



Review

Head CT in Adult Mild Traumatic Brain Injury: A Global Review of Indications and Decision Rules

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Abstract

Mild traumatic brain injury (mTBI) in adults is extremely common worldwide, but only a small fraction of these patients harbor clinically significant intracranial injuries. Computed tomography (CT) of the head is the standard diagnostic tool to detect traumatic brain hemorrhages or lesions, yet indiscriminate CT scanning of all mTBI patients is inefficient, costly, and exposes patients to ionizing radiation. To optimize patient care, numerous clinical decision rules and guidelines have been developed internationally to identify which adult patients with mTBI should undergo head CT. This review provides a global perspective on the indications for head CT in adult mTBI, comparing key decision rules including the Canadian CT Head Rule, New Orleans Criteria, UK NICE Head Injury Guidelines, and others. Methods: We conducted a comprehensive analysis of major international guidelines and decision rules for head CT in adult mTBI, focusing on their inclusion criteria, risk factors, and diagnostic performance. Results: All the examined rules prioritize near-100% sensitivity for identifying patients who need neurosurgical intervention, but they differ greatly in specificity and recommended CT utilization rates. North American rules such as the New Orleans Criteria tend to favor higher sensitivity, scanning almost all patients with any symptom, whereas the Canadian CT Head Rule and certain European guidelines (NICE, Scandinavian) are more selective, significantly reducing CT usage while maintaining safety. Discussion: We discuss how these variations reflect different healthcare settings and risk tolerances, and we examine the implications for neurosurgical practice. We also highlight challenges in guideline implementation, the impact on global CT utilization, and emerging approaches (such as biomarker-assisted triage) that may further refine decision-making. In conclusion, appropriate use of clinical decision rules for head CT in mTBI can safely minimize unnecessary imaging, but local adaptation and clinician judgment remain crucial to ensure that no significant injuries are missed while avoiding over-scanning.

Keywords: mild traumatic brain injury (mTBI); head CT scan; clinical decision rule; neurosurgical intervention



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1. Introduction

Traumatic brain injury (TBI) is a leading cause of emergency department visits and hospitalizations worldwide. The vast majority of these cases—approximately 90–95—are classified as mild TBI (mTBI), typically defined by an initial Glasgow Coma Scale (GCS)

score of 13–15 in patients who may have experienced a brief loss of consciousness, confusion, or amnesia following a blunt head injury. Despite being labeled “mild,” this condition carries a non-negligible risk of intracranial complications such as brain hemorrhages or contusions. Fortunately, only a small fraction of adults with mTBI have serious intracranial injuries: roughly 5–10% of patients have acute traumatic findings on head imaging, and an estimated 1% or fewer will require urgent neurosurgical intervention (such as craniotomy for hematoma evacuation). Identifying this subset of patients promptly is critical, as delayed diagnosis of an epidural or subdural hematoma, for example, can lead to preventable morbidity or mortality [1].

Cranial computed tomography (CT) is the gold-standard diagnostic modality for the acute evaluation of TBI. CT scans are highly sensitive for detecting skull fractures, intracranial hemorrhages, and brain edema that may result from head trauma. However, routine CT for every mTBI patient is neither practical nor desirable. Overuse of head CT in minor head injury scenarios is well documented: more than 90% of head CT scans performed for mTBI end up showing no acute traumatic pathology. This reality has multiple implications: unnecessary radiation exposure (which can slightly increase lifetime malignancy risk, especially concerning for younger patients with repetitive scans), increased healthcare costs, and prolonged patient length of stay in crowded emergency departments. Moreover, liberal scanning approaches may strain resources, particularly in regions where CT availability is limited [2].

To address the challenge of deciding which mTBI patients truly need imaging, clinical decision rules have been developed and validated over the past two decades. A clinical decision rule is an evidence-based tool that uses a set of clinical criteria and has published head injury guidelines that serve as a nationwide standard. Other contributions include the NEXUS-II decision instrument in the United States, the Scandinavian Neurotrauma Committee (SNC) guidelines in Northern Europe (which uniquely incorporate a blood biomarker), and the “CHIP” rule from The Netherlands [3–6].

Each of these rules was developed in different healthcare environments, yet all share the fundamental aim of optimizing the use of CT in mTBI. This review will examine the indications for head CT in adult mTBI from a global perspective, focusing on the content and performance of key international decision rules. We will compare their criteria, discuss their sensitivity and specificity in detecting significant injuries, and consider how these guidelines are applied in practice. Our analysis excludes pediatric head injury decision rules, as children require distinct considerations and fall outside the scope of this paper. By understanding the similarities and differences among these adult mTBI CT guidelines, neurosurgeons and emergency clinicians can better appreciate the rationale behind imaging decisions and work together to ensure patients receive appropriate and timely care [7,8].

