Imaging of Nonaccidental Injury and the Mimics: Issues and Controversies in the Era of Evidence-Based Medicine

Patrick D. Barnes, MD

KEYWORDS

- Evidence-based medicine • Nonaccidental injury
- Nonaccidental trauma • Nonaccidental head injury
- Child abuse

Nonaccidental injury (NAI) is reportedly the most frequent cause of traumatic injury in infants (peak incidence age 6 months; 80% of traumatic brain injury deaths under the age of 2 years).[1–4] NAI, nonaccidental trauma (NAT), and nonaccidental head injury are more recently used terms instead of the traditional labels, child abuse, battered child syndrome, and shaken baby syndrome (SBS). The traditional definition of NAI/SBS is intentional or inflicted physical injury to infants characterized by the triad of (1) subdural hemorrhage (SDH), (2) retinal hemorrhage (RH), and (3) encephalopathy (ie, diffuse axonal injury [DAI]) occurring in the context of inappropriate or inconsistent history (particularly when unwitnessed) and commonly accompanied by other apparently inflicted injuries (eg, skeletal).[1–4] This empirical formula is under challenge by evidence-based medical and legal principals.[4–14]

TRAUMATIC BRAIN INJURY

Traumatic brain injury has been categorized in several ways.[1,4] Primary injury directly results from the initial traumatic force and is immediate and irreversible (eg, contusion or shear injury). Secondary injury arises from or is associated with the primary injury and is potentially reversible (eg, swelling, hypoxia-ischemia, seizures, or herniation). Traditional biomechanics describes impact loading as linear forces that produce localized cranial deformation and focal injury (eg, fracture, contusion, or epidural hematoma). Accidental injury (AI) is considered typically associated with impact and, with the exception of epidural hematoma, is usually not life threatening. Impulsive loading refers to angular acceleration/deceleration forces resulting from sudden nonimpact motion of the head on the neck (ie, whiplash) and produces diffuse injury with tissue disruption (eg, bridging vein rupture with SDH and white matter shear with DAI). Young infants are thought particularly vulnerable to the latter mechanism (ie, SBS) because of weak neck muscles, a relatively large head, and an immature brain. SBS is traditionally postulated to result in the triad of primary traumatic injury (ie, SDH, RH, and DAI), which has been reportedly associated with the most severe and fatal CNS injuries. Stated assault mechanisms

Disclosure: Dr Barnes provides expert consultation and testimony in child abuse cases, occasionally with compensation, and including on behalf of the defense.
Department of Radiology, Lucile Packard Children's Hospital, Stanford University Medical Center, 725 Welch Road, Palo Alto, CA 94304, USA
E-mail address: pbarnes@stanford.edu

Radiol Clin N Am 49 (2011) 205–229
doi:10.1016/j.rcl.2010.08.001
0033-8389/11/$ – see front matter

radiologic.theclinics.com

in NAI include battering, shaking, impact, shaking-impact, strangulation, suffocation, and combined assaults (shake-bang-choke).[1–4] Although the spectrum of injury in NAI overlaps that of AI, certain patterns have been previously reported as characteristic of or highly suspicious for NAI.[1–4] These include multiple or complex cranial fractures (**Fig. 1**), acute interhemispheric SDH (**Fig. 2**), acute-hyperacute SDH (**Fig. 3**), DAI, chronic SDH, and the combination of chronic and acute SDH (**Fig. 4**). The latter combination is thought indicative of more than one abusive event. Imaging evidence of brain injury may occur with or without other clinical findings of trauma (eg, bruising) or other traditionally higher-specificity imaging findings of abuse (eg, classic metaphyseal lesions or rib fractures) (**Fig. 5**).[1–4] Therefore, clinical and imaging findings of injury out of proportion to the history of trauma and injuries of different ages have been the basis of making a medical diagnosis and offer expert testimony that such "forensic" findings are "proof" of NAI/SBS, particularly when encountered in premobile, young infants.

