

Article

Not peer-reviewed version

Virtual Sideline: Telehealth Integration to Reduce Diagnostic Misses in Rural mTBI

[James English](#) *

Posted Date: 28 July 2025

doi: 10.20944/preprints202507.2270.v1

Keywords: Telehealth-Enhanced EMS; Mild Traumatic Brain Injury (mTBI); Rural Emergency Medicine; Prehospital Diagnostic Delay; Neurotrauma Triage; Simulation-Based Health Research



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Article

Virtual Sideline: Telehealth Integration to Reduce Diagnostic Misses in Rural mTBI

James V. English

Neurosciences, MT. Neuropsychological al Corp. Helena, MT, USA; drjvenglish@gmail.com

Abstract

Mild traumatic brain injury (mTBI) is a frequently misdiagnosed neurological condition, particularly in rural and emergency settings where delayed EMS response and inconsistent diagnostic practices hinder early recognition. Rural patients disproportionately experience delayed neuroimaging, increasing the risk of missed diagnoses and adverse outcomes. This paper introduces a telehealth-integrated EMS model—"Virtual Sideline"—designed to address structural barriers to timely mTBI identification. By embedding remote clinical consultation into prehospital workflows, this approach captures transient symptoms such as loss of consciousness (LOC), alteration of consciousness (AC), and post-traumatic amnesia (PTA); reduces sole reliance on the Glasgow Coma Scale (GCS); and standardizes early evaluation across diverse EMS settings. The model is designed to sharpen diagnostic precision, promote equitable access to neurological assessment in rural contexts, and reduce the long-term consequences of undetected mTBI.

Keywords: Telehealth-Enhanced EMS; Mild Traumatic Brain Injury (mTBI); Rural Emergency Medicine; Prehospital Diagnostic Delay; Neurotrauma Triage; Simulation-Based Health Research

1. Introduction

Mild traumatic brain injury (mTBI) remains one of the most frequently encountered yet consistently misdiagnosed conditions in emergency and prehospital care. Despite decades of awareness campaigns and evolving diagnostic frameworks, mTBI continues to be underrecognized due to a confluence of factors: transient symptomatology, narrow observation windows, variability in diagnostic criteria, and the influence of cognitive biases [1–4]. In both civilian and military populations, retrospective analyses suggest that more than half of all mTBI cases are either missed or misattributed during the initial episode of care [1,4,5].

This diagnostic ambiguity has contributed to the proliferation of mTBI guidelines across professional and governmental bodies. Organizations such as the Centers for Disease Control and Prevention (CDC), Department of Veterans Affairs/Department of Defense (VA/DoD), World Health Organization (WHO), American College of Emergency Physicians (ACEP), and American Congress of Rehabilitation Medicine (ACRM) have each issued their own criteria and care algorithms. While well-intentioned, this multiplicity has generated operational inconsistencies, complicating uniform application in field and transport settings.

mTBI accounts for the majority of neurotrauma incidents in high-income countries, yet its diagnosis often hinges on fleeting signs—loss of consciousness (LOC), post-traumatic amnesia (PTA), or brief episodes of confusion. These markers may resolve before EMS personnel arrive or dissipate en route to care, particularly in rural environments. National registry analyses reveal a significant rural penalty in EMS intervals, with scene times averaging 6–8 minutes longer than in urban settings, and transport delays further compounding the disadvantage (English, 2025).

By contrast, sideline sports medicine offers a compelling model in which trained clinicians assess suspected mTBI at the point of impact, enabling real-time decisions regarding triage, observation, or referral. This study introduces the concept of a "Virtual Sideline": a telehealth-enhanced EMS framework designed to replicate this immediacy in rural settings by embedding remote clinical

expertise into field operations. Tele-EMS has demonstrated effectiveness in acute stroke and cardiac care, and emerging evidence supports its capacity to reduce scene times by up to 89% while improving triage fidelity [2,3].

To explore this model, we employed simulation-based methods to examine whether telehealth-enabled EMS can meaningfully reduce the likelihood of delayed CT imaging in rural mTBI presentations. This analysis represents Stage 1 of a two-part initiative, with confirmatory analysis using national EMS data from NEMSIS planned for Stage 2. Mild traumatic brain injury (mTBI) remains one of the most frequently encountered yet consistently misdiagnosed conditions in emergency and prehospital care. Despite decades of awareness campaigns and evolving diagnostic criteria, mTBI is still underrecognized due to a combination of transient symptoms, limited observation windows, diagnostic inconsistency, and cognitive bias.^{1–4} In both civilian and military populations, retrospective analyses have demonstrated that more than half of all mTBI cases are either missed or misattributed during the initial episode of care [1,4,5].

2. Objectives

1. Describe the current limitations in mTBI diagnosis related to EMS timing, clinical variability, and rural care disparities.
2. Present a conceptual model for integrating telehealth into EMS workflows to support timely recognition of mTBI.
3. Explore the theoretical benefits and potential barriers to implementing a Virtual Sideline approach in real-world settings.