2. Materials and Methods

We performed a structured literature review and guideline analysis to gather information on established clinical decision rules for head CT in adult mild traumatic brain injury. Our focus was on widely recognized international guidelines and decision algorithms that specifically address the indications for acute head CT in adult patients (typically defined as age ≥ 16 years) with non-penetrating, blunt head injury and an initial GCS of 13–15. We identified major decision rules through database searches and by examining references from key TBI guideline publications. The rules selected for comparison in this review include: the Canadian CT Head Rule (CCHR), the New Orleans Criteria (NOC), the NEXUS II head CT decision instrument, the NICE guideline for head injury (United Kingdom), the Scandinavian Neurotrauma Committee (SNC) guideline, and the CT in Head Injury Patients (CHIP) rule (The Netherlands). We extracted each guideline’s inclusion and ex-

clusion criteria, specific risk factors or clinical findings that trigger a CT scan, and any available data on diagnostic performance (sensitivity for intracranial injuries and specificity or projected CT reduction).

Our analysis emphasizes adult patient populations; any guidelines or studies exclusively focused on pediatric TBI were excluded. Because this is a narrative review of published decision rules rather than a new clinical study, formal statistical analysis was not performed. Instead, we qualitatively and quantitatively compared the guidelines based on reported performance in validation studies and meta-analyses. We also considered contextual factors such as the healthcare setting in which each rule was developed and is applied. No patient-level data were collected for this review; rather, the data presented are drawn from existing research and guideline publications. By juxtaposing these sources, we aimed to highlight both common themes and key differences in how various regions approach head CT decision-making in mild TBI.

3. Results

Identified Decision Rules and Guidelines

Using the methodology above, we identified six major clinical decision rules or guidelines for head CT in adult mTBI that have been influential internationally. These are the Canadian CT Head Rule (CCHR), the New Orleans Criteria (NOC), the NEXUS-II Head CT Rule, the NICE Head Injury Guidelines (UK), the Scandinavian Neurotrauma Committee (SNC) guidelines, and the CT in Head Injury Patients (CHIP) rule (The Netherlands). Each is summarized below, including its core criteria and known performance metrics, followed by a comparative overview of their effectiveness.

Canadian CT Head Rule (CCHR)

The CCHR was developed in Canada for adults with GCS 13–15 head injuries who experienced loss of consciousness, amnesia, or confusion (it was not designed for completely asymptomatic patients, and the original study excluded some high-risk cases like those on anticoagulation or aged < 16). The rule recommends a head CT if any one of several criteria is present. These include high-risk features indicating the need for neurosurgical intervention: GCS < 15 at 2 h post-injury, suspected open or depressed skull fracture, signs of basal skull fracture, ≥ 2 episodes of vomiting, or age ≥ 65 . It also includes two medium-risk factors (for clinically important but less acute injuries) that warrant CT: retrograde amnesia > 30 min and a dangerous mechanism of injury. If none of these criteria are met, CCHR deems the risk of a significant intracranial injury to be extremely low, and no CT is required [9].

In validation studies, the Canadian rule achieved 100% sensitivity for identifying patients who required neurosurgical intervention and effectively 100% sensitivity for any clinically important brain injury on CT. Its specificity is more moderate: roughly 40–50% of mTBI patients can avoid scanning under CCHR criteria. In practice, applying CCHR results in about 50–60% of mild head injury patients getting a CT, a substantial reduction compared to scanning everyone. Implementation studies have shown that using CCHR can reduce overall head CT ordering by around 15% while maintaining patient safety (virtually no serious injuries are missed when the rule is correctly applied) [10,11].

New Orleans Criteria (NOC)

The New Orleans Criteria is an early U.S. decision rule for minor head injury, derived for patients with an initial GCS of 15 (i.e., the mildest cases, fully conscious on arrival). It mandates a head CT if any one of seven clinical factors is present: headache, vomiting, age > 60, drug or alcohol intoxication, short-term memory deficit, visible trauma above the clavicle, or seizure. NOC is intentionally very inclusive-while it technically applies to

the GCS 15 population; in practice, its cautious “scan if any symptom” approach has often been extended to other mTBI patients as well [12].

