



Original Contribution

History and physical exam predictors of intracranial injury in the elderly fall patient: A prospective multicenter study



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ARTICLE INFO

Article history:

Received 28 July 2018

Received in revised form 17 October 2018

Accepted 22 October 2018

Keywords:

Geriatric trauma

Intracranial injury

Head trauma

Neuroimaging in trauma

ABSTRACT

Objectives: A prior single-center study demonstrated historical and exam features predicting intracranial injury (ICI) in geriatric patients with low-risk falls. We sought to prospectively validate these findings in a multicenter population.

Methods: This is a prospective observational study of patients ≥ 65 years presenting after a fall to three EDs. Patients were eligible if they were at baseline mental status and were not triaged to the trauma bay. Fall mechanism, head strike history, headache, loss of consciousness (LOC), anticoagulants/antiplatelet use, dementia, and signs of head trauma were recorded. Radiographic imaging was obtained at the discretion of treating physicians. Patients were called at 30 days to determine outcome in non-imaged patients.

Results: 723 patients (median age 83, interquartile range 74–88) were enrolled. Although all patients were at baseline mental status, 76 had GCS < 15 , and 154 had dementia. 406 patients were on anticoagulation/antiplatelet agents. Fifty-two (7.31%) patients had traumatic ICI. Two study variables were helpful in predicting ICI: LOC (odds ratio (OR) 2.02) and signs of head trauma (OR 2.6). The sensitivity of these items was 86.5% (CI 73.6–94) with a specificity of 38.8% (CI 35.1–42.7). The positive predictive value in this population was 10% (CI 7.5–13.3) with a negative predictive value of 97.3% (CI 94.4–98.8). Had these items been applied as a decision rule, 273 patients would not have undergone CT scanning, but 7 injuries would have been missed.

Conclusion: In low-risk geriatric fall patients, the best predictors of ICI were physical findings of head trauma and history of LOC.

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1. Introduction

Falls are the most common cause of injury-related morbidity and mortality in elderly Americans [1]. In 2014, almost 30% of independently living older adults reported at least 1 fall in the prior year, resulting in a total of 29 million falls with 2.8 million emergency department visits, 7 million injuries, 800,000 hospitalizations, and 27,000 deaths [1]. Head trauma is the most common cause of mortality in elderly patients who fall, and unlike in younger age groups, incidence of traumatic brain injury in older adults is increasing [2,3].

Elderly patients are more likely than younger patients to suffer significant intracranial injury after minor head trauma for a number of reasons. Use of anticoagulants and antiplatelet agents may play a role in severity of injury, and elderly patients are less likely to protect their

heads with their arms during a fall [4]. Additionally, it is believed that generalized cerebral atrophy allows for increased tension on the cerebral bridging veins, which are thought to be more fragile than those of younger adults [5,6]. The mechanism of falling imparts ideal biomechanical forces to cause shear forces and bridging vein rupture. Forward acceleration as well as a sagittal rotational component delivered over a brief period of time results in a high rate of subdural hemorrhage in this population [7]. Animal models investigating subdural hemorrhage from ruptured bridging veins use head acceleration over time to induce injury as opposed to direct head strike [8]. This increased risk of injury in geriatric fall patients has led to widespread CT utilization, with some practitioners routinely imaging the heads of elderly fall patients who deny striking their heads and who lack signs of trauma, because of concern of shear injury to bridging veins even without direct head impact and recommendations for liberal use of head injury in geriatric fall patients [9]. A study of data from the National Hospital Ambulatory Care Survey from 2001 to 2010 demonstrated significantly higher CT

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utilization in older individuals who fall compared to younger patients, with approximately 50% of individuals over age 75 getting a head CT [10].

Cranial computed tomography (CT) is a reliable way to assess for intracranial injury, however this technology may be overused in patients with minor trauma or with other fall-related trauma (such as hip fracture) without signs of head injury [11–13]. Advanced medical imaging is one of the fastest growing sets of expenditures by Medicare, with spending more than doubling between 2000 and 2006. In 2014, Congress passed legislation to constrain imaging outside of “appropriate use criteria.” [14] This “appropriate use criteria” is still largely undefined, but the goal of appropriate use criteria is to provide guidelines to help clinicians determine what imaging should be performed based upon patient presentation, the scientific evidence, the risk/benefit ratio of testing, and available resources.

