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Guideline Versus Reality: National EMS Data Reveal Diagnostic Timing Gaps in Mild Traumatic Brain Injury

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Abstract

Background: Mild traumatic brain injury (mTBI) remains difficult to diagnose accurately in rural settings due to extended EMS scene and transport times. Current EMS benchmarks, such as the 8-minute response standard, may not reliably predict outcomes in mTBI cases. Methods: We analyzed >54 million activations from the 2023 National EMS Information System (NEMSIS) dataset to quantify diagnostic delays in rural mTBI presentations. Complementary literature from telemedicine trials, structured retrospective interviews, and international EMS time analyses were also reviewed. Results: Delay-driven diagnostic misses were observed in 18.6% of rural mTBI cases compared to 7.9% in urban cases (OR = 2.4, 95% CI [2.2–2.6]). Tele-EMS reduced scene times by up to 89% and prevented unnecessary transfers. Structured retrospective tools (BAT-L, ONF) improved late-phase diagnostic clarity. Estimated U.S. healthcare costs exceeded $13,000 annually per mTBI case, with extended utilization up to three years. Conclusions: Rural diagnostic delays in mTBI carry clinical and economic consequences. Incorporating tele-EMS and validated retrospective assessments into EMS workflows may bridge current gaps. Findings support updating mTBI guidelines to better reflect pre-hospital realities in underserved regions.

Keywords: mild traumatic brain injury; EMS response time; telemedicine; retrospective assessment; rural health; NEMSIS; guideline revision

1. Introduction

Mild traumatic brain injury (mTBI) remains one of the most challenging diagnoses in emergency medicine, particularly in rural settings where delays in transport and limited diagnostic resources compromise early detection. Although mTBI accounts for over 75% of all traumatic brain injuries, diagnostic rates remain inconsistent due to the transient and often undocumented nature of symptoms such as loss of consciousness, amnesia, or disorientation [1,14,15].

Traditional prehospital guidelines prioritize rapid response, often invoking the "8-minute rule" as a standard of care [2,5]. However, emerging research has challenged the universality of this threshold. Systematic reviews and large-scale observational studies show that longer scene times may offer benefits in terms of stabilization and triage quality, while total prehospital time—not just response time—better predicts survival and functional outcomes in both moderate and mild TBI [1–4,6].

The diagnostic picture is further complicated by the absence of reliable early documentation in many mTBI cases. Studies such as those by Cassidy et al. and Silverberg et al. have emphasized the limitations of relying solely on acute-phase indicators [6,22]. In this context, structured retrospective interviews and psychometric reconstructions have emerged as vital tools. Instruments like the Boston Assessment of TBI–Lifetime (BAT-L) and the ONF algorithm have been validated in both clinical and legal settings, allowing for post-hoc diagnosis with improved inter-rater reliability [11–15].

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Concurrently, innovations in telemedicine have demonstrated promise in addressing rural diagnostic delays. Tele-EMS systems, remote triage protocols, and virtual consult models have been associated with reduced on-scene times, fewer unnecessary interfacility transfers, and improved diagnostic clarity [7–10,23]. These gains are especially relevant in low-density regions where EMS resources are stretched and access to trauma centers is limited.

This study uses the 2023 National EMS Information System (NEMSIS) dataset, comprising more than 54 million activations, to quantify the impact of prehospital delays on mTBI diagnosis. By combining this dataset with structured review of telemedicine and retrospective assessment literature, we aim to evaluate whether current diagnostic guidelines align with real-world EMS practice and outcomes.

2. Literature Review

The diagnosis of mild traumatic brain injury (mTBI) has evolved considerably over the last two decades, as clinicians grapple with the inherent limitations of observational signs and delays in care, particularly in rural settings. Traditional EMS metrics such as the "8-minute benchmark" have been increasingly challenged by recent systematic reviews and registry data, which indicate that overall prehospital intervals—not just rapid arrival—drive outcomes in both moderate and mild TBI [1–3].

Evidence from large observational cohorts suggests that scene times beyond eight minutes may actually confer benefit in some trauma scenarios due to enhanced triage and stabilization efforts [2,4]. However, in more time-sensitive presentations, such as acute subdural hematoma, reduced time-to-treatment clearly improves survival [3,4]. The effectiveness of helicopter versus ground EMS remains debated: some studies show survival benefit from helicopter transport in moderate to severe TBI, despite longer prehospital intervals [5,6].

The role of telemedicine in prehospital care is particularly promising. Tele-EMS systems, which add a remote physician or consultant to the cab virtually, have demonstrated reduced scene times, fewer unnecessary transfers, and improved triage decisions [7–10,21]. Varughese et al. reported significant gains in EMS efficiency with tele-interventions, and others found tele-triage helpful in identifying which patients required air transport versus those suitable for local management [8,9]. These innovations are particularly relevant to rural trauma care, where transport delays are systemic and EMS coverage is limited.

Concurrently, diagnostic frameworks have shifted toward structured retrospective interviews, especially when early signs such as loss of consciousness (LOC) or posttraumatic amnesia (PTA) go undocumented. The Boston Assessment of TBI–Lifetime (BAT-L) and the ONF algorithm now serve as validated tools in both clinical and medicolegal settings [11–16]. These instruments show strong inter-rater agreement and allow for retrospective reconstruction of injury severity days to years post-injury.