NOC provides near-100% sensitivity for detecting traumatic intracranial injuries, but at the cost of very low specificity. In comparative studies, NOC would recommend CT for roughly 90–100% of patients with minor head injury (since at least one of its seven criteria is positive in almost everyone—e.g., post-traumatic headache is extremely common). This means that although NOC almost never misses an injury, it results in many CT scans that ultimately show no pathology. The strength of NOC lies in its simplicity and safety (few if any injuries will be missed), whereas its weakness is efficiency: it offers little reduction in CT utilization compared to not using a rule at all [13,14].

NEXUS-II Head CT Decision Instrument

NEXUS-II is a decision instrument from a large U.S. multicenter study (the National Emergency X-Radiography Utilization Study II) aimed at maximizing sensitivity for intracranial injury. It defines a set of high-risk criteria in blunt head trauma; if none of these criteria are present, the patient is considered low-risk enough that a CT scan is not necessary, but if any are present, a head CT is recommended. The NEXUS-II criteria include: age ≥ 65 , signs of significant skull fracture (such as a depressed or open skull fracture on exam, or a large scalp hematoma suggesting underlying injury), any focal neurological deficit, an altered level of alertness or abnormal behavior (GCS < 15 or any confusion/agitation), evidence of coagulopathy (bleeding disorder or anticoagulant use), and persistent vomiting. These criteria overlap with those in CCHR and NOC (for example, older age, skull fracture signs, vomiting), but NEXUS-II uniquely emphasizes factors like scalp hematomas and explicitly includes anticoagulation as a reason to scan [15].

In derivation and validation studies, NEXUS-II achieved approximately 98–100% sensitivity for clinically significant intracranial injuries, comparable to the ultra-sensitive NOC rule, with very low specificity. By design, it sacrifices efficiency to maximize safety: a large proportion of patients meet at least one NEXUS-II criterion (for instance, any elderly patient or any patient on blood thinners will trigger a scan). Thus, like NOC, NEXUS-II ends up recommending CT for a majority of mTBI patients in order to avoid missing rare injuries. While NEXUS-II is not as universally cited in practice as CCHR or NOC, its principles (such as always scanning patients with coagulopathy or those over a certain age threshold) have been incorporated into many institutional protocols and subsequent guidelines [16,17].

NICE Head Injury Guidelines (UK)

The National Institute for Health and Care Excellence (NICE) head injury guidelines are a comprehensive set of recommendations used across the UK. For adults (aged ≥ 16) with mTBI, NICE outlines specific criteria for when to perform a head CT and how urgently. An immediate CT (within 1 h of injury or arrival) is recommended if any of the following high-risk indications are present: GCS < 13 at initial assessment, GCS < 15 at 2 h post-injury, suspected open or depressed skull fracture, any sign of basal skull fracture (e.g., “raccoon eyes,” Battle’s sign, CSF leak from nose/ear), post-traumatic seizure, focal neurological deficit, or more than one episode of vomiting. Additionally, if a patient had any loss of consciousness or post-traumatic amnesia, then a head CT within 8 h of injury is indicated if any of these risk factors are present: age ≥ 65 , a history of bleeding/clotting disorder or use of anticoagulant therapy, a dangerous mechanism of injury (such as a pedestrian struck by a vehicle, occupant ejected from a vehicle, or a fall from >1 m/5 stairs), or retrograde amnesia lasting >30 min before impact [18].

The NICE guideline is more selective than the North American rules, reserving CT for patients with clear risk factors and otherwise advocating observation for those at very low risk. As a result, the proportion of mTBI patients who get scanned under NICE is

much lower. Estimates suggest that strict application of NICE criteria would lead to about 40–50% of mild head injury patients receiving a CT, which is roughly half the rate seen with rules like NOC. This comes with a trade-off: NICE may miss a small number of intracranial injuries that other more inclusive rules would detect. Studies indicate NICE criteria have around 70–80% sensitivity for any traumatic brain injury on CT, lower than NOC or CHIP. Crucially, however, the injuries missed by NICE tend to be minor (e.g., tiny contusions or hemorrhages that do not require surgical intervention or ICU care). The guideline's priority is that no patient with a serious injury (one requiring neurosurgery or causing significant neurologic deterioration) goes un-imaged, and validation studies have shown that NICE achieves near 100% sensitivity for those critical outcomes. By accepting a slight drop in sensitivity for the most minimal injuries, NICE dramatically increases specificity (on the order of 50–60%) and avoids a large number of unnecessary scans. Patients who do not meet CT criteria are typically observed in the ED for a period and discharged with head injury precautions, an approach that has been effective in the UK for safely managing mTBI with fewer scans [7,19–21].

