ORIGINAL ARTICLE

Imaging Evidence and Recommendations for Traumatic Brain Injury: Conventional Neuroimaging Techniques

Max Wintermark, MD, MAS[a,*], *Pina C. Sanelli, MD, MPH*[b,*], *Yoshimi Anzai, MD*[c], *A. John Tsiouris, MD*[d,e], *Christopher T. Whitlow, MD, PhD*[f], *on Behalf of the ACR Head Injury Institute*[†]

Abstract

Imaging plays an essential role in identifying intracranial injury in patients with traumatic brain injury (TBI). The goals of imaging include (1) detecting injuries that may require immediate surgical or procedural intervention, (2) detecting injuries that may benefit from early medical therapy or vigilant neurologic supervision, and (3) determining the prognosis of patients to tailor rehabilitative therapy or help with family counseling and discharge planning. In this article, the authors perform a review of the evidence on the utility of various imaging techniques in patients presenting with TBI to provide guidance for evidence-based, clinical imaging protocols. The intent of this article is to suggest practical imaging recommendations for patients presenting with TBI across different practice settings and to simultaneously provide the rationale and background evidence supporting their use. These recommendations should ultimately assist referring physicians faced with the task of ordering appropriate imaging tests in particular patients with TBI for whom they are providing care. These recommendations should also help radiologists advise their clinical colleagues on appropriate imaging utilization for patients with TBI.

Key Words: Traumatic brain injury, brain imaging, CT, MRI

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INTRODUCTION

Traumatic brain injury (TBI) is one of the most common neurologic disorders, currently affecting 1.7 million Americans each year [1,2]. The incidence of TBI, especially mild TBI, is underestimated [3], as patients frequently dismiss their symptoms and never present to the emergency department (ED), or they believe that the admission of symptoms may compromise their work situation (eg, athletes, military personnel [4]). Although the majority of patients (nearly 80%) with diagnosed TBI are treated and released from EDs [5], the remaining 20% have more severe injuries, resulting in approximately 275,000 hospitalizations and 52,000 deaths each year. Furthermore, TBI contributes to one-third of all injury-related deaths in the United States. The economic cost of TBI was an estimated at $76.5 billion in 2010 ($11.5 billion in direct medical costs and $64.8 billion in indirect costs such as lost wages, lost productivity, and nonmedical expenditures) [6]. Moreover, affected military veterans generate an annual cost of $11,700 in medical treatment per patient, compared with $2,400 in TBI-free veterans [7]. Leading causes of TBI in the general population include falls, motor vehicle accidents, assaults, and sports-related injuries.

Imaging plays an essential role in identifying TBI patients with intracranial injury. The goals of imaging include (1) detecting injuries that may require immediate surgical or procedural intervention, (2) detecting injuries that may benefit

[a]Division of Neuroradiology, Stanford University, Palo Alto, California.
[b]Department of Radiology, North Shore – LIJ Health System, Manhasset, New York.
[c]Department of Radiology, University of Washington, Seattle, Washington.
[d]Department of Radiology, Weill Cornell Medical College, New York, New York.
[e]Department of Radiology, New York-Presbyterian Hospital, New York, New York.
[f]Department of Radiology and Translational Science Institute, Wake Forest School of Medicine, Winston-Salem, North Carolina.
Corresponding author and reprints: Max Wintermark, MD, MAS, Stanford University, Department of Radiology, Neuroradiology Division, 300 Pasteur Drive, Room S047, Stanford, CA 94305-5105; e-mail: max.wintermark@gmail.com.

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*Drs Wintermark and Sanelli contributed equally to this work.

†A list of significant contributors is provided in the Appendix.

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from early medical therapy or vigilant neurologic supervision, and (3) determining the prognosis of patients to tailor rehabilitative therapy or help with family counseling and discharge planning. A wide variety of imaging techniques have become available to assess patients presenting with TBI. This, coupled with the inconsistent use of clinical decision rules [8], has led to increased utilization and variations in numerous imaging practices. Among hospitals reporting to the National Hospital Ambulatory Medical Care Survey, CT utilization for head trauma in the pediatric population increased from 12.8% in 1995 to 28.6% in 2000 despite stable hospitalization rates for head trauma [9]. The practical challenge for physicians is to understand the multiple facets of these imaging techniques, including which imaging techniques to implement and how to use them optimally for specific patients.