To assist in stewardship of this advanced technology, several decision rules have been put forth as guidelines to CT imaging in patients who have suffered head injury. The Canadian CT Head Rule (CCHR), the New Orleans Criteria (NOC), and NEXUS-II have all demonstrated utility in identifying patients at high risk for intracranial injury after minor head trauma who might benefit from CT imaging, but all three utilize age cut-offs (age 60 or 65, depending on the rule) [15–18]. Therefore, these guidelines are not helpful in determining which elderly fall patients are at increased risk for intracranial injury.

We sought to better describe the geriatric population presenting to 3 medical centers' emergency departments (EDs) for low acuity falls (i.e. not triaged to the trauma bay). We further sought to determine which historical and physical exam findings were most predictive of ICI in these patients who present at baseline mental status after a fall.

2. Materials and methods

2.1. Study design

This is a prospective observational study of geriatric patients (age 65 and older) presenting to 3 EDs with a chief complaint of fall. A convenience sample of geriatric patients seen after a fall was identified by research assistants or medical providers, depending on the institution. Patients, their family members, or chronic care facility personnel provided verbal consent for telephone contact follow-up at the time of enrollment. Historical and physical exam elements were provided by the physician caring for the patients. Patient charts were subsequently reviewed for CT scan results per radiology read. The study protocol did not alter patient management. The research protocol was reviewed and approved by the institutional review board at each of the 3 study facilities, and all investigators completed mandatory research training and certification.

2.2. Study setting and population

The study was performed at one urban tertiary care level 1 trauma center with an academic emergency medicine program, one community-based tertiary care level 1 trauma center with an academic emergency medicine program, and one community-based ED. The 3 study sites are in 3 different U.S. states. The combined volume of these 3 EDs is about 240,000 patient visits annually. At academic sites, physicians were educated regarding the study and data collection by monthly announcements made during mandatory education time and by protocol posters which were located in prominent areas in the ED. The community ED employed research assistants who were trained by the primary investigator regarding the study and its data collection. Patients were eligible for the study if they were 65 years of age or older and presented to the ED with a complaint related to a fall. Additionally, patients were included if they were at their baseline neurologic status as per their family members or chronic care facility staff. Patients were excluded if they met major trauma criteria and were triaged to the trauma

bay or if they were determined to have an acute change in baseline neurologic functioning as per the physician caring for the patient. Patients were not excluded due to dementia, aphasia, or any cognitive or neurologic deficit that was determined by the physician caring for the patient to be the patient's baseline.

2.3. Study protocol and measurements

All 3 sites enrolled patients as a convenience sample. For the 2 academic sites, patients were enrolled 24 h a day, 7 days a week. At the community site, patients were enrolled 5 days per week, 4 h per day as per the schedule of the research assistant. Patients eligible for this study were identified by attending physicians, resident physicians, and research assistants based on their chief complaint as entered into the electronic tracking system at each site. Providers caring for the eligible patients were asked to assess whether the patient was at his or her baseline neurologic function. The provider or research assistant would then approach the patient, caretaker, or chronic care facility personnel for verbal consent for phone follow-up contact to determine patient outcome. The physician caring for the patient or research assistant would then complete a data collection form that queried historical elements including: mechanical/non-mechanical fall (mechanical being secondary to tripping, slipping or loss of balance, and non-mechanical being secondary to weakness, dizziness, or syncope), head strike, loss of consciousness, headache, anti-platelet or anticoagulant use, preexisting dementia, and physical exam elements including: signs and location of head trauma and GCS. Age, gender, and whether a head CT was performed were also recorded. The data collection form contained a closed list of possibilities for each question, and the person completing the data collection sheet was instructed to circle his or her responses. Raw data were entered by trained research associates into a standardized Microsoft Excel 2007 spreadsheet (Microsoft Corporation, Redmond, WA). Data points coded as “unknown” (for example, loss of consciousness) were conservatively estimated to be positive for the purposes of data analysis and in accordance with priority being placed on avoiding missed injuries.

Research associates retrospectively reviewed each patient's medical record after his or her ED visit to determine the results of head CT, when performed, the disposition decision, and any neurosurgical interventions performed during the hospitalization.

At 4–6 weeks after the index ED visit, a research associate called study patients or their caregivers in follow-up. This was done to assure that any patients who were neither admitted and observed nor imaged had no significant sequelae related to head injury. Patients who were called were queried as to how they were feeling globally as well as specifically queried as to ongoing headache, dizziness, unsteadiness, neck pain, numbness, tingling, weakness, and the presence of other neurologic symptoms. Patients were queried about interval ED visits and their outcome. Patients with new or ongoing symptoms were encouraged to return to the ED for further evaluation. Date of follow-up and patient responses were recorded.

