

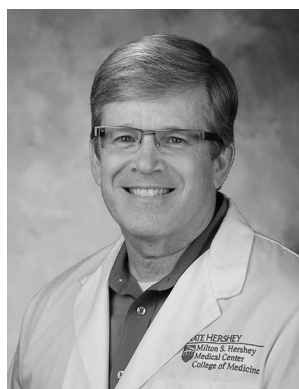


Joining Families

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REAL WORLD RESEARCH FOR FAMILY ADVOCACY PROGRAMS

FEATURED INTERVIEW



Development and Validation of an Evidence-Based Procedure for Evaluation of Abusive Head Trauma in Young Children

Interview with Kent P. Hymel, MD

Kent P. Hymel, MD

Kent P. Hymel, MD, is Professor of Pediatrics at the Penn State College of Medicine. He completed a fellowship in Child Abuse Pediatrics at The Children's Hospital, Denver, Colorado in 1996. He served as the U.S. Air Force Medical Consultant for Child Abuse, and has directed

child abuse programs at Inova Fairfax Hospital for Children and the Dartmouth Hitchcock Medical Center. In 2014, Dr. Hymel joined the Center for the Protection of Children at Penn State Hershey Medical Center. He is a past member of the American Academy of Pediatrics' Committee on Child Abuse and Neglect, a past President of the Ray E. Helfer Society (the professional society for physicians specialized in child abuse), and was the Deputy Medical Editor of the Subboard in Child Abuse Pediatrics of the American Board of Pediatrics. Much of his career has been devoted to research on the objective diagnosis of pediatric abusive head trauma. Dr. Hymel founded and directs the Pediatric Brain Injury Research Network (PediBIRN), and is the Principle Investigator of an NIH-funded clinical trial testing the impact of a novel, Pediatric Intensive Care Unit (PICU)-based screening tool for pediatric AHT. He has a wide variety of medical publications on the pathophysiology of traumatic intracranial hemorrhage, the timing of its clinical signs, and related topics such as race and ethnic disparities and biases in the evaluation and reporting of suspected head-injured children.

In This Issue

The subject of this *JFJF* is head trauma related to infant/child abuse, sometimes in the past referred to as "shaken baby syndrome," but more accurately now called abusive head trauma (AHT). We present an interview with Kent P. Hymel, MD, a pediatrician specialized in child abuse. He is Professor, Department of Pediatrics, Penn State College of Medicine, Penn State Health Children's Hospital, Hershey, PA. The interview describes what constitutes AHT: the mechanisms of injury, his research on developing an evidence-based screening tool for physician use in order to minimize missed cases of AHT, and a procedure for estimating the probability that a head-injured child has been abused based on the outcome of the medical workup. Additional articles supplement Dr. Hymel's interview by providing information on the incidence of AHT, clinical findings, outcomes, and programs to prevent AHT in young children. Our statistics article gives descriptions of sensitivity and specificity, which are used in developing screening tools. Websites of Interest includes Dr. Hymel's research network, the PediBIRN, as well as other sources of information on AHT for clinicians, caregivers, and educators.

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Dr. McCarroll: Abusive head trauma (AHT) is a major cause of death of abused infants and young children. Over half of the 600 deaths of children under age five who were reported to the National Violent Death Reporting System during 2003–2006 were due to AHT (Klevens

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When someone acts spontaneously it is more likely that they would strike or throw a baby rather than pick them up and shake them.

& Leeb, 2010). This is an alarming statistic and a topic of medical and social concern. What would a physician in an emergency department see in a child admitted for head trauma?

Dr. Hymel: There is a big variety. Not every head trauma is inflicted. However, most simple falls and indoor accidental traumas that the average ambulatory child experiences, do not end up in an ICU. Most children with head trauma, whether it is inflicted or accidental, present for urgent care to an emergency department. When the severity of the injury is recognized — such as by a life-threatening clinical sign like seizures, respiratory compromise, shock, or unconsciousness — the child is stabilized and transported to the nearest regional intensive care unit or a pediatric ICU (PICU). These are places where pediatric surgeons and neurosurgeons are available. In the most severe cases, these children present as unresponsive with respiratory compromise and may have stopped breathing. Those are the children that frequently do not survive. If they do survive, they often have major brain injuries. When you stop breathing or you go into shock your brain is not receiving oxygen and the negative impacts begin pretty quickly.