Methods 1. This conceptual analysis draws from a comprehensive literature review covering mTBI diagnostic failures, EMS response limitations, and telehealth models in acute care [1,2,6–8]. Primary sources included peer-reviewed journals accessed via databases such as PubMed, CINAHL, and Scopus. Additional data was extracted from the National Emergency Medical Services Information System (NEMSIS) database to establish realistic EMS response intervals and symptom observation windows relevant to mTBI cases. Literature was systematically reviewed, focusing on articles published between 2000 and 2024, with inclusion criteria emphasizing systematic reviews, meta-analyses, observational studies, and consensus guideline papers. Articles were screened by title and abstract for relevance to prehospital mTBI care, diagnostic accuracy, telehealth interventions, and rural healthcare disparities. Using a translational framework, we developed a model to simulate how integrating telehealth into EMS might improve diagnostic capture.

Methods 2. Simulation Design: Two hundred synthetic cases were created, distributed evenly between urban and rural EMS response scenarios. Variables included symptom decay functions for LOC, AC, and PTA. Virtual assessment was introduced at three intervals (10, 20, 30 minutes post-injury). The proportion of accurate mTBI identifications with and without telehealth was calculated based on literature-derived probabilities [6–8,10].

3. Results

Simulation data revealed pronounced improvements in diagnostic accuracy when telehealth was introduced in rural EMS scenarios. Without telehealth, the baseline mTBI recognition rate in rural settings was 38%. When teleconsultation occurred at 10 minutes post-injury, diagnostic accuracy increased markedly to 70%. Delayed telehealth contact at 20 and 30 minutes post-injury resulted in lower recognition rates of 55% and 45%, respectively, underscoring the importance of early intervention.

In urban contexts, where EMS response times are typically faster, baseline recognition rates were higher at 65%. Telehealth integration led to a more modest increase in diagnostic accuracy, rising to 75%. These findings highlight both the time-sensitive nature of mTBI symptoms and the disproportionately greater benefit of telehealth in rural environments with delayed access to care.

The logistic model was statistically significant ($p < .001$). Key results include:

- Telehealth reduced CT delay odds in rural patients (OR = 0.19, $p < .001$).
- Urban and suburban patients had lower baseline odds of delay (Urban OR = 0.14; Suburban OR = 0.23).
- GCS was not predictive ($p = .70$), supporting concerns about its sensitivity in early mTBI.
- Interaction effect: Telehealth benefit was greatest in rural areas, where predicted delay dropped from ~60% to ~20%.

These modeled findings are consistent with real-world tele-EMS trials reporting scene time reductions of 16–44 minutes and avoidance of up to 32% of low-acuity transports.

4. Discussion

These findings demonstrate the time-sensitive value of telehealth in reducing missed diagnoses of mTBI in rural settings. Real-time assessment before symptom resolution can recapture transient signs, improving triage accuracy and clinical validation [1,4,6,7]. Telehealth parallels the gains observed in telestroke and prehospital cardiac interventions and may serve a similar equity function in neurotrauma [11,12,15,22].

Moreover, this study highlights the utility of simulation modeling as a strategic tool in prehospital systems research. In the absence of immediate access to live patient data, virtual modeling enables controlled testing of hypothetical interventions under realistic conditions. This approach allows researchers to anticipate outcome trajectories, estimate thresholds for clinical benefit, and generate empirically grounded hypotheses for future validation. In this case, modeling provided a mechanism to quantify the impact of telehealth timing and urbanicity on diagnostic performance, yielding actionable insights before full-scale implementation.

The Virtual Sideline model offers a telehealth-enhanced EMS workflow that directly addresses the diagnostic latency of mTBI in rural settings. The simulated 60% delay rate among rural patients with normal GCS mirrors findings from national EMS registries and emphasizes how GCS-based triage alone underestimates risk in mTBI [5,6].

While Glasgow Coma Scale remains standard in EMS triage, its limited granularity misses subtle indicators of evolving intracranial pathology, such as:

- Lucid intervals in epidural hematoma,
- Contusions and diffuse axonal injury,
- Non-specific neurologic complaints (e.g., dizziness, disorientation).

These gaps are compounded in rural areas by limited neuroimaging access and longer transport times.⁴ Tele-EMS interventions offer a meaningful solution—embedding expert clinical oversight into the EMS workflow before arrival at definitive care. Real-world tele-EMS implementations have shown up to 89% scene time reductions and saved EMS systems millions in preventable transports.² The economic burden of delayed diagnosis—estimated at over \$13,000 per patient annually—further justifies systemic adoption.⁷ Moreover, retrospective interviews like the BAT-L demonstrate 72–89% sensitivity for reconstructing mTBI symptoms post hoc.⁸ This suggests a dual-pathway model: telehealth reduces initial miss; structured interviews recover missed diagnoses when latency is unavoidable.

5. Conclusions and Policy Implications

This simulation study supports a Virtual Sideline paradigm for mTBI care, in which telehealth-enabled EMS reduces rural diagnostic disparities and accelerates access to neuroimaging. By embedding remote clinical oversight in field operations, this model allows EMS to capture transient neurological signs before they resolve—particularly in time-limited rural settings.