A patient was determined to have no significant acute head injury if any of the following was met: 1. he/she had a negative head CT at the index visit, 2. the patient was admitted to the hospital and had no sequelae at discharge, 3. review of his/her medical record revealed repeat hospital visits unrelated to falls with no sequelae or complaints related to the index visit, or 4. the patient had no complaints at 30 days post-injury in telephone follow-up.

Staff radiologist interpretations were used as the gold standard for identifying all head CT abnormalities. Staff radiologists had access to the indication for CT scanning and the clinical data present in the chart at the time of CT interpretation.

Investigators from all sites compiled data into identical data collection spreadsheets. Data was completely deidentified and pooled for analysis.

2.4. Data analysis

With a predicted low effect size and given a desired statistical power of 0.8, a type I error rate of 0.05, and 7 independent predictors in our regression model, our projected sample size was 721. Independent predictors included age ≥ 80 , prior history of dementia, history of head strike, reported loss of consciousness, new headache, antiplatelet/anticoagulant use, and exam findings with signs of head trauma. Signs of head trauma could be contusion, abrasion, laceration, avulsion, or ecchymosis. Multiple logistic regression was done using these variables to determine which variables best predicted the outcome of intracranial injury. “Signs of head trauma” and “loss of consciousness” were assessed in terms of sensitivity and specificity in accordance with a prior study demonstrating these items to have sufficient negative predictive value to apply as a decision rule in determining need for head CT in geriatric fall patients [19]. Data were also analyzed using descriptive statistics and Chi square. Data were analyzed using MedCalc (©1993–2013, Ostend, Belgium) and Microsoft Excel 2007 (Microsoft Corporation, Redmond, Washington).

3. Results

3.1. Demographic data

723 patients were enrolled from March 2013 through February 2015. Twelve patients were not imaged, nor were they admitted, and were ultimately lost to follow-up (Fig. 1). They are not included in this analysis. The demographics of the enrolled patients are shown in Table 1. Although enrolled patients were required to be at their baseline mental status, $>10\%$ had a GCS < 15 documented, and $>20\%$ had dementia at baseline.

The majority of patients (57.1%) were taking antiplatelet or anticoagulant medications, the details of which are listed in Table 2. In 16 patients (2.3%), complete medication lists were not available. In logistic regression (Table 3), use of any antiplatelet or anticoagulant medication was not statistically associated with increased likelihood of intracranial injury when controlling for other factors in our model. In unadjusted

Table 1

Baseline characteristics

	Total (n = 711)
Median age (IQR)	83 (74–88)
Gender (%)	
Male	243 (34.2)
Female	468 (65.8)
Dementia history (%)	
No	514 (72.3)
Yes	155 (21.8)
Not documented or unknown	42 (5.9)
First recorded GCS (%)	
15	584 (82.1)
14	60 (8.4)
13	9 (1.3)
12	3 (0.4)
11	3 (0.4)
10	1 (0.1)
Not documented	53 (7.5)
Mechanism of fall (%)	
Mechanical	468 (65.8)
Non-mechanical	70 (9.8)
Unsure	173 (24.3)
Anticoagulant/antiplatelet use (%)	
None	289 (40.6)
Aspirin	322 (45.3)
Clopidogrel/dipyridamole	46 (6.5)
Warfarin/NOACs/heparin	117 (16.5)
Unknown	16 (2.3)

subgroup analysis of patients taking aspirin versus other antiplatelet agents versus anticoagulants versus those on multiple agents, those on multiple agents had a higher rate of intracranial traumatic injury ($p = 0.008$, Fisher Exact. Data demonstrated in Table 2).

Most patients underwent CT imaging of the head (79.9%, $n = 568$) and over half of patients (53.3%, $n = 379$) were admitted. Fifty-two percent of these ($n = 197$) were for traumatic injuries, 44.1% ($n = 167$) were for primary medical issues, and 15 patients had no listed diagnosis. Fifty-two (7.3%) of patients had traumatic intracranial injuries (ICI). Of these, 30 had SDH, 5 had SAH, and 17 had a combination of intracranial injuries. One patient had rapid deterioration and died in the ED, one was transferred to hospice for an aortic dissection which apparently precipitated the fall, and 2 were discharged back to long term care facilities with no intervention. None of the admitted patients had acute operative intervention.

