REUE | Original Article

Adequacy of head computed tomography requests in mild traumatic brain injury: a need for change

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OBJECTIVE. To assess the degree of adherence to clinical protocols and clinical practice guidelines for mild traumatic brain injury (mTBI)—NICE, New Orleans, Canadian, and MAPAC—in requesting computed tomography (CT) scans. Additionally, estimate the impact that introducing the SEMES clinical protocol for the management of mTBI based on intracranial injury biomarkers (ICIB) would have on an emergency department (ED) of a tertiary referral center.

MATERIAL AND METHODS. We conducted retrospective observational study reviewing the health records of patients aged ≥ 16 years treated in our hospital ED for mTBI over a 6-month period.

RESULTS. We studied a total of 545 patients, 377 (69.2%) of whom received CT scans, revealing 56 (10.3%) intracranial lesions (ICL). Statistically significant associations with the finding of ICL included the presence of mTBI symptoms or signs [13.6% vs 2.4%; OR 8.7 (95%CI, 2.7-28.6); $p < 0.001$], age ≥ 65 years [13.1% vs 5.5%; OR, 2.6 (95%CI, 1.3-5.1); $p = 0.006$], and dangerous mechanism of injury [17.6% vs 9.1%; OR, 2.1 (95%CI, 1.1-4.2); $p = 0.029$]. Adherence to clinical practice guidelines was low. Clinical practice showed predictive values for finding ICL similar to those using the guidelines. We estimate that applying the SEMES protocol would have saved 24 (4.4%) CT scans vs current clinical practice.

CONCLUSIONS. Strict adherence to mTBI guidelines in our department would not reduce CT requests, and the use of ICIB would only do so slightly. We need to explore under which situations ICIB determination is most useful to improve the efficiency of EDs.

Keywords: Mild traumatic brain injury. Clinical practice guidelines. Clinical guideline adherence. Head trauma (imaging). Biomarkers.

Adecuación de la petición de tomografías computarizadas en el traumatismo craneoencefálico leve: necesidad de un cambio

OBJETIVO. Valorar el grado de cumplimiento de los protocolos y guías clínicas para el traumatismo craneoencefálico leve (TCE-L) NICE, New Orleans, Canadiense y MAPAC en la solicitud de tomografía computarizada (TC) y estimar la repercusión que tendría la introducción del protocolo clínico de manejo del TCE-L basado en biomarcadores de lesión intracraneal (BLC) propuesto por la Sociedad Española de Urgencias y Emergencias (SEMES) en un servicio de urgencias (SU) de un hospital terciario.

MATERIAL Y MÉTODOS. Estudio observacional retrospectivo de pacientes ≥ 16 años atendidos en el SU de nuestro hospital por TCE-L durante 6 meses.

RESULTADOS. En 545 pacientes, se realizaron 377 (69,2%) TC, encontrando 56 (10,3%) lesiones intracraneales (LIC). Mostraron asociación estadísticamente significativa con el hallazgo de LIC la existencia de síntomas o signos de TCE [13,6% vs 2,4%; OR 8,7 (IC 95%: 2,7-28,6); $p < 0,001$], la edad ≥ 65 años [13,1% vs 5,5%; OR 2,6 (IC 95%: 1,3-5,1); $p = 0,006$] y mecanismo lesional peligroso [17,6% vs 9,1%; OR 2,1 (IC 95%: 1,1-4,2); $p = 0,029$]. El grado de adherencia a las guías fue bajo. La práctica clínica ha presentado valores predictivos para encontrar LIC similares al empleo de las guías. Aplicando el protocolo de SEMES se hubieran ahorrado 24 (4,4%) TC respecto a la práctica clínica realizada.

CONCLUSIONES. El seguimiento estricto de las guías para TCE-L en nuestro servicio no reduciría la petición de TC y el uso de BLC lo haría levemente. Debemos avanzar en el conocimiento de las situaciones más útiles para la determinación de BLC, para mejorar la eficiencia de los SU.