Dr. McCarroll: A term that we commonly see in child abuse literature is “shaken baby syndrome.”

Dr. Hymel: Shaken baby syndrome was a term used in the past to describe children whose head trauma was believed to have resulted from violent shaking. Most of us prefer the term abusive head trauma or AHT. There are often other injuries in addition to shaking that these children experience. There have been individuals who have implied that changing terminology from shaken baby to AHT means that we no longer believe violent shaking is dangerous. I think that is wrong. The overwhelming majority of practicing physicians believe that shaking an infant is clearly dangerous and precipitates the constellation of findings that would be labeled as abusive. I do not recall a child over one year old where I had concluded that the child had experienced only shaking. When someone acts spontaneously it is more likely that they would strike or throw a baby rather than pick them up and shake them.

Dr. McCarroll: At what age does child shaking tend to occur?

Dr. Hymel: The peak age of AHT correlates well with the peak age of crying, four-to-five-months of age. Its frequency drops after six-to-nine months. Babies are hard to shake when they get heavy. It is less likely that babies older than nine or twelve months are shaken. Violent shaking is a mechanism that some children experience, but many also experience an impact that contributes to their injury. For the overwhelming majority of children, we find evidence of impact.

The brain is protected from impacts because it is enclosed in the skull and is suspended in a layer of water-like fluid, cerebrospinal fluid. So, it floats. That helps decrease injury if the head experiences an impact. But if the head is put into rotational motion, substantial damage occurs. With that, brain tissues of different density are moving at different rates, shearing. In shaking, because the head is tethered to the body by the neck, shaking typically causes a whiplash, arc-like motion. Let's say shaking has put the head in violent motion and it is now moving forward towards the chest. As the skull moves forward, the brain lags behind because it is not rigid and you can imagine that the brain begins to catch up and it is moving forward as well. But then, the chin hits the chest, the skull abruptly stops, and the brain continues to move forward until it impacts the inner surfaces of the front of the skull and the base of the skull and it stops.

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JOINING FORCES

Joining Families

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Any one of four variables can identify which children need a thorough workup for abuse: (1) bleeding overlying the brain (subdural hematoma), (2) respiratory compromise before hospital admission, (3) any bruising of the torso, ears, or neck (4) and a complex skull fracture.

This is where the brain interfaces with the more rigid structures of the skull and we expect the damage to occur.

Dr. McCarroll: Can you distinguish the mechanism of injury, shaking versus blunt trauma?

Dr. Hymel: Yes. That is also interesting. Closed head trauma can occur from an impact or from a whiplash-like mechanism. So, there are three possible mechanisms of injury. By interpreting the findings in the context of what must have happened to the head, we can begin to get an idea of what the child experienced: isolated impact that did not cause significant head motion; severe head motion in isolation; or a combination of the two. The vast majority of children have suffered impact sufficient to put their head into violent motion.

Dr. McCarroll: Do you see other injuries in addition to head injuries across a wide range of children's ages?

Dr. Hymel: Yes. We do see non-cranial injuries in babies who also have head injuries from abuse. It is not uncommon to see fractures and abdominal injuries. The appropriate workup once we have been convinced that a child has suffered physical abuse is to look thoroughly for injuries. If we suspect abuse in a young child, we get a number of tests including head imaging studies and lab tests to screen for abdominal trauma such as liver injury. They will also often have urine tests to look for blood that might suggest kidney injury.

Dr. McCarroll: What about damage to the nerves in the brain, axonal damage? Does that also occur?

Dr. Hymel: In fatal cases, forensic neuropathologists can look microscopically for evidence of nerve damage. Patterns of axonal injury can provide information about mechanisms of injury, but it is only useful in fatal cases. There are some CT findings that are occasionally seen that have been associated with those microscopic finding at autopsy. But in general, it is only found in fatal cases. It is a pretty ominous finding. If they survive they almost certainly will have moderate or severe deficits, more likely severe.