Logistic regression demonstrated 2 study variables helpful in predicting those with ICI from those without: history of LOC (odds ratio (OR) 2.02, confidence interval (CI) 1.10–3.71, $p = 0.02$) and the presence of signs of head trauma (OR 2.6, CI 1.22–5.51, $p = 0.01$). The sensitivity of these items was 86.5% (CI 73.6–94) with a specificity of 38.8% (CI 35.1–42.7). The positive predictive value in this population was 10% (CI 7.5–13.3) with a negative predictive value of 97.3% (CI 94.4–98.8). Had these items been applied as a decision rule, 273 patients would not have undergone CT scanning, but 7 injuries would have been missed, none of which required surgical intervention. Logistic regression also demonstrated an inverse relationship between age ≥ 80 and ICI (OR 0.53, Table 3). No other variables were helpful in predicting ICI (Table 3).

4. Discussion

Unlike other traumatic head injury studies in heterogeneous patient populations, our study population included only elderly patients, aged 65 years or older, and only those with a fall as the mechanism of injury. Although most studies assessing for serious traumatic sequelae of minor head injury exclude patients on the basis of a GCS less than 15, we chose to include any patient who was believed to be at his or her baseline mental status. This is important in the elderly population as many patients do not have a GCS of 15 at their baseline. More than half of nursing

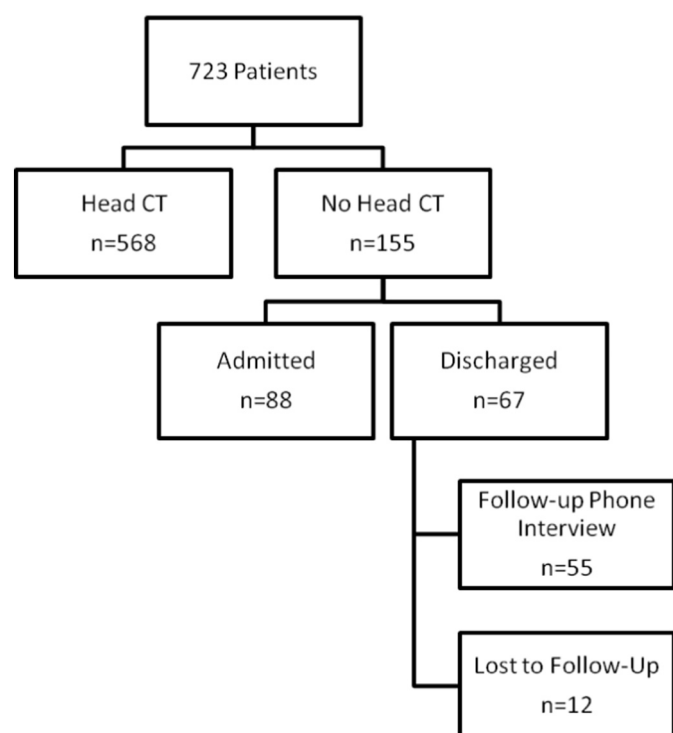


Fig. 1. Flow diagram representing patient neuroimaging, admission, and follow-up.

Table 2
Antiplatelet and anticoagulant use in elderly fall patients

	Total (n = 711)	No intracranial injury (n = 659)	Intracranial injury (n = 52)
No antiplatelet or anticoagulant (%)	289 (40.6)	274 (41.6)	15 (28.8)
Aspirin alone (%)	203 (28.6)	187 (28.4)	16 (30.8)
Coumadin/heparin/ NOACs alone (%)	98 (13.8)	91 (13.8)	7 (13.5)
Plavix and other antiplatelets alone (%)	30 (4.2)	29 (4.4)	1 (1.9)
Multiple agents (%)	75 (10.5)	64(9.7)	11(21.2) ^a
Unknown	16 (2.3)	14(2.1)	2 (3.8)

^a Denotes statistical significance.

home patients have moderate to severe cognitive impairment, with another 13% demonstrating mild cognitive impairment [20]. Over 25% of geriatric patients presenting to EDs for any reason exhibit cognitive impairment, 12.7% of the elderly report confusion and difficulties with memory, and over 1/3 report functional decline [21,22]. Since these studies are largely based on voluntary surveys and assessments, they likely underestimate the degree of cognitive impairment in the geriatric population. Therefore, inclusion of elderly patients who were believed to be at their baseline mental status per their facilities or family members regardless of their actual GCS likely better represents the geriatric fall population at large. Our data appear to be comparable to these other studies, as 21% of our patients had a history of dementia, and 18% had a GCS less than 15.