Scandinavian Neurotrauma Committee (SNC) Guidelines

The Scandinavian Neurotrauma Committee guideline, used in countries like Sweden, Norway, and Denmark, is similar in spirit to NICE and CCHR but adds an innovative component: the use of a serum biomarker (S100B) to aid decision-making. The SNC guidelines categorize adult patients with head injury by risk level. Those with moderate TBI (GCS < 14, or any focal neurological deficit, etc.) are imaged immediately. Patients with mTBI (GCS 14–15) who have risk factors such as signs of skull fracture, neurological deficits, repeated vomiting, age > 65, coagulopathy, a dangerous mechanism, or seizure are also recommended to undergo CT (paralleling other international rules). The distinctive aspect is in patients who are mTBI with no major risk factors but who did have a loss of consciousness or amnesia—essentially a very low-risk subgroup that still has some concern due to the transient LOC. In these patients, if the injury occurred within the past 6 h, the SNC guideline recommends measuring serum S100B. S100B is a protein biomarker that is released into the blood following brain injury. If the S100B level is below a defined cutoff (commonly 0.1 µg/L) and the patient is clinically well, the guideline indicates that a CT scan is not needed. If the S100B is elevated or the test cannot be obtained (e.g., injury more than 6 h ago), then a CT is performed [5].

By incorporating S100B testing, the Scandinavian protocol further refines triage beyond clinical criteria alone. Studies in Europe have shown that this approach has very high sensitivity— a normal S100B effectively rules out significant intracranial injury in low-risk mTBI patients. Using the biomarker, roughly 20% or more of patients in that low-risk, LOC-positive category can safely avoid a CT scan that they might otherwise have received. Performance-wise, the SNC guideline has been found to catch all injuries that matter: patients who need neurosurgical intervention or have significant hemorrhages would either have clinical risk factors prompting a CT, or an elevated S100B if they were in the low-risk category. There is an exceedingly small chance that an insignificant lesion could be missed if it failed to raise the S100B level and there were no other clinical clues, but available research suggests such missed injuries are clinically benign. One practical challenge with the Scandinavian approach is the need for rapid biomarker testing and confidence in its negative predictive value; emergency departments must have access to S100B assays and integrate this step into the workflow. Additionally, clinicians must be educated to trust a low S100B as a basis for not scanning. This strategy of combining biochemical and clinical assessment has not yet been widely adopted outside Scandinavia, but it represents a promising direction to further reduce unnecessary CT scans [22–24].

CT in Head Injury Patients (CHIP) Rule

The CT in Head Injury Patients (CHIP) prediction rule from The Netherlands takes a very comprehensive approach to identifying traumatic brain injuries. One notable difference in the CHIP derivation study was that it included some patients who had not lost consciousness, expanding the applicability beyond the narrower inclusion criteria of rules like CCHR and NOC. The CHIP rule stratifies risk factors into high-risk and medium-risk categories, with a point-based scoring system (making it one of the more complex rules). In simple terms, CHIP incorporates essentially all the risk factors found in other rules, and then some. High-risk factors that each independently mandate a CT include: GCS < 14 (or any deterioration in GCS), any suspicion of skull fracture (open or depressed) or signs of basal skull fracture, two or more vomiting episodes, age $\geq$ 65, post-traumatic seizure, and any focal neurological deficit. Additional factors are also considered: loss of consciousness, short-term memory impairment (amnesia), headache, dangerous mechanism of injury, use of anticoagulant drugs, and being in an intermediate age range (e.g., 40–64 years). In the CHIP algorithm, the presence of multiple additional factors (or certain single factors in an older patient) can also trigger a CT, even if none of the standalone high-risk criteria are present [25].

Because of its thoroughness, the CHIP rule is very sensitive to intracranial injuries. The developers reported that using CHIP could reduce CT scanning by around 30% compared to scanning every minor head injury patient. In validation, CHIP demonstrated a sensitivity on the order of 95% for any traumatic intracranial finding, with a specificity around 20–30%. In practical terms, CHIP will recommend scanning a large majority of patients, though fewer than the New Orleans or NEXUS approaches. For example, studies comparing multiple rules found that CHIP might classify about 75–80% of patients as needing CT (thus missing only ~5% of all injuries), whereas CCHR would scan closer to 50–60% (missing closer to 15–20% of injuries, albeit very minor ones) and NOC would scan almost 100%. Thus, CHIP sits between CCHR and NOC in terms of balancing sensitivity and specificity. Despite its strong performance metrics, the complexity of the CHIP rule (with its weighted scoring of numerous factors) has made it harder to implement from memory, and it has not become as globally popular as simpler rules like CCHR or NOC. However, many of the elements that CHIP pioneered—such as explicitly accounting for anticoagulation and not requiring LOC for inclusion—have influenced newer guidelines. CHIP underscores a general evolution in head CT decision aids: as evidence accumulated, more recent rules expanded to include broader patient populations and risk considerations, ensuring that even patients without classic concussion symptoms are evaluated for risk if other factors (like anticoagulant use) are present [6,26].