Palabras clave: Traumatismo craneoencefálico leve. Guía de práctica clínica. Adherencia a guía clínica. Traumatismo craneoencefálico. Biomarcadores.

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Introduction

Traumatic brain injury (TBI) is a common reason for emergency department (ED) consultation, with 70% to 90% classified as mild (mTBI), defined by a Glasgow Coma Scale (GCS) score ≥ 13.[1] Although intracranial injury (ICI) is detected on computed tomography (CT) in only 7% to 10% of mTBI cases, with neurosurgical intervention required in < 1% and mortality remaining very low (0.1%),[2-4] the absence of specific symptoms that reliably identify patients at high risk of ICI leads to a very high rate of head CT requests.[4]

To address this, multiple studies,[5,6] protocols, and clinical practice guidelines recommend when CT should be performed in mTBI. Some of the most widely used are the NICE guidelines,[7] the New Orleans criteria,[8] the Canadian guidelines,[9] and, more recently in Spain, the MAPAC guidelines[10] from the Spanish Society of Emergency Radiology. However, several studies show that adherence to these guidelines is highly variable,[11] with "non-indicated" CT requests in mTBI ranging between 10% and 35%.[12]

Recently, the Spanish Society of Emergency Medicine (SEMES), together with other scientific societies, published a management protocol for mTBI based on the determination of brain injury biomarkers (BIBs).[13] Combined measurement of ubiquitin carboxy-terminal hydrolase L1 (UCH-L1) and glial fibrillary acidic protein (GFAP) within the first 12 hours after trauma, if both are negative, yields a negative predictive value (NPV) > 99%, which would allow more efficient management of mTBI.[14,15] In the study by Bazarian *et al.*,[14] which validated the use of these biomarkers in the United States, as well as in more recent studies conducted in Spain,[16,17] approximately one third of mTBI patients had negative results. Unfortunately, this test is not available in most Spanish hospitals, preventing implementation of the SEMES protocol.

Objectives

This study aims to assess the degree of adherence to the previously mentioned mTBI clinical practice guidelines in requesting head CT in an ED setting. In addition, we sought to estimate the potential impact of introducing the biomarker-based clinical management protocol for mTBI in terms of reducing urgent cranial CT requests.

Materials and methods

We conducted a retrospective observational study reviewing electronic health records (Jimena 4 system) of patients ≥ 16 years of age seen at the ED of the *Hospital Clínico Universitario de Valladolid (HCUV)* for mTBI (GCS ≥ 13) during a 6-month period, from February 1st through July 31st 2023.

Patients were selected if they had a diagnosis of "S0" (head trauma) coded according to the International Classification of Diseases, 10th Revision (ICD-10). Exclusion criteria were patients < 16 years, those referred from other hospitals for specialist evaluation (with imaging already performed), patients with moderate or severe TBI, and those coded as "S03" (dislocation, sprain, and strain of joints and ligaments of the head), as these did not correspond to the target study population (Figure 1).