We found an incidence of intracranial injury lower than in other studies assessing injury rates in geriatric populations, however our study specifically excluded higher risk patients triaged to the trauma bay and also required patients have no alteration in their mental status [16,23,24]. In contrast to studies assessing for injury in all-comers, an Italian study that retrospectively assessed over 2000 elderly patients with minor trauma, GCS 15 and no anticoagulant use found that the overall rate of intracranial injury was 2.2% in this low-risk cohort. Fewer than 0.2% of these patients required neurosurgical intervention [25].

Few studies have looked at ICH rates specifically in geriatric patients who fall. A retrospective cohort study of 514 elders who fell found an ICH rate of about 2% [26]. Another retrospective study of 404 patients who fell, had no focal findings and underwent head CT after presenting to a level 1 trauma center found an ICH rate of 11.6% [27]. This study did not specify whether these individuals were assessed in the ED, trauma bay or both, but given an operative rate of 14.9%, this likely represents a more significantly injured cohort. Our traumatic ICH rate of 7.3% was in between these two values and lower than the majority of studies looking at all cause head trauma. These studies' data suggest that there may be a subset of minor head injury geriatric patients with lower risk in whom CT scanning may be deferred.

Like Hamden et al., we found that the best predictors of intracranial injury were any physical finding of head trauma (OR 2.60) and a history of loss of consciousness (OR 2.02) [19]. In our cohort, the very elderly

were less likely to have intracranial injury (OR 0.53). It is unclear why this might be, as intuitively, it would seem the very elderly would have increased injury for similar mechanism as compared to their younger counterparts because of increased frailty. It is possible that this finding may be a reflection of the heterogeneous nature of the mechanism “fall,” with unrecorded differences in height and/or velocity of falls. Unfortunately, we did not collect data on specific fall mechanisms beyond “mechanical” vs. “non-mechanical.” Interestingly, “a history of hitting head” was not a statistically significant predictor of intracranial injury. This is likely secondary to innate historical inaccuracies in elderly patients and/or observers of witnessed falls in regards to both the presence and absence of head strike.

Using the high-risk predictors (signs of trauma and/or loss of consciousness) as a screen for intracranial injury would have provided a sensitivity of 86.5% (CI 73.6–94) with a specificity of 38.8% (CI 35.1–42.7). The positive predictive value in this fairly low risk population was 10% (CI 7.5–13.3) with a negative predictive value of 97.3% (CI 94.4–98.8). The incidence of intracranial injury in patients with signs of trauma and/or loss of consciousness was 11.2%, while patients with absence of these variables had an injury incidence of 2.7%. Had these items been applied as a decision rule, 273 patients would not have undergone CT scanning, but 7 injuries would have been missed, none of which required surgical intervention.

We did not find antiplatelet or anticoagulant use to be predictive of intracranial injury in our cohort. Although the American College of Surgeons recommends that patients with pre-injury anticoagulation use be transported to a trauma center or a center capable of rapid diagnosis and treatment, the data for intracranial injury incidence in this population is mixed [28]. Some studies suggest these agents impart an increased risk of intracranial injury [25,29–33], while others suggest that there is no increased risk [34–38]. Data from other studies suggest that, in the presence of anticoagulation, geriatric trauma patients have worse outcomes [34–37]. It stands to reason that in the subset of patients that suffer intracranial injury, anticoagulant use may complicate management and increase mortality, but our study was not powered to detect differences in outcomes in this subgroup of patients.

In our cohort of minor head injury patients, no patient underwent surgical intervention. Brain Trauma Foundation guidelines endorsed by the American Association of Neurological Surgeons recommend surgery for patients with traumatic hemorrhages of large size, with midline shift, with significantly elevated intracranial pressure or significantly depressed GCS or worsening GCS over time [39–41]. Therefore, it is not surprising that a group of patients with a low velocity mechanism of injury who are at their baseline mental status at presentation would have minor intracranial injuries that would not necessitate neurosurgical treatment. Our results are similar to the reported 0.14% of patients in the cohort by Riccardi et al. who required neurosurgical intervention [25]. Three percent of minor head injury elderly patients in the cohort reported by Mack et al. required neurosurgery, but this study included individuals with GCS 13–15 [23]. These rates of neurosurgical intervention are not significantly different than rates reported for other, younger cohorts. For those patients with indications for neurosurgical intervention, advanced age is not a contraindication to surgery. Two studies retrospectively analyzing the Japan Neurotrauma Data Bank demonstrated that surgery was associated with improved survival in elders with moderate and severe head injury [42,43]. These results have been replicated in a reported German cohort as well [44].