Since 2009, multiple health care agencies involving experts from the international TBI community have worked on developing and refining common data elements (CDEs) in TBI to promote the use of consistent terminology and definitions in characterizing intracranial injuries across all imaging studies, as well as all clinical aspects of TBI [10,11]. These CDEs can be used in a consistent manner for clinical practice, research, and treatment trials across multiple institutions and research studies. The CDEs include a list of the injuries that can be identified, with definitions of terms used to describe these injuries on the images, and recommended protocols and descriptors for image acquisition methods. The goal of the CDEs is to promote consistency across the field in future investigations aimed at evaluating TBI imaging.

In an effort parallel to, but distinct from, the CDEs, we performed a review of the evidence on the utility of various imaging techniques in patients presenting with TBI to provide guidance for evidence-based, clinical imaging protocols. We indicated the quality of publications for diagnostic test and interventions by assigning stratified and preferential levels of evidence (Table 1) and classes of recommendations (Table 2). These levels of evidence are based on the National Institute for Health and Care Excellence (http://www.nice.org.uk), adapted from the Oxford Centre for Evidence-Based Medicine (http://www.cebm.net) levels of evidence (2001). The intent of this article is to suggest practical imaging recommendations for patients presenting with TBI across different practice settings and to simultaneously provide the rationale and background evidence supporting their use. These recommendations should ultimately assist referring physicians faced with the task of ordering appropriate imaging tests in particular patients with TBI for whom they are providing care. These recommendations should also help radiologists advise their clinical colleagues on appropriate imaging utilization for patients with TBI. For practical purposes, recommendations are presented separately for TBI severity and apply to the differentiation of acute, subacute, and chronic TBI, as defined by Defense and Veterans Brain Injury Center recommendations (http://www.traumaticbraininjuryatoz.org/Resource-Center/The-Defense-and-Veterans-Brain-Injury-Center). Acute injuries refer to those from the time of injury to

Table 1. Levels of evidence for studies of the accuracy of diagnostic tests

Level of Evidence	Type of Evidence
Ia	Systematic review (with homogeneity)* of level 1 studies†
Ib	Level 1 studies†
II	Level 2 studies‡
	Systematic reviews of level 2 studies
III	Level 3 studies§
	Systematic reviews of level 3 studies
IV	Consensus, expert committee reports or opinions, and/or clinical experience without explicit critical appraisal, or based on physiology, bench research, or "first principles"

Note: Adapted from The Oxford Centre for Evidence-Based Medicine Levels of Evidence (2001) and Centre for Reviews and Dissemination Report Number 4 (2001).

*Homogeneity means that there are no or minor variations in the directions and degrees of results among individual studies that are included in the systematic review.

†Level 1 studies are studies: (1) that use blind comparisons of the test with a validated reference standard (2) in samples of patients that reflect the population to whom the test would apply.

‡Level 2 studies are studies that have only one of the following: (1) narrow populations (the samples do not reflect the population to whom the test would apply), (2) poor reference standards (defined as that for which the "test" is included in the "reference," or for which the "testing" affects the "reference"), (3) nonblinded comparisons between the test and reference standard, and (4) case-control designs.

§Level 3 studies are studies that have at least two or three of the features listed above.

Table 2. Classification of recommendations

Class I: Conditions for which there is evidence for or general agreement that a procedure or treatment is beneficial, useful, and effective

Class II: Conditions for which there is conflicting evidence or a divergence of opinion about the usefulness or efficacy of a procedure or treatment

Class IIa: Weight of evidence or opinion is in favor of usefulness or efficacy

Class IIb: Usefulness or efficacy is less well established

Class III: Conditions for which there is evidence or general agreement that a procedure or treatment is not useful or effective and in some cases may be harmful

Note: From the American Heart Association.