Comparative Performance of Decision Rules

All of these decision rules aim to maximize patient safety by achieving near-100% sensitivity for life-threatening intracranial injuries, especially those requiring neurosurgical intervention. Indeed, across various studies, rules such as CCHR, NOC, NEXUS-II, CHIP, NICE, and SNC have each demonstrated essentially 100% sensitivity in identifying patients who needed neurosurgical treatment (none of the rules would intentionally tolerate missing a sizable epidural, subdural, or other lesion that could deteriorate). The differences among the rules emerge in their sensitivity for detecting any intracranial injury (including minor ones) and in their specificity or proportion of patients they spare from scanning.

At one extreme, the New Orleans Criteria (and similarly NEXUS-II) are the most inclusive, prioritizing sensitivity above all. NOC will recommend CT for almost any patient with even a minor symptom or risk factor. In practice, applying NOC to a general mTBI population means approximately 90–100% of patients would get scanned. This yields an extremely high sensitivity (~98–100% for any trauma-related finding on CT),

but the specificity is abysmal (on the order of 5–12% in studies) since nearly everyone is imaged. Essentially, NOC's philosophy is to catch every possible injury, at the cost of many unnecessary scans [27,28].

At the other end, the NICE guideline is the most selective of the major protocols. By focusing on a defined set of high-risk indicators and not scanning for softer symptoms alone, NICE manages to scan a much smaller fraction of patients. Estimates suggest that strict adherence to NICE criteria would result in only about 40–50% of mTBI patients receiving a CT. The specificity of NICE has been reported around 55–60%, far higher than NOC's. The trade-off is reduced sensitivity for the tiniest injuries: NICE may only detect roughly 70–80% of all intracranial injuries. However, the missed injuries under NICE are generally very small and clinically benign, and importantly the guideline maintains nearly 100% sensitivity for those injuries that truly matter (i.e., those requiring intervention or hospital observation). In the UK practice, the small risk of missing a minor lesion is mitigated by observing patients and instructing them on returning if symptoms worsen [29,30].

Canadian CT Head Rule (CCHR) and CHIP can be viewed as intermediate strategies. CCHR was reported with about 80–85% sensitivity for any intracranial injury in some validations and about 100% for neurosurgical cases, with specificity around 40–50%. This translates to recommending CT for roughly 50–60% of patients—significantly fewer than NOC, but more than NICE. The CHIP rule, being more aggressive, scans an estimated 75–80% of patients, achieving sensitivity in the mid-90s% for any injury and specificity around 20–30%. In a direct comparison on one large cohort, it was found that NOC would scan ~96% of patients (catch ~99% of injuries), CHIP ~80% of patients (catch ~94% of injuries), CCHR ~58% of patients (catch ~80% of injuries), and NICE ~42% of patients (catch ~73% of injuries). Notably, all approaches were virtually 100% sensitive for lesions requiring neurosurgery, reinforcing that they differ mostly in how many minor injuries are accepted as initially undetected in exchange for reduced scanning [6,31].

The Scandinavian SNC guideline aligns most closely with NICE in its clinical criteria, but the addition of S100B biomarker testing can incrementally boost performance. Real-world data from Scandinavian hospitals indicate that using S100B allows roughly an additional 10–20% of low-risk patients to avoid CT compared to a clinical-only strategy, without missing significant injuries. In other words, SNC can potentially combine high sensitivity with improved specificity by ruling out some patients via a blood test [24,32].

In summary, there is an inherent trade-off between sensitivity and specificity among these decision rules. More liberal rules like NOC and NEXUS-II maximize sensitivity (few, if any, injuries will be missed) but at the cost of almost universal scanning. More selective rules like NICE (and to a lesser extent CCHR) dramatically cut down on CT utilization, but clinicians must accept that a very small number of minor injuries might not be immediately diagnosed (with the understanding that these are low-risk and that patients are advised to return if they worsen). The choice of which approach to use can depend on a healthcare system's resources, the medicolegal environment, and cultural attitudes toward risk. Crucially, regardless of which rule is used, all guidelines stipulate that if a patient's condition deteriorates or if new red flag symptoms develop, a CT scan should be obtained even if it was initially deferred. These rules are meant to guide initial management for patients who appear low-risk and stable, and they work best in tandem with good clinical judgment and observation. Table 1 summarizes key indications in the above-mentioned rules.