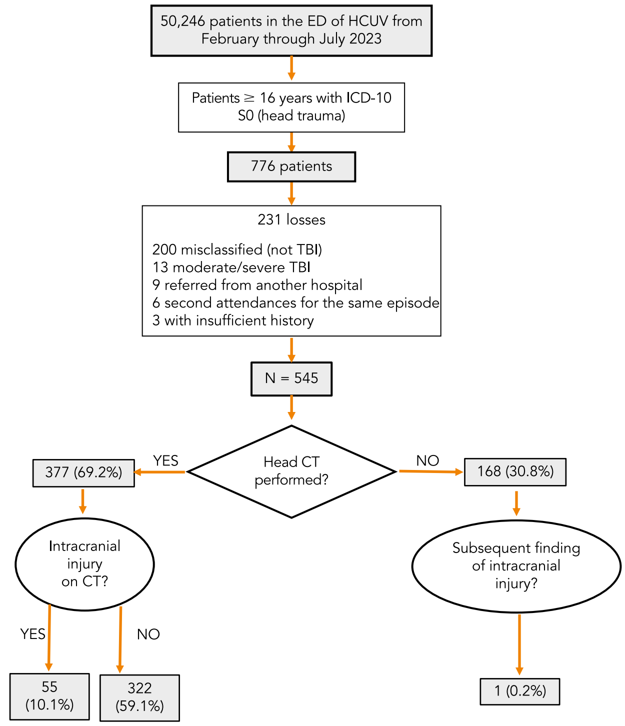

Figure 1. Study flow chart.
ED: emergency department; HCUV: Hospital Clínico Universitario de Valladolid; TBI: traumatic brain injury; CT: computed tomography.

We reviewed records to collect past medical history, clinical and care data of the episode, and ED management (CT request, results), with 1-month follow-up. CT indication was evaluated according to the above-mentioned protocols and guidelines (NICE, New Orleans, Canadian, and MAPAC). A dangerous mechanism of trauma was defined, following the NICE guideline,[7] as a fall from > 1 meter or > 5 stairs, or pedestrian or cyclist struck by a motor vehicle. Pathologic CTs were classified, in line with Bazarian *et al.*,[14] as those showing cranial or facial bone fractures, hemorrhage, or other intracranial trauma-related injuries.

Data were collected using Microsoft Excel 2021 and analyzed with IBM SPSS Statistics 29. Normality of distribution of quantitative variables was assessed using the Kolmogorov-Smirnov test only for mean arterial pressure (MAP); therefore, medians and interquartile ranges (IQRs) were reported for the remaining variables. For analysis of the statistical association between the presence of ICI (dichotomous variable) and each clinical factor, Student t test was used for quantitative variables, and Pearson's chi-square test (or Fisher's exact test if indicated) for dichotomous variables. Odds ratios (ORs) with 95% confidence intervals (CIs) were then calculated for each risk factor.

Sensitivity, specificity, and predictive values of the different scales for detecting ICI on CT were calculated using contingency tables. Receiver operating characteristic (ROC) curves were generated for each protocol, and the area under the curve (AUC) was calculated.

Finally, agreement between CT indication in the HCUV ED and each clinical guideline was estimated. Inter-rater agreement between two evaluators was quantified using Cohen's kappa for each guideline.

The study was approved by the Research Ethics Committee on Medicinal Products of the Valladolid East Health Area (PI 23-3313TFG).

Results

A total of 545 patients were studied, with a median age of 75 years (IQR, 55–86 years); 286 (52.5%) were women. The Charlson comorbidity index was 0 (IQR, 0–2). A total of 190 (35.0%) patients had coagulation-altering factors, such as antiplatelet use in 92 (16.9%), direct-acting oral anticoagulants in 65 (11.9%), and vitamin K antagonists in 30 (5.5%). In 74 (13.6%) patients the mechanism of trauma was dangerous, and in 53 (9.7%) it occurred in the context of alcohol and/or drug use (Table 1). The median length of ED stay was 3.2 hours (IQR, 2.0–5.1).

A total of 377 (69.2%) head CTs were performed, with reports available at a median of 2.1 hours (IQR, 1.6–2.8) from arrival. Fifty-six ICIs (10.3%) were identified, 2 of which (0.4%) were not detected during the initial evaluation (1 case without an initial CT). The most frequent finding was subdural hemorrhage (26, 48.1%), followed by subarachnoid hemorrhage (17, 31.5%) and parenchymal hemorrhage (12, 22.2%). Forty-five patients (8.3%) required hospital admission, 4 (0.7%) required intensive care unit (ICU) admission, 3 (0.6%) underwent neurosurgical intervention, and 7 (1.3%) died, 5 (0.9%) directly related to TBI.