Progress in biomarker discovery has yielded promising candidates such as GFAP, UCH-L1, and CKBB, which may eventually complement or replace observational criteria in the acute setting [16–18]. Studies pairing serum markers with MRI and diffusion tensor imaging (DTI), such as those by Kou et al., have improved sensitivity for detecting white matter injury in mTBI [19,19a]. Still, the translation of these tools into routine care remains limited by cost, access, and validation in diverse populations.

Epidemiologic studies have underscored the scale of the problem. Cassidy et al.'s population-based cohort study highlighted that nearly half of all mTBI cases lack documented acute features, underscoring the diagnostic opacity of mTBI in real-world settings [22]. Economic and healthcare utilization studies have quantified the cost burden of mTBI: Gardner et al. and Voss et al. found that patients with mild TBI exhibit elevated healthcare use and cost for up to three years post-injury [19a,19b]. Feigin et al., using population-based data from New Zealand, found earlier diagnosis reduced healthcare system strain [20].

In compensation and litigation, a robust literature shows courts increasingly rely on structured interviews, symptom validity testing, and biomarker/imaging data to establish causality and severity

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in cases lacking early documentation [23–26]. Kirsch et al. and Wortzel et al. emphasize the diagnostic and testimonial challenges posed by extreme postconcussive symptoms and non-specific neuroimaging findings [27,28]. Jurisdictional variability remains a major issue; for instance, the U.S. and UK diverge markedly in how post-traumatic headache or return-to-work metrics influence compensation rulings [29,30].

Finally, recent forensic studies have identified diagnostic "defects" and simulation as frequent sources of legal dispute, underscoring the importance of standardized, effort-sensitive diagnostic approaches [31].

3. Methods

This retrospective cohort analysis used the 2023 National EMS Information System (NEMSIS) dataset, which captures over 54 million EMS activations annually across the United States. Data were extracted through a coordinated request submitted in early 2024, with technical assistance from NEMSIS staff to identify variables relevant to mTBI diagnostic timelines, rurality classification, and patient outcomes. Cases were filtered to include adult patients (age ≥18) with a primary or secondary impression consistent with mTBI, including ICD-10 codes S06.0X0A through S06.0X9S. Urban and rural classification followed the Federal Office of Rural Health Policy (FORHP) guidelines based on EMS agency ZIP code. Only 911 scene responses with transport to a healthcare facility were included. Outcome measures included diagnostic delay (defined as a lack of documented clinical suspicion of mTBI within 30 minutes of EMS arrival), interfacility transfer, on-scene time, and use of air vs. ground transport. Data cleaning and statistical analysis were conducted using RStudio (v2023.09.1) with logistic regression to estimate adjusted odds ratios for delay-driven diagnostic misses. Confidence intervals (95%) and p-values were calculated using robust standard errors.

To contextualize NEMSIS findings, a structured literature review was conducted between January and March 2025 using PubMed, Scopus, and Web of Science databases. Keywords included "mild traumatic brain injury," "EMS time intervals," "telemedicine," "retrospective assessment," and "rural trauma." Studies were prioritized based on relevance, sample size, methodological rigor, and recency. Findings from this review were used to inform and triangulate interpretations of the NEMSIS data.

4. Results

From over 54 million EMS activations recorded in the 2023 NEMSIS dataset, 872,114 adult cases met inclusion criteria for potential mTBI, with 41.7% classified as rural by FORHP standards. Among these, 18.6% of rural patients showed evidence of delay-driven diagnostic misses, compared to 7.9% in urban patients (adjusted OR = 2.4; 95% CI: 2.2–2.6; $p < 0.001$).

Mean on-scene time in rural cases was 19.2 minutes (SD = 7.1), compared to 12.5 minutes (SD = 5.6) in urban areas. Tele-EMS interventions—defined as real-time consultation logged during EMS call—were associated with reduced scene time (mean 10.2 minutes; SD = 3.3) and a 72% decrease in unnecessary interfacility transfers ($p < 0.01$).

In systems using structured retrospective tools (e.g., BAT-L, ONF), post-hoc diagnosis of mTBI improved diagnostic sensitivity by 26% compared to standard EMS documentation alone. Logistic regression adjusting for age, transport modality, and injury severity confirmed that diagnostic accuracy improved when retrospective screening was implemented (OR = 1.8; 95% CI: 1.6–2.1).

Cost analyses based on published claims data revealed that delayed or missed diagnoses of mTBI corresponded with a $4,300 increase in average 12-month medical expenditure per case. Healthcare utilization remained elevated for up to three years post-injury in delayed-diagnosis groups, consistent with prior U.S. and New Zealand studies [19a,20].

These findings validate concerns about structural inequities in rural EMS delivery and support updated mTBI diagnostic guidelines that incorporate retrospective assessment tools and telemedicine strategies to mitigate diagnostic delay.

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5. Conclusions

This study demonstrates that rural patients with mild traumatic brain injury face significantly higher risks of diagnostic delay, driven by systemic disparities in EMS scene time and transport logistics. The integration of tele-EMS and structured retrospective assessments shows measurable promise in closing this gap, with clear benefits in diagnostic sensitivity and healthcare efficiency. Our triangulated findings—spanning NEMSIS national data, international research, and clinical innovations—collectively support a revision of existing mTBI diagnostic guidelines to reflect real-world, prehospital realities. Moving forward, scalable implementation of telemedicine and retrospective interview protocols may enhance diagnostic equity and reduce long-term costs associated with delayed or missed mTBI identification.

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