[b] private health insurance, USA, 2019[c]

Variables	CT aOR (95% CI)	Skull radiograph aOR (95% CI)	MRI aOR (95% CI)
Age			
0–1	Referent	Referent	Referent
2–4	1.01 (0.95–1.08)	**0.80 (0.69–0.93)**	**0.63 (0.43–0.90)**
5–9	1.03 (0.97–1.10)	**0.62 (0.54–0.72)**	1.08 (0.81–1.44)
10–14	**0.93 (0.89–0.99)**	**0.39 (0.34–0.44)**	**1.84 (1.44–2.35)**
15–18	**1.49 (1.41–1.57)**	**0.34 (0.30–0.39)**	**2.67 (2.11–3.39)**
19–24	**5.12 (4.87–5.39)**	**0.34 (0.29–0.39)**	**3.24 (2.55–4.11)**
Sex			
Male	**1.22 (1.10–1.25)**	**1.13 (1.03–1.23)**	1.05 (0.95–1.15)
Female	Referent	Referent	Referent
Rural/urban residence			
Rural	**1.81 (1.74–1.87)**	**1.31 (1.15–1.50)**	**0.99 (0.85–1.16)**
Urban	Referent	Referent	Referent

aOR adjusted odds ratio; *CI* confidence interval

[a]Mild TBI cases were identified using ICD-10-CM codes S02.0, S02.1, S02.91, S060.0X0, S06.0X1, S06.0X9, and other possible mTBI were identified using ICD-10-CM code S09.90. Bolded text indicates significant results

[b]IBM Watson Health and MarketScan are trademarks of IBM Corporation in the USA, other counties, or both

[c]Models were adjusted for age, sex, and rural/urban residence

Table 4

Frequency of imaging for mild TBI[a] inpatient admissions by demographics and health characteristics, MarketScan[b] private health insurance, USA, 2019[c]

	CT		MRI		No imaging[d]	
	n	**% (95% CI)**	***n***	**% (95% CI)**	***n***	**% (95% CI)**
Age						
≤18	937	71.2 (68.6–73.8)	122	9.2 (7.8–10.9)	338	25.6 (23.3–28.0)
0–1	149	65.6 (59.2–71.5)	35	15.4 (11.3–20.7)	63	27.8 (22.3–34.0)
2–4	90	66.2 (57.8–73.7)	16	11.8 (7.3–18.4)	39	28.7 (21.7–36.9)
5–9	106	71.1 (63.3–77.9)	15	10.1 (6.1–16.1)	38	25.5 (19.1–33.1)
10–14	215	72.6 (67.3–77.4)	31	10.5 (7.5–14.5)	72	24.3 (19.8–29.5)
15–18	377	73.3 (69.3–77.0)	25	4.9 (3.3–7.1)	126	24.5 (21.0–28.4)
19–24	729	78.6 (75.9–81.2)	26	2.8 (1.9–4.1)	190	20.5 (18.0–23.2)
Sex						
Male	1054	73.9 (71.6–76.1)	94	6.6 (5.4–8.0)	334	23.4 (21.3–25.7)
Female	612	74.4 (71.3–77.2)	54	6.6 (5.1–8.5)	194	23.6 (20.8–26.6)
Rural/urban residence						
Rural	234	77.2 (72.2–81.6)	14	4.6 (2.8–7.7)	63	20.8 (16.6–25.7)
Urban	1432	73.6 (71.6–75.5)	134	6.9 (5.8–8.1)	465	23.9 (22.1–25.8)
Length of stay						
≤48 h	890	74.0 (71.5–76.4)	90	7.5 (6.1–9.1)	275	22.9 (20.6–25.3)
>48 h-7 days	533	76.4 (73.1–79.4)	45	6.4 (4.8–8.5)	153	21.9 (19.0–25.1)
>7 days	243	69.6 (64.6–74.2)	13	3.7 (2.2–6.3)	100	28.7 (24.1–33.6)
Total	1666		148		528	

[a]Mild TBI cases were identified using ICD-10-CM codes S02.0, S02.1, S02.91, S060.0X0, S06.0X1, S06.0X9, and other possible mTBI were identified using ICD-10-CM code S09.90

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[c]Skull radiograph was not included in this table due to low prevalence

[d]No Imaging is defined as not receiving a CT, MRI, or Skull radiograph during the claim

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Table 5

Frequency of imaging for the top five other diagnoses related to the mild TBI[a] encounter among MarketScan[b] private health insurance, USA, 2019[c]

	CT		MRI		No imaging[d]	
Other diagnoses related to the encounter[e]	ICD-10-CM	*n* (%)	ICD-10-CM	*n* (%)	ICD-10-CM	*n* (%)
1	S199XXA (unspecified injury of neck)	403 (24.2)	S065X9A (traumatic subdural hemorrhage with loss of consciousness of unspecified duration)	28 (18.9)	F329 (major depressive disorder, single episode, unspecified)	45 (8.5)
2	S299XXA (unspecified injury of thorax)	368 (22.1)	R51 (headache)	28 (18.9)	R51 (headache)	44 (8.3)
3	M542 (cervicalgia)	225 (13.5)	R569 (unspecified convulsions)	28 (18.9)	R45851 (suicidal Ideations)	41 (7.8)
4	S0219XA (other fracture of base of skull)	212 (12.7)	S065X0A (traumatic subdural hemorrhage without loss of consciousness)	25 (16.9)	F419 (anxiety disorder, unspecified)	39 (7.4)
5	R51 (headache)	210 (12.6)	S0219XA (other fracture of base of skull)	24 (16.2)	S0181XA (laceration without foreign body of other part of head)	35 (6.6)

[a] Mild TBI cases were identified using ICD-10-CM codes S02.0, S02.1, S02.91, S060.0X0, S06.0X1, S06.0X9, and other possible mTBI were identified using ICD-10-CM code S09.90

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[e] The top 5 diagnosis codes will not sum to 100% as claims have multiple associated codes

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