Dr. McCarroll: There are many complex medical and social issues associated with the decision to evaluate a child for AHT. I was surprised at the degree of controversy in

the literature. I thought that if trauma occurs, that you push on with the evaluation and do what you can. How is it that cases of AHT are missed?

Dr. Hymel: It sometimes is baffling to me that physicians who are caring for a child with obvious trauma to the head, with findings of severe brain injury and bleeding overlying the brain, hear a story that it was caused by a simple fall and somehow accept it as valid. If we have children or have been around children or grandchildren, they fall all the time once they learn to walk and yet they do not end up in intensive care units. There are lots of reasons why doctors suspect, but fail to report abuse. It is not only a failure to recognize the signs and symptoms, it is more than that. It can be an unwillingness to consider or make the diagnosis, a fear of making an erroneous diagnosis, or a fear of being wrong. To some degree, it can also be a fear of courtroom testimony and all of the other aspects of engagement with child protective services, police investigators, lawyers, and eventually testifying. In addition, there is a small, but ardent group of defense attorneys and their medical experts who testify frequently for the defense. These are individuals who argue that AHT does not exist or occurs only very rarely. (See Leventhal & Edwards, 2010 for a discussion of these issues.)

Physicians may also be hesitant to report suspected abuse if they know the family because they do not want to jeopardize their relationship with the family. There is also evidence that some doctors' practice with bias (Hymel et al., 2018). We tend to look for the diagnosis where we suspect we will find it. We tend to not look for the diagnosis in families and cases where we do not expect to find it. We tend to evaluate more children with head trauma who come from minority race/ethnicity families and have only a single adult caregiver in the home or who are on the lower end of the socioeconomic spectrum. Doctors tend to less frequently evaluate equivalent children if they are from a white family with two parents and a higher socioeconomic status. It is a clarion call that we need unbiased assessment tools. We need tests to better inform consistent decisions that will move us beyond race and socioeconomic status and guessing that can give clear guidance as to when a head-injured child should be evaluated for abuse.

Dr. McCarroll: As I understand the background

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One type of clinical prediction rule is based on statistical estimates of probability. Every finding, every test result, every lab result has a predictive value. For every test you can imagine, every finding, you can measure its predictive contribution as positive or negative.

of your research, it is based on the fact that there are a lot of cases of AHT coming into pediatric PICUs that are missed. Your research is directed toward providing physicians with decision rules to help guide deciding whether to perform an extensive evaluation of a head-injured child for abuse and whether to subsequently report them for child physical abuse. You have developed two clinical prediction rules. Would you explain those?

Dr. Hymel: The purpose of the first rule is to identify which acutely head-injured children presenting to intensive care settings should be evaluated immediately for AHT. This is a four-variable rule that informs doctors that an abuse evaluation should be performed if any one of four variables is positive during the initial examination (see fuller discussion of four-variable rule below and “Abusive Head Trauma in Young Children: Definition, Clinical Findings, Mechanism of Injury, and Outcomes” summary in this edition of JFJF). The second rule is for doctors to use after the abuse evaluation has been completed to inform their decision to confirm, exclude and/or report suspected child abusive head trauma — child abuse. The latter rule (the PediBIRN-7) estimates the probability that a head-injured child was physically abused based on seven variables that were evaluated.

Dr. McCarroll: How did you become interested in this research?

Dr. Hymel: My interest began one day when I was in training to become a child abuse pediatrician. My mentor, Dr. Carole Jenny, walked into the conference room in the clinic where we were seeing patients and she threw a stack of records down on the table. She said that the medical system screwed this child. The child almost certainly had suffered abusive head trauma at the age of four months. Now the child was being seen again at 11 months old for a new injury with multiple new and healing fractures. No one diagnosed abusive head trauma. Right then and there she decided that we were going to do a study of missed cases of abuse. She invited me to help. (See Jenny, Hymel, Ritzen, Reinert, & Hay, 1999.)