When assessing the association between each risk factor and the presence of ICI (Tables 1 and 2), the only statistically significant variables that were not clinical signs or symptoms of TBI were age ≥ 65 years [13.1% vs 5.5%; OR, 2.6 (95% CI,1.3–5.1); *P* = .006] and dangerous trauma mechanism [17.6% vs 9.1%; OR, 2.1 (95% CI,1.1–4.2); *P* = .029]. A multivariate analysis, adjusted for these factors, showed that the following clinical parameters maintained statistical significance: GCS < 15 at 2 hours [77.8% vs 9.1%; OR, 41.7 (95% CI,7.9–218.7); *P* < .001], presence of focal neurologic deficit [45.5% vs 9.6%; OR, 7.4 (95% CI, 2.0–27.2); *P* = .003], ≥ 2 episodes of vomiting [33.3% vs 9.5%; OR, 5.8 (95% CI, 2.0–16.9); *P* = .001], loss of consciousness [23.3% vs 8.7%; OR, 4.1 (95% CI, 2.0–8.4); *P* < .001], amnesia of the event [23.8% vs 9.1%; OR, 3.3 (95% CI,1.4–7.5); *P* = .005], GCS < 15 on ED arrival [25.0% vs 9.7%; OR, 3.1 (95% CI, 1.0–9.3); *P* = .044], and headache [18.0% vs 9.3%; OR, 2.4 (95% CI,1.1–5.0); *P* = .020]. Overall, the presence of any clinical symptom or sign of TBI showed an OR of 8.7 (95% CI, 2.7–28.6; *P* < .001).

Table 3 illustrates the degree of adherence of clinical practice to guideline recommendations for CT ordering (low). The scale with the highest level of agreement with actual clinical practice was MAPAC, with 75.8% concordance and a Cohen's kappa of 0.37 (low agreement). There was marked variability among guidelines, with CT indications ranging from 259 (47.5%) in NICE to 495 (90.8%) in New Orleans. MAPAC and the Canadian guidelines would have indicated 437 (80.2%) and 405 (74.3%) CTs, respectively. Our clinical practice was intermediate, at 69.7%.

Regarding predictive ability for ICI (Table 4, Figure 2), all guidelines showed high NPVs (94.4% for NICE, 97.9% Canadian, 98.1% MAPAC, and 100% New Orleans). However, AUC values were modest, ranging from 0.634 (NICE) to 0.551 (New Orleans). Clinical practice at HCUV showed similar results, with an NPV of 99.4% and the highest AUC (0.662).

Applying the SEMES protocol to our sample, BIB testing would have been performed in 470 (86.2%) patients, while direct CT (without prior biomarkers) would have been indicated in 40 (7.3%). Thirty-five patients (6.5%) would not

Table 1. Characteristics of the sample and association of risk factors indicated in clinical guidelines with the presence of intracranial injury on computed tomography