Table 1. Comparative table of adult mTBI head CT indications (major international rules).

Criterion/ Trigger	CCHR	NOC	NEXUS-II	NICE (Adult)	SNC (Adult)	CHIP
GCS threshold/ not normal	CT if GCS < 15 at 2 h (high-risk)	Applies to GCS 15 only	CT if altered alert- ness/abnormal behavior	CT if GCS < 13 initially or <15 at 2 h	CT if GCS < 15 (risk-tier dependent)	CT if GCS < 14/deterioration (weighted)
Suspected open/depressed skull fracture	Yes	Not explicit (covered indirectly by trauma above clavicles)	Yes (significant skull fracture)	Yes	Yes	Yes
Basal skull fracture signs	Yes	Not explicit	Often captured under skull fracture	Yes	Yes	Yes
Vomiting	≥2 episodes	Any vomiting	Recurrent/persistent vomiting	>1 episode	Yes (threshold varies by tier)	Yes (typically recur- rent/weighted)
Post-traumatic seizure	Not a core criterion	Yes	Not a core criterion (varies by implementation)	Yes	Yes	Yes
Focal neurologic deficit	Not listed as a formal item (but would override clinically)	Not listed	Yes	Yes	Yes	Yes
Age threshold	≥65	>60	≥65	≥65 (esp. with LOC/amnesia; also more liberal if anticoagulated)	Typically ≥65 (risk-tier dependent)	Often ≥65 (and sometimes lower age strata weighted)
Dangerous mechanism	Yes (defined list)	Not explicit	Not explicit	Yes (defined list)	Often Yes (tiered)	Yes (weighted)
Retrograde amnesia	>30 min	“Memory deficit” (short-term)	Not explicit	>30 min (with LOC/amnesia)	Often considered (tiered)	Considered (weighted)
Headache	Not a criterion	Yes	Not a criterion	Not a primary criterion	Not a primary criterion	Often included (weighted)
Intoxication	Not a criterion	Yes	Indirect via “abnormal behav- ior/alertness”	Not a primary criterion	Not a primary criterion	Sometimes included (variable)
Visible trauma above clavicles/ scalp hematoma	Not a criterion	Yes (trauma above clavicle)	Yes (scalp hematoma)	Not primary (fracture signs matter more)	Not primary	Sometimes included (vari- able/weighted)
Coagulopathy/ anticoagulants	Not in original scope (often ex- cluded/handled separately)	Not in original scope	Yes	Yes (very CT-forward)	Yes (risk-tiered; often CT)	Yes
Biomarker option to avoid CT	No	No	No	No	Yes: S100B pathway (selected low-risk within time window)	No
Overall “style” (how it feels in practice)	Balanced: tries to reduce CT while staying safe	CT-liberal: “scan if any symptom”	CT-liberal: broad safety net	Selective: fewer scans + structured timing	Selective + modern: clinical tiering + biomarker	Comprehensive: broad factors, more complex

4. Discussion

Balancing Risk and Resource Utilization in a Global Context

Differences among international head CT decision rules reflect broader themes in healthcare practice—especially risk tolerance and resource availability. In the United States (and North America generally), there has historically been an extremely low tolerance for missed diagnoses, driven in part by fear of litigation and high patient expectations. This climate encourages a very cautious approach: more liberal use of CT scans for head injuries,

often “just to be safe.” The American-derived rules like NOC and NEXUS-II epitomize this philosophy by scanning nearly all but the most trivial cases to ensure no hemorrhage is overlooked. In contrast, healthcare systems with centralized guidelines and a mandate for cost-effectiveness, such as the National Health Service (NHS) in the UK, have adopted rules like NICE that consciously trade a small drop in sensitivity for a large reduction in scans. The rationale is that CT scanners, radiologist time, and hospital resources are finite, and exposing every mild head injury patient to radiation (when only a few per hundred actually benefit from the scan) is not an efficient or necessary use of resources [28].

Canada’s use of the CCHR can be seen as a pragmatic middle ground. The rule was developed in response to variable CT use across Canadian hospitals in the 1990s—some emergency departments were scanning almost everyone with a head bump, while others scanned very selectively. CCHR provided an evidence-based standard to minimize that variation. In practice, it increased specificity relative to the older NOC rule (saving a significant number of scans) while still maintaining 100% sensitivity for neurosurgical injuries. Implementation studies in Canada confirmed that using CCHR leads to modest but meaningful reductions in CT utilization and improves the yield of positive findings per scan. This balance of safety and efficiency made CCHR appealing in many settings that wanted to avoid the excesses of an NOC-style approach without taking on much risk [33,34].