The case that Dr. Jenny presented never left me. For years I thought about how we could lessen the number of missed cases and improve the accuracy of doctors’ decisions to workup or not workup head injured kids for abuse. I had a conversation with another doctor who asked me about my research. When I told him what I

wished I could do, he said, “You need a clinical prediction rule.” One type of clinical prediction rule is based on statistical estimates of probability. Every finding, every test result, every lab result has a predictive value. For every test you can imagine, every finding, you can measure its predictive contribution as positive or negative. Some tests end up being most useful when they are part of a *screening* tool because they cast a broad net. In other words, a high percentage of the kids with the diagnosis will have that finding. Other results are more useful to be included in *diagnostic* tests because they are *only* positive when you have that diagnosis. We captured data from both laboratory tests and radiological findings that we thought might be useful in making a diagnosis and, more specifically, might contribute to a screening tool. My goal was not to miss cases. We captured the data across 14 sites where children were evaluated for AHT and identified which variables were reliable. To create a screening tool, I only need to consider variables that are available at the time of hospital admission in order to inform doctors’ early decision of whether or not to launch an abuse evaluation. Based on our analyses, we discovered that four variables were pretty darn good at identifying which children needed a thorough workup for abuse. These four variables were (1) bleeding overlying the brain (subdural hematoma), (2) respiratory compromise before hospital admission, (3) any bruising of the torso, ears, or neck (4) and a complex skull fracture (Hymel et al., 2014). We found that 96% of the cases later categorized as abuse based had one or more of those four predictor variables. Our clinical rule then became a *directive* rule: If your patient with closed head trauma under the age of three is admitted and presents with any one or more of these four things, you should consider them higher risk and we recommend a thorough workup.

Dr. McCarroll: Your research has been conducted with investigators in the Pediatric Brain Injury Research Network (PediBIRN), a group in which 18 pediatric sites around the United States and Canada have participated. Can you lead us through your thinking on the development of the clinical prediction and clinical decision rules and then tell us where your research is now?

Dr. Hymel: Yes. Whenever a clinical prediction rule is developed there is an expected trajectory of research. You first have to do a

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Abusive Head Trauma in Young Children: Definition, Clinical Findings, Mechanisms of Injury, and Outcomes

By James E. McCarroll, PhD, Joshua C. Morganstein, MD, Ronald J. Whalen, PhD and Robert J. Ursano, MD

The youngest infants (under six months) are the most vulnerable as AHT is commonly triggered by infant crying. Parents may also shake children under two years of age as a method of discipline.

Background. Caffey was the first to use the term “whiplash shaken infant syndrome” (Caffey, 1974). Shaken baby syndrome (SBS) has, since Caffey, been the term used in medical literature and in popular publications. It has also been the term used in prevention programs (see Websites of Interest). The American Academy of Pediatrics (AAP) has proposed to change the terminology from SBS to abusive head trauma (AHT), away from the mechanism of injury (shaking) and toward the clinical findings (head trauma) (Christian & Block, 2009). SBS is still a recognized diagnosis (S. K. Narang, Estrada, Greenberg, & Lindberg, 2016; Strouse, 2018). SBS is a useful concept for medical and social service providers to educate children’s caregivers about the importance of never shaking an infant. However, shaking frequently includes other injuries. In addition to shaking, which produces an injury due to rotation of the head, brain, eyes, and spine, there are other injury mechanisms including injuries from slamming, striking with an object, throwing, and crush forces (Greeley, 2015).

Definition and Costs. The AAP definition of AHT is any injury intentionally inflicted on the head or brain of a child (Christian & Block, 2009). Regardless of severity, the medical, surgical, and social costs of AHT of children can be enormous. More than 40% of children with AHT are severely injured. It is estimated that one in 14 cases admitted for severe AHT will die before hospital discharge. Children who survive AHT will have health care costs that can last for their lifetime. Even those with a mild case have an estimated loss of 15.5% of their health-related quality of life and a cost of over \$1million. (Quality of life costs include lost work time and costs associated with personal care.) Costs for those with severe AHT can exceed \$3 million (Miller et al., 2018).