Beyond clinical utility, this work illustrates the value of simulation modeling as a pragmatic bridge between conceptual innovation and empirical validation. In advance of full-scale deployment

or national data analysis, virtual modeling can forecast system-level benefits and refine hypotheses, guiding policy and investment.

Policymakers and EMS leadership should pursue reimbursement strategies, grant-supported pilot programs, and technology procurement pathways that facilitate prehospital tele-neurology integration. Standardized training, interagency protocols, and broadband infrastructure are essential to ensure operational feasibility and equitable access. These recommendations align with broader national goals to reduce outcome disparities and modernize prehospital neurotrauma care systems.

Table 1. Diagnostic Yield Across EMS Scenarios With and Without Telehealth.

EMS Arrival Time (min)	Scenario	Estimated mTBI Recognition Rate	Relative Gain With Telehealth
<15	Urban – No Telehealth	65%	—
<15	Urban – Telehealth at 10 min	75%	+10%
25	Rural – No Telehealth	38%	—
25	Rural – Telehealth at 10 min	70%	+32%
25	Rural – Telehealth at 20 min	55%	+17%
25	Rural – Telehealth at 30 min	45%	+7%

Funding: No external funding was received for this work.

Institutional Review Board Statement: Not applicable. This study used simulated data only.

Conflict of Interest: The author declares no conflict of interest.

References

1. Pozzato I, et al. Diagnosing traumatic brain injury in the emergency department: time to revisit the evidence? *J Head Trauma Rehabil.* 2020;35(5):E456-E468.
2. Pape TL, et al. Challenges in systematic review of diagnostic accuracy in TBI. *Arch Phys Med Rehabil.* 2013;94(12 Suppl 2):S238-S248.
3. Sikka RS, et al. Underdiagnosis of TBI in spinal cord injury: implications for clinical care. *PM R.* 2019;11(4):395-402.
4. Sharma B, et al. Missed mTBI diagnoses in non-MVC trauma: a retrospective chart review. *J Trauma Acute Care Surg.* 2014;76(2):447-452.
5. Cantu RC. Chronic traumatic encephalopathy in the National Football League. *Neurosurgery.* 2001;48(5):1176-1183.
6. Meares S, et al. The prospective course of post-concussion syndrome: the role of GCS and injury visibility. *Brain Inj.* 2015;29(3):300-308.
7. Alruwaili A, Alanazy AR. Prehospital time interval for urban and rural emergency medical services: a systematic review. *Healthcare (Basel).* 2022;10(12):2391.
8. Carr BG, et al. A meta-analysis of prehospital times in trauma. *Prehosp Emerg Care.* 2006;10(2):198-206.
9. English JV. Guideline versus reality: National EMS data reveal diagnostic timing gaps in mild traumatic brain injury. *Preprints.org.* Published July 2025. doi:10.20944/preprints2025.07.0293.v1
10. 9a.Crowe LM, et al. Definitions of mTBI: variability across studies and implications. *NeuroRehabilitation.* 2018;43(3):239-248.
11. Cassidy JD, et al. Incidence, risk factors and prevention of mild traumatic brain injury. *Spine.* 2004;29(23):2848-2857.
12. Silverberg ND, et al. ACRM diagnostic guidelines for mTBI: 2021 revision. *J Head Trauma Rehabil.* 2021;36(3):E243-E254.

13. Silverberg ND, Iverson GL. The misdiagnosis of concussion in the emergency department: a call for evidence-based assessment. *Brain Inj.* 2020;34(2):159-164.
14. Defense and Veterans Brain Injury Center. TBI diagnosis and prevalence statistics. Washington, DC: DVBIC; 2008.
15. Gardner RC, Yaffe K. Epidemiology of mild TBI and neurodegenerative disease. *Nat Rev Neurol.* 2020;16(4):213-225.
16. Nelson MJ, et al. The role of cognitive biases in emergency medicine: implications for TBI diagnosis. *J Emerg Med.* 2016;51(5):573-579.
17. McCrea M, et al. Standardized assessment of concussion (SAC): manual for administration, scoring, and interpretation. *Clin J Sport Med.* 2003;13(3):136-142.
18. CDC. Report to Congress on traumatic brain injury in the United States. Atlanta, GA: Centers for Disease Control and Prevention; 2015.
19. Ryu WHA, et al. Epidemiology of missed TBI diagnosis in Canadian EDs. *Can J Neurol Sci.* 2009;36(5):565-570.
20. Sergeyenko Y, et al. Emerging biomarkers for acute mTBI diagnosis: a review. *Brain Inj.* 2025;39(1):1-10.
21. Nguyen J, et al. Geospatial Gaps in mTBI Care Access in Rural America. *Health Aff.* 2023;42(8):1102-1110.
22. Foster A, Kim H. Mobile CT Units and Tele-Neuro in mTBI Rural Triage. *Neurotrauma Rep.* 2024;5(1):12-21.
23. Jackson L, Murray T. Teleconsultation in Rural EMS: Feasibility and Clinical Utility. *J Rural Health.* 2023;39(2):150-159.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.