In Scandinavia and parts of Europe, we see even more nuanced strategies to balance risk and resources. The introduction of S100B testing in the SNC guideline was motivated by both resource considerations (for example, avoiding unnecessary transfers or scans in hospitals that might not have 24/7 CT readily available) and a drive to innovate beyond the limits of the clinical exam. European emergency departments often have the capacity for longer observation periods in short-stay units, which fits well with a selective scanning strategy: if a patient does not meet criteria for immediate CT, they can be observed for a few hours, and a delayed scan can be done if anything changes. This is feasible in systems where hospital flow and follow-up are structured to allow observation (unlike some busy urban U.S. ERs where keeping mild TBI patients under prolonged observation can be challenging). Moreover, in many low-resource or rural settings around the world, access to CT is limited or requires transfer to a distant facility; in such places, deciding who truly needs a scan becomes even more critical. The principles of rules like CCHR and NICE—focusing on key “danger” signs and risk factors—are universally applicable and can guide clinicians when over-scanning is not just a cost issue but logistically impractical. Notably, when Western-derived decision rules have been validated in other regions (Asia, Latin America, etc.), they generally perform well, though minor adjustments are sometimes made to fit local patient demographics or practices (for example, using a lower age threshold in a younger population, or combining elements of multiple rules to cover gaps) [35,36].

Real-World Application, Limitations, and Neurosurgical Implications of CT Decision Rules

Although clinical decision rules for head CT in adult mTBI are well validated, their implementation in everyday practice remains challenging. Clinicians do not always adhere strictly to algorithms when their clinical intuition suggests otherwise, particularly in borderline cases where the patient’s appearance or trajectory feels concerning. Decision rules are designed to support—not replace—experienced judgment, and deviations often reflect appropriate caution rather than misuse. However, correct application requires an understanding of each rule’s intended population and exclusions. Many original rules were not designed for anticoagulated patients, those with severe intoxication, or individuals with unreliable neurologic examinations. In modern practice, anticoagulation in particular has become an independent driver for imaging, as even trivial trauma may result in clinically

significant hemorrhage, underscoring the need to recognize when a rule should not be applied mechanistically [31,37].

Operational complexity further limits real-world uptake. Multi-criterion or weighted rules, as well as detailed flowcharts, can be difficult to recall and apply in high-throughput emergency settings without decision-support tools. Studies have shown that even established guidelines may be misinterpreted or inconsistently followed, especially when additional steps such as biomarker testing are involved. Without structured training, simple checklists, or integration into electronic ordering systems, the theoretical benefits of decision rules—reduced unnecessary imaging without compromising safety—may not be fully realized. Medicolegal pressures and defensive medicine also play a significant role, particularly in environments with low tolerance for missed diagnoses, where clinicians may choose to scan despite negative rule criteria to avoid even rare adverse outcomes [38,39].

Patient expectations add another layer of complexity. Many patients and families equate CT imaging with quality care and reassurance, and clinicians may find it easier to order a scan than to negotiate expectations, particularly when symptoms such as headache persist. At the same time, decision rules focus narrowly on detecting acute intracranial injury and do not address broader aspects of mTBI care, including concussion management, cervical spine injury, or evolving symptoms over time. Their use also assumes a reliable neurologic examination, which may not be possible in intoxicated or cognitively impaired patients. In such cases, most clinicians appropriately default to CT or prolonged observation, highlighting that rules are most effective in stable patients with dependable clinical assessment [6,37].

From a neurosurgical perspective, well-applied CT decision rules generally improve system efficiency by filtering referrals toward patients with meaningful pathology rather than generating large volumes of normal scans. However, neurosurgeons must understand both the strengths and limitations of these rules, as early triage decisions shape downstream care. Rare delayed deteriorations after discharge emphasize the importance of robust safety-netting, including clear written and verbal return instructions. Neurosurgeons also influence imaging behavior through local policy: aggressive consultation or transfer thresholds may incentivize over-scanning, whereas acceptance of conservative management for selected minor injuries allows emergency clinicians to rely more confidently on selective CT strategies. Globally, neurosurgeons are well-positioned to advocate for rational imaging—reducing unnecessary scans where overuse is entrenched, while emphasizing prompt CT in genuinely high-risk patients—thereby helping calibrate systems toward an optimal balance of safety and resource stewardship [40,41]. Tables 2 and 3 summarize triggers and scan vs. observe rules for each guideline.