	n (%)	Injury with RF n (%)	Injury without RF n (%)	*P* value
Female sex	286 (52.5)	26 (9.1)	30 (11.6)	ns
Age group				
<35 years	58 (10.7)	4 (6.9)	52 (10.7)	ns
35–49 years	46 (8.4)	3 (6.5)	53 (10.6)	ns
50–64 years	97 (17.8)	4 (4.1)	52 (11.6)	.026
65–79 years	121 (22.2)	45 (13.2)	11 (9.4)	ns
≥ 80 years	223 (40.9)	29 (13.0)	27 (8.4)	ns
Age ≥ 65 years	347 (63.7)	45 (13.1)	11 (5.5)	.005
Charlson Comorbidity Index				
0	288 (52.8)	29 (10.1)	27 (10.5)	ns
1	93 (17.1)	6 (6.5)	50 (11.1)	ns
2	84 (15.4)	11 (13.1)	45 (9.8)	ns
3	34 (6.2)	6 (17.6)	50 (9.8)	ns
4	19 (3.5)	1 (5.3)	55 (10.5)	ns
≥ 5	27 (5.0)	3 (11.1)	53 (10.2)	ns
GCS on ED arrival				
15	525 (96.3)	51 (9.7)	5 (25.0)	.044
13-14	20 (3.7)	5 (25.0)	51 (9.7)	.044
Previous neurosurgical intervention	16 (2.9)	1 (6.3)	55 (10.4)	ns
Dangerous trauma mechanism	74 (13.6)	13 (17.6)	43 (9.1)	.037
Alcohol or drug intoxication	53 (9.7)	6 (11.3)	50 (10.2)	ns
Coagulation disorders	190 (34.9)	21 (11.1)	35 (9.9)	ns
Single antiplatelet therapy	87 (16.0)	11 (12.6)	45 (9.8)	ns
Dual antiplatelet therapy	6 (1.1)	1 (16.7)	55 (10.2)	ns
Vitamin K	30 (5.5)	3 (10.0)	53 (10.3)	ns
Direct oral anticoagulants	65 (11.9)	7 (10.8)	49 (10.2)	ns
Low-molecular-weight heparin	5 (0.9)	0 (0.0)	56 (10.4)	ns
Liver cirrhosis	3 (0.6)	0 (0.0)	56 (10.3)	ns
Thrombocytopenia	4 (0.7)	0 (0.0)	56 (10.4)	ns
Clinical signs and symptoms	381 (69.9)	52 (13.6)	4 (2.4)	< .001
External head/neck injury	279 (51.2)	30 (10.8)	26 (9.8)	ns
Headache	61 (11.2)	11 (18.0)	45 (9.3)	.034
Loss of consciousness	60 (11.0)	14 (23.3)	42 (8.7)	< .001
Amnesia of event	42 (7.7)	10 (23.8)	46 (9.1)	.003
≥ 2 episodes of vomiting	18 (3.3)	6 (33.3)	50 (9.5)	.006
Focal neurologic deficit	11 (2.0)	5 (45.5)	51 (9.6)	.003
GCS <15 at 2 hours	9 (1.7)	7 (77.8)	49 (9.1)	< .001
Signs of basilar skull fracture	4 (0.7)	1 (25.0)	55 (10.2)	ns
Post-traumatic seizure	2 (0.4)	0 (0.0)	56 (10.3)	ns
Open skull fracture signs	1 (0.2)	1 (100)	55 (10.1)	ns

RF: risk factors; GCS: Glasgow Coma Scale; ns: not significant ; ED: emergency department.

Table 2. Crude and adjusted odds ratios of risk factors with statistically significant association with intracranial lesions on head computed tomography

Risk factor	Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)*	*P* value
Age ≥ 65 years	2.6 (1.3-5.1)	.006	–	–
Dangerous trauma mechanism	2.1 (1.1-4.2)	.029	–	–
Clinical signs and symptoms	6.3 (2.2-17.8)	< .001	8.7 (2.7-28.6)	< .001
GCS < 15 at 2 hours	34.8 (7.0-172.1)	< .001	41.7 (7.9-218.7)	< .001
Focal neurologic deficit	7.9 (2.3-26.8)	< .001	7.4 (2.0-27.2)	.003
≥ 2 episodes of vomiting	4.8 (1.7-13.2)	.003	5.8 (2.0-16.9)	.001
Loss of consciousness	3.2 (1.6-6.3)	< .001	4.1 (2.0-8.4)	< .001
Amnesia of event	3.1 (1.4-6.7)	.004	3.3 (1.4-7.5)	.005
GCS < 15 on ED arrival	3.1 (1.1-8.8)	.035	3.1 (1.03-9.3)	.044
Headache	2.1 (1.0-4.4)	.038	2.4 (1.1-5.0)	.020
Signs of open skull fracture	26.5 (1.1-65.7)	.046	1.38×10^{10} (0-α)	ns

*Adjusted odds ratios are adjusted for age ≥ 65 years and presence of dangerous trauma mechanism.
OR: odds ratio; CI; confidence interval; GCS: Glasgow Coma Scale; ED: emergency department; ns: not significant.

have required either biomarker testing or CT. If, as shown in prior studies, BIBs were negative in one third of patients tested, 313 CTs would have been requested, avoiding 157. In total, 353 CTs would have been performed, 24 (4.4%) fewer than in observed clinical practice, and 52 (9.5%), 84 (15.4%), and 142 (26.1%) fewer than the Canadian, MAPAC, and New Orleans guidelines, respectively. Conversely, 94 (17.2%) more CTs would have been performed compared with the NICE guideline.