Incidence. A recent extensive review of infant and child head trauma described its incidence, clinical findings, secondary injuries, and outcomes (Greeley, 2015). The youngest infants (under six months) are the most vulnerable as

AHT is commonly triggered by infant crying. Parents may also shake children under two years of age as a method of discipline. Male children are slightly more likely to be abused with fathers being the most common perpetrators, followed by boyfriends and female babysitters. There are many difficulties in estimating the incidence of AHT: abused infants may not be taken for medical care; medical providers may not recognize AHT as symptoms can be misinterpreted in young children; there are disagreements among doctors about whether to and how to evaluate symptoms; and caregivers may avoid giving an accurate history of the child’s injuries.

Clinical Findings. The clinical picture most often seen includes injuries to the skull and central nervous system and subdural hematoma (bleeding overlying the brain). There can also be bruising and swelling of the skin, long bone and rib fractures, injuries to the neck, and bleeding in the eye and the retinal nerve. Symptoms and signs of the injury usually appear in seconds or minutes and can include vomiting, altered mental status, seizures, and apnea (disturbance or stoppage of breathing) (Greeley, 2015).

Evaluation and Mechanisms of Injury. The clinical findings are most informative when they occur in combination. The combination of clinical findings and their association with AHT is at the core of Dr. Hymel’s research. Dr. Hymel’s clinical approach for physicians to use to evaluate AHT indicates that AHT should be evaluated in a child presenting for medical care when any one of the following is observed: subdural hematoma, retinal bleeding, respiratory compromise before hospital admission, or any bruising of the torso, ears, or neck (Hymel et al., 2014). Two mechanisms of axonal injury have been described. In the first, there is immediate traumatic injury. The main mechanism of damage to the brain is immediate physical injury to the nerves (Fitzpatrick, Maxwell, & Graham, 1998). The second mechanism consists of delayed effects of nerve damage (Adams, Graham,

Shaking can produce an injury due to rotation of the head, brain, eyes, and spine. Other possible injuries can result from slamming, striking with an object, throwing, and crush forces.

S., & Scott, 1982). These delayed effects can result in brain swelling, decreased blood flow, and hypoxia, all of which may contribute to neuronal death. (Greeley, 2015).

Outcomes. AHT is a common cause of death from child traumatic maltreatment accounting for 80% of all deaths from non-accidental trauma (Paul & Adamo, 2014) and an estimated incidence of 16 to 33 cases per 100,000 children per year in the first 2 years of life (Narang & Clarke, 2014). Estimates are that 8-25% of victims of AHT die from their injuries and that the survivors typically have severe disabilities. A Canadian study of 364 cases of shaken baby syndrome reported to pediatric tertiary care hospitals in 1988-1998 found about 60% had a moderate or greater degree of disability of neurologic function, 65% had visual impairment, and 12% were in a permanent vegetative state. Only 7% were reported to have normal neurologic function. The median age of child victims was 4.6 months; 56% were boys (King, MacKay, & Sirnick, 2003). A prospective study of 56 cases in Switzerland from 2002-2007 found that 64% of AHT victims were disabled and 36% had a good outcome after 13 months. The preponderance of victims were males (63%) and the median age was 4 months (Fanconi & Lips, 2010).

Conclusions. Authors from a variety of medical fields have emphasized the enormous effects of AHT on children, families and other caregivers, medical providers, and even the legal systems, which have to judge the circumstances of these injuries to children. The diagnosis of AHT can be a difficult clinical decision. The clinical presentation includes diverse findings that may be non-specific or even unnoticed. It is the presence of one or more specific clinical findings in head-injured children that should lead to a complete evaluation (Hymel et al., 2014) and a later decision based on clinical findings about whether the trauma to head-injured children is due to child abuse (Hymel et al., 2019).

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Prevention of Abusive Head Trauma in Infants

By James E. McCarroll, PhD, Joshua C. Morganstein, MD, Ronald J. Whalen, PhD and Robert J. Ursano, MD

Most AHT is due to parents' or caregivers' responses to prolonged, unsoothable infant crying during the first months of life. The infant's crying can be interpreted as something wrong with the infant rather than recognizing it as part of normal development.