Beyond traumatic intracranial injury, it is worth noting the high burden placed on healthcare resources from injuries due to falls in geriatric patients. Studies have demonstrated a high rate of admission in this population, and our cohort was no different, with an overall admission rate of 53.3% [21,45]. Although more than half of patients were admitted with injuries related to the fall itself including 106 patients with fractures, medical comorbidity was common, with syncope accounting for 52 of the 379 patients admitted after a fall. This is similar to other study data on fall related injury [19,46]. Even among the admitted

Table 3
Multivariate logistic regression with adjusted odds ratios

Variable	Odds Ratio (95% CI)
Age ≥ 80	0.53 (0.29 to 0.99) ^a
History of hitting head	5.67 (0.69 to 46.4)
Loss of consciousness	2.02 (1.10 to 3.71) ^a
New headache	1.32 (0.72 to 2.40)
Signs of head trauma	2.60 (1.22 to 5.51) ^a
Prior history of dementia	0.85 (0.41 to 1.74)
Antiplatelet/anticoagulant use	1.69 (0.89 to 3.22)

^a Statistically significant variables.

patients determined to have suffered a mechanical fall, 15.8% ($n = 32$) were found to have underlying medical reasons for their falls, including pneumonia, arrhythmia, urinary tract infection, dehydration, renal failure, and myocardial infarction. As we discuss the need and utility of cranial CT in geriatric fall patients, it is unclear which geriatric fall patients might benefit from other sorts of investigations, including laboratory tests and EKGs. It is also unclear which mechanical fall patients require medical evaluation, and what is the best approach to maximize injury identification and diagnose treatable disease in as cost-effective a way as possible. These questions are beyond the scope of our study, but are areas for future research endeavors.

This study has several limitations. Not every patient in this study underwent cranial CT, and although we have assigned this group as being uninjured if they had no symptoms at follow-up, it is possible that they had intracranial injury that resolved spontaneously. We believe the clinical relevance of these potential injuries is likely low, as the patients were asymptomatic, but cannot definitively state there were no missed injuries. Additionally, 12 patients were lost to follow-up, and were entirely excluded from analysis. If these excluded patients had injuries, the incidence of disease in our population has been underestimated, and the negative predictive value of “no signs of trauma” and “no loss of consciousness” would be lower, with less clinical utility.

Our study is also limited by nature of the enrolled patients. We did not include patients triaged to the trauma bay, and therefore our data should not be applied to high-risk fall patients. Additionally, we did not consider any mechanism of traumatic injury beyond fall. Therefore, this data cannot be applied to mechanisms such as motor vehicle crashes or assault. We excluded patients who were not at their baseline mental status, and therefore our findings do not apply to patients with altered mental status.

Although patients were enrolled at 3 different facilities, the patients were enrolled as a convenience sample, and therefore our study is subject to enrollment bias. We are unable to retrospectively determine the total number of fall patients who presented to the ED during enrollment to assess for population or mechanism differences in the geriatric patients enrolled as compared to those not enrolled. This is not feasible due to the heterogeneity of chief complaints that might represent “fall” (such as “wrist pain,” “head injury,” “laceration,” “palpitations,” “syncope,” “weakness,” etc.) and the search limitations of the electronic medical record. Although every attempt was made to enroll all eligible patients, we cannot determine if the enrolled population was completely representative of all low-acuity geriatric fall patients.

5. Conclusions

The incidence of CT identified ICI in elder patients who are at their baseline mental status presenting to the ED after a fall is about 7%. Signs of trauma to the head and face or loss of consciousness is predictive of ICI. Most patients do not require neurosurgical intervention. Larger studies are needed to determine if elderly patients may forgo head CT after a low risk fall event.

Funding sources/disclosures

All authors have no conflicts of interest. This study was not funded.

Author contribution

Study design and conception: RJ, DJ, JR.
Data collection: LV, JR, RJ, DJ, MR, EB, JW, SA, NS.
Data analysis: RJ.
Site coordinator: SA, MR, RJ, DJ.
Data interpretation: SA, DJ, MR, RJ.
Drafting of manuscript: DJ, RJ.
Editing of manuscript: DJ, RJ, SA, MR, JR, LV, EB, NS, JW.
Responsible for study as a whole: RJ, DJ.

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