Discussion

In this study we confirmed that adherence to clinical guideline recommendations regarding head CT ordering in mTBI was low in our ED. This finding has already been shown in other studies, such as that of Lagares *et al.*,[11] who administered a questionnaire to 188 physicians from 131 hospitals across 4 European countries (Portugal, France, Greece, and Spain). What appears more striking in our sample is the wide discrepancy among guidelines in CT indication, ranging from 259 in NICE to 495 in New Orleans. However, this finding is not new. In the study by Melnik *et al.*,[12] there was a difference of 25.8 percentage points between the Canadian scale and New Orleans (64.7% vs 90.5%, respectively), whereas our study found a difference of 16.5 points between them. The major difference between the 2 studies is that in ours the NICE guideline behaved very differently from the others (indicating CT in only 47.5% of patients, with markedly lower sensitivity for detecting ICI). To explain this, it should be noted that unlike the other guidelines, NICE considers currently common CT indications such as age ≥ 65 years, coagulation disorders (except anticoagulant use), trauma mechanism, or retrograde amnesia only if loss of consciousness or anterograde amnesia has also occurred.

The number of CTs performed in our study (377) was intermediate between NICE and the other guidelines. Therefore, it cannot be said that CT was "overused." In fact, our clinical practice demonstrated predictive values for ICI similar to, and in some cases with higher AUC, than those of the guidelines. We believe this is because, although clinicians did not strictly adhere to guidelines, they were aware of the different risk factors from multiple sources and individualized decision-making based on each patient's characteristics and condition.

From all of the above we can conclude that following clinical guidelines for CT requests in mTBI provides safety,

Table 3. Degree of adherence to clinical guidelines regarding the request for head computed tomography

Scale	CTs indicated	% Concordance	Cohen's κ (95% CI)	Level of agreement
New Orleans	495	71.7	0.18 (0.11-0.24)	Insignificant
MAPAC	437	75.8	0.37 (0.29-0.45)	Low
Canadiense	405	72.1	0.31 (0.23-0.40)	Low
NICE	259	69.2	0.39 (0.32-0.47)	Low

NICE: National Institute for Health and Care Excellence; MAPAC: Mejora de la Adecuación de la Práctica Asistencial y Clínica (Improvement of Healthcare and Clinical Practice Appropriateness); CT: computed tomography; CI: confidence interval.

Table 4. Predictive values for the detection of intracranial injury according to different clinical guidelines and local clinical practice (HCUV)

	New Orleans	MAPAC	Canadien	NICE	HCUV
Sensitivity	100	96.4	94.6	71.4	98.2
Specificity	10.2	21.7	28.0	55.2	34.2
PPV	11.3	12.4	13.1	15.4	14.6
NPV	100	98.1	97.9	94.4	99.4
AUC	0.551	0.591	0.613	0.634	0.662
P value	ns	0.010	0.001	0.000	0.000

HCUV: routine clinical practice at *Hospital Clínico Universitario de Valladolid*; NICE: National Institute for Health and Care Excellence; MAPAC: *Mejora de la Adecuación de la Práctica Asistencial y Clínica* (Improvement of Healthcare and Clinical Practice Appropriateness); PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curve; ns: not significant.