Abusive head trauma (AHT) is a form of child abuse that is a significant cause of child death and disability. About two-thirds of 1,374 child maltreatment fatalities in children under age five that were reported to the National Violence Death Reporting System (NVDRS), 2003-2006, were due to AHT (Klevens & Leeb, 2010). Homicide was the second leading cause of violence-related injury deaths for children under one year of age and the third leading cause for children 1-4 in the U.S. in 2017 https://www.cdc.gov/injury/images/lc-charts/leading_causes_of_death_by_age_group_violence_2017_1100w850h.jpg. These reports are known to be underestimates (Klevens & Leeb, 2010; Reese, Heiden, Kim, & Yang, 2014). Of the head-injured children that survive their abuse, most are likely to suffer temporary or permanent disability (Fanconi & Lips, 2010; King et al., 2003).

Most AHT is due to parents' or caregivers' responses to prolonged, unsoothable infant crying during the first months of life (Barr, Rajabali, Aragon, Colbourne, & Brant, 2015; Barr, Trent, & Cross, 2006). In addition to caregiver frustration, the infant's crying can be interpreted as something wrong with the infant rather than recognizing it as part of normal development (Barr, 2012). Given the seriousness of AHT, many preventive programs have been put into effect and evaluated. In a review of 35 articles on AHT prevention, three categories of AHT-prevention initiatives were found: (1) efforts to reduce infant crying in the first few months of life, (2) emotional regulation strategies for caregivers, and (3) raising awareness of AHT (Lopes & Williams, 2018). The conclusion of this review was that raising awareness by educating parents and caregivers on the pattern of infant crying and the risks of shaking a baby was the best strategy. Educational strategies have lower costs and ease of implementation compared to reducing infant crying and emotional regulation strategies. Attempts to reduce infant crying and emotional regulation strategies require longer intervention times and specialized training of health professionals, both of which are impractical for large-scale application.

The prevention of AHT is an excellent target for primary prevention: (1) the outcomes

are severe and financially costly, (2) AHT has clear risk behavior (shaking) and a stimulus (crying), and (3) evidence is emerging that it is preventable. In addition, it needs to be primary (delivered before AHT occurs). It also needs to be universal in that all new parents should receive training. Furthermore, messaging and training should be attractive, consistent, meaningful, and positive for many different cultures. It should be delivered to all parents of newborns, not just "at risk" parents and caregivers since AHT can occur in the absence of risk factors (Barr, 2012).

An SBS prevention program that has received extensive worldwide application and evaluation is the Period of Purple Crying (see Websites of Interest). There are many reasons why babies cry, but this program refers to the crying that is specifically associated with colic. The causes are unknown, but it is a normal phase of child development. Three steps are suggested to deal with infant crying: 1) holding and walking with the baby, (2) placing the baby in a safe place and walking away for a few minutes, and (3) never shaking or harming the baby (Lopes & Williams, 2018). A randomized trial of educational materials designed to change behavior and increase knowledge regarding crying and SBS found significant increases in knowledge regarding infant crying patterns, risks of shaking an infant, and sharing information with other caregivers about the importance of walking away when frustrated with the crying. However, this study was not sufficiently large to test whether the Period of Purple intervention prevents SBS (Barr et al., 2009). It is also important to inform transient caregivers such as baby sitters, parents' partners, and other family members about infant crying. Transient caregivers may interpret crying as a failure on their part to provide good care and may resort to shaking to stop it (Barr, 2012)

An evaluation of the Period of Purple Crying was conducted in five birthing hospitals in a Midwest city in 2011 as part of a state-wide mandate to provide voluntary AHT prevention programs to caregivers of infants and young children (Reese et al., 2014). The program was delivered in person by nurses to 211 mothers prior to discharge. The program was evaluated

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Prevention of Abusive Head Trauma in Infants, from page 7

Three steps to deal with infant crying are: (1) holding and walking with the baby, (2) placing the baby in a safe place and walking away for a few minutes, and (3) never shaking or harming the baby.