EVIDENCE-BASED MEDICINE

Evidence-based medicine (EBM) is now the guiding principle as medicine moves from an authoritarian to an authoritative era to overcome bias and ideology.[4,15–20] EBM quality-of-evidence ratings of the literature (eg, classes I–IV) are based on levels of accepted scientific methodology and biostatistical significance (eg, *P* values) and apply to the formulation of standards and guidelines for every aspect of medicine, including diagnostics, therapeutics, and forensics. EBM analysis reveals that few published reports in the traditional NAI/SBS literature merit a quality-of-evidence rating above class IV (eg, expert opinion alone).[5] Such low ratings do not meet EBM recommendations for standards (eg, level A) or for guidelines (eg, level B). Difficulties exist in the rational formulation of a medical diagnosis or forensic determination of NAI/SBS based on an alleged event (eg, shaking) that is inferred from clinical, imaging, or pathology findings in the subjective context of (1) an unwitnessed event, (2) a noncredible history, or (3) an admission or confession under dubious circumstances.[6] This problem is further confounded by the lack of consistent and reliable criteria for the diagnosis of NAI/SBS and because much of the traditional literature on child abuse consists of anecdotal case series, case reports, reviews, opinions, and position papers.[5,6,10,11,21,22] Many reports include cases having impact injury, which

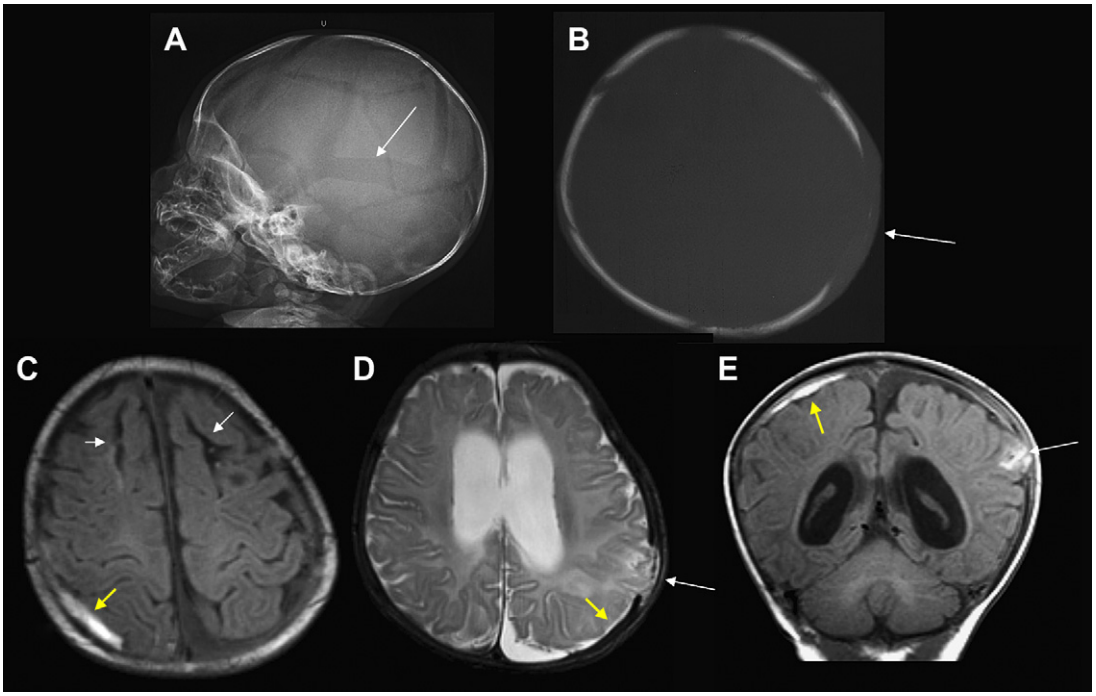

Fig. 1. Nine-week-old infant with triad and alleged NAI; also, history of traumatic labor and delivery. Skull film (*A*), CT (*B*) plus FLAIR (*C*), T2 (*D*), and T1 (*E*) MR imaging shows bilateral skull fractures with left growing fracture (*long white arrows*), chronic bifrontal cerebral white matter clefts (*short white arrows*) (*C*) plus acute, subacute, and chronic SDHs/rehemorrhages (*yellow arrows*).