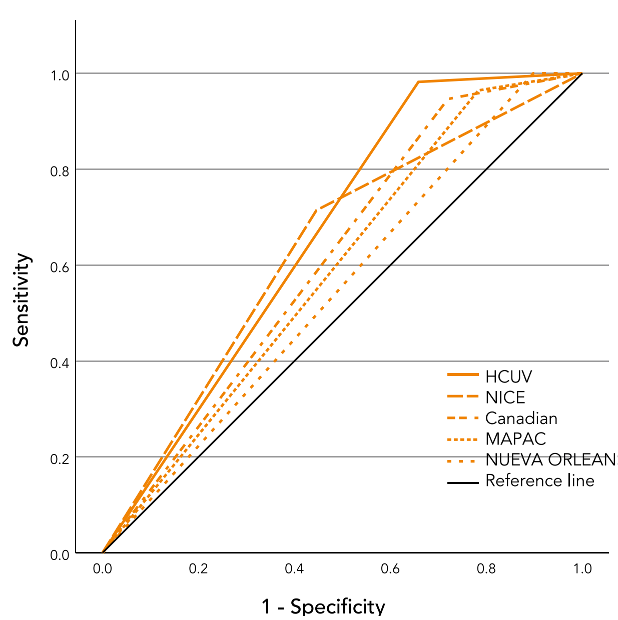

Figure 2. AUC curves obtained.
HCUV: routine clinical practice at Hospital Clínico Universitario de Valladolid; NICE: National Institute for Health and Care Excellence; MAPAC: Mejora de la Adecuación de la Práctica Asistencial y Clínica (Improvement of Healthcare and Clinical Practice Appropriateness).

given the high NPV observed across all of them, and has improved patient management. However, discrepancies remain regarding appropriate indications, which, as we have shown, are often highly subjective. In this sense, the introduction of BIBs into clinical protocols, providing an objective parameter with high NPV for ICI, may be of great help. The protocol promoted by SEMES proposes, for patients with mTBI presenting a risk factor or clinical suspicion of ICI within the first 12 hours post-trauma, a 2-step approach: first, BIB testing, and if UCH-L1 and/or GFAP test positive, then CT. Although experience with this strategy is still limited, some studies already show reductions in CT use or length of ED stay.[16-18]

Applying the SEMES protocol to our sample would have achieved, except compared with NICE, a substantial reduction in CTs relative to guideline use (142 fewer, –26.1% of total patients, compared with New Orleans; 84 fewer, –15.4%, compared with MAPAC; and 52 fewer, –9.5%, compared with the Canadian guideline). These data are consistent with previous reports. However, the reduction was more modest relative to our clinical practice (24 fewer, –4.4%). This may be explained by the fact that guidelines are designed to maximize sensitivity in detecting ICI. On the other hand, we documented a relatively short median time to CT report (2.1 hours). These observations suggest that implementation of BIBs in our clinical practice might not yield as significant an impact on CT use or ED stay as in other studies. Nonetheless, we believe the greatest potential benefit of BIBs in TBI lies in something intangible and not easily measurable: providing clinicians with greater confidence in decision-making, particularly in complex clinical situations such as evaluation of intoxicated patients or those with underlying disease or neurodegenerative conditions.

In the present study, of all potential ICI risk factors identified by the guidelines, aside from age and trauma mechanism, only symptoms due to TBI showed a statistically significant increase in risk (GCS < 15, neurologic deficit, vomiting, post-traumatic loss of consciousness, amnesia, or headache). Other symptoms such as seizures, evidence of cranial fracture, or suspected basilar skull fracture likely did not reach statistical significance because of their low incidence. Conversely, risk factors such as coagulation disorders or intoxication, common reasons for CT requests, did not show significant associations. Distinguishing between patients who may benefit from BIB testing and those for whom CT should be initially indicated may therefore help optimize diagnostic management of this condition. Further studies are needed to determine in which clinical scenarios BIB negativity is most common, as patients in these groups may derive the greatest benefit from BIB use.

The main limitation of our study is that it was single-center and retrospective, meaning our results may differ from those obtained in other hospitals with different organizational structures. We encourage other research groups, especially those in centers already using BIBs, to further investigate their utility in different patient groups, which will likely contribute to broader implementation.

ARTICLE INFORMATION

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