Table 2. Check-sign matrix for adult mTBI head CT decision-making.

Trigger	CCHR	NOC	NEXUS-II	NICE	SNC	CHIP
GCS not normal/deterioration (esp. GCS < 15 at 2 h or worse)	✓	(not applicable; GCS 15 only)	✓	✓	✓	✓
Suspected open/depressed skull fracture	✓	-	✓	✓	✓	✓
Signs of basal skull fracture	✓	-	(via skull fracture)	✓	✓	✓
Focal neurologic deficit	(clinical override)	-	✓	✓	✓	✓
Post-traumatic seizure	-	✓	-	✓	✓	✓
Repeated vomiting (threshold varies; see AMBER below for “any vomiting”)	✓(≥2)	✓(any)	✓(persistent)	✓(>1)	✓	✓

Table 3. Check-sign matrix: scan vs. observe.

Trigger	CCHR	NOC	NEXUS-II	NICE	SNC	CHIP
Age threshold alone (older adult well-appearing)	✓ (≥65)	✓ (>60)	✓ (≥65)	✓ (≥65, especially with LOC/amnesia)	✓ (tiered)	✓ (weighted)
Dangerous mechanism (e.g., high-energy fall/vehicle)	✓	-	-	✓	✓ (tiered)	✓
Amnesia severity	✓ (>30 min retrograde)	✓ (memory deficit)	-	✓ (>30 min retrograde with LOC/amnesia)	✓ (tiered)	✓ (weighted)
Any vomiting (single episode)	-	✓	(depends)	-	(depends)	(weighted)
Headache alone	-	✓	-	-	-	(sometimes weighted)
Intoxication (clinically “unreliable exam”)	-	✓	✓ (via behavior/alertness)	(not primary)	(not primary)	(variable)
Visible trauma above clavicle/scalp hematoma	-	✓	✓	-	-	(variable)
Anticoagulant/bleeding disorder	(often excluded historically; many sites CT)	(not core)	✓	✓ (CT-forward)	✓ (tiered; often CT)	✓

5. Conclusions

Adult patients with mild traumatic brain injury present a diagnostic dilemma: the vast majority are uninjured, but a small number have intracranial lesions that require prompt detection and possible intervention. Over the past two decades, clinical decision rules and guidelines around the world have significantly informed and standardized the approach to head CT in this context. From North America’s highly sensitive, scan-heavy rules (like the New Orleans Criteria and NEXUS-II) to Europe and Canada’s more selective algorithms (like CCHR and NICE) and innovative additions like biomarker-based triage in Scandinavia, each strategy offers lessons in balancing patient safety with prudent resource use. No matter the locale, the cornerstone principles remain consistent: any sign of serious head trauma or neurological impairment warrants immediate imaging, and patients without high-risk features can often be safely managed with observation rather than reflexive scanning.

For neurosurgeons and acute care providers, understanding these guidelines is essential to ensure that critical cases are not overlooked while avoiding unnecessary imaging. Applying these rules in practice can reduce patient exposure to radiation and the overall burden of negative scans on the healthcare system, all while maintaining excellent outcomes. As research continues, we can expect further refinements of decision aids—potentially incorporating new biomarkers or computational risk models—to augment clinical judgment. Ultimately, the care of mTBI patients should be individualized and clinician judgment will always have a role; however, the consistent global message is that a structured, evidence-based approach to CT decision-making saves lives, saves resources, and is a hallmark of good clinical practice in modern neurosurgical and emergency care. Importantly, in many regional and transitional healthcare systems, particularly in countries facing economic and legal constraints, these guidelines have emerged not only as clinical tools but as necessary adaptations to balance medical efficacy with limited resources and systemic pressures.

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Abbreviations

The following abbreviations are used in this manuscript:

CT	Computed Tomography
TBI	Traumatic Brain Injury
mTBI	Mild Traumatic Brain Injury
GCS	Glasgow Coma Scale
LOC	Loss of Consciousness
ED	Emergency Department
CCHR	Canadian CT Head Rule
NOC	New Orleans Criteria
NICE	National Institute for Health and Care Excellence (head injury guidelines)
NEXUS-II	National Emergency X-Radiography Utilization Study II (head CT rule)
SNC	Scandinavian Neurotrauma Committee (head injury guidelines)
CHIP	CT in Head Injury Patients (The Netherlands decision rule)
ICH	Intracranial hemorrhage

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