in a non-experimental post-only design after the program was delivered in the hospital and followed up two months later. The study measures included attitudes about the education session and AHT, knowledge about crying and shaking a baby, techniques for coping with infant crying, and intent to share the information with another care provider. Nurses reported feeling comfortable delivering the program. Seventy-six percent of the mothers rated the program as very useful. However, despite the high ratings of the program, only 41% of mothers shared the content with their infant's other care providers. One of the reasons given for this were that the mothers thought there was a low perceived risk for shaking by their children's caregivers. However, the majority of AHT-perpetrators are not mothers. In a review of 459 AHT-injured children, 53% were fathers, 22% were parent partner, 8% were mothers, 8% were baby-sitters, and 5% were another adult caregiver (Scribano, Makoroff, Feldman, & Berger, 2013). In a study of 34 perpetrators of AHT, males were younger than females (27 and 34, respectively), and victims of males had more severe acute presentations, neurosurgical interventions, and worse clinical outcomes (Esernio-Jenssen, Tai, & Kodsi, 2011).

Other evaluations of the effects of providing information to new mothers have reported decreases in the incidence of AHT. A program in western New York State provided a parental education program delivered by nurses about violent infant shaking. The result was a 47% decrease (from 41.5 cases per 100,000 to 22.2/100,000) in the incidence of AHT during a 5.5-year study period, 1998-2004 (Dias et al., 2005). Another parent educational SBS prevention program also delivered by nurses was conducted in New York State, 2005-2008, found a 75% reduction in infants treated for shaking injuries, from 14 cases in five years to 2 cases in three years (Altman et al., 2011).

Most AHT prevention programs aimed at increasing new mothers' knowledge about infant crying and the risks of shaking occur in hospital. In a German population-based study of AHT knowledge, a large majority stated that they thought AHT education should occur before birth (Berthold et al., 2019). Education of new parents prior to birth might be easier for them to incorporate into learning to be parents when they are not distracted or otherwise occupied learning to care for an infant. It also gives a better opportunity for additional sessions after a child's birth. There are additional

procedures that are simple and easy to implement following the initial briefing of the new mother (and father, hopefully). Among these are text message reminders, home visits, and follow-up phone calls.

In addition to educating parents and caregivers about infant crying and the risks of shaking, another factor to consider to help those who are frustrated with the challenges of consoling a crying infant is the potential for disturbance of the parent-infant relationship. Parents who are unable to console their infants may feel rejected, that they are not good parents, and cannot cope with parenthood. A review of the impact of crying on this relationship emphasized the importance of programs, such as home visiting and social and medical services, to help parents with challenges of infant crying during this early period. Failure of parents to meet these challenges can result in diminishing the parents' enjoyment of the early weeks and months of their child's life that may be remembered with a sense of loss and regret and decrease parent-infant bonding, which has implications for future child development (Oldbury & Adams, 2015).

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BUILDING BRIDGES TO RESEARCH

Sensitivity and Specificity: Two Statistical Measures Used in Tests Screening for Disease

By James E. McCarroll, PhD, Joshua C. Morganstein, MD, Ronald J. Whalen, PhD and Robert J. Ursano, MD

Screening is a procedure in medical practice to identify people with a disease or condition so that they may be brought to treatment.

Screening. Screening is a procedure in medical practice to identify people with a disease or condition so that they may be brought to treatment. Screening aims to separate people into those who have the condition and those who do not. Ideally, a screening test would give perfect results in achieving this separation, but tests are rarely this precise. Screening results are typically a probability statement, usually expressed as a percent.

Sensitivity and Specificity. The ability of a test to correctly identify people with the condition is known as its sensitivity. A perfect test should also identify people who do not have the condition. This is known as the specificity of the test. Calculating sensitivity and specificity requires knowledge of (1) those persons who are correctly identified as having or not having the condition (true positives and true negatives) and (2) those persons who are incorrectly identified as having and not having the condition (false positives and false negatives). The table below shows the relationships of these measures.

Sensitivity. For an imaginary screening test, if the sensitivity were 95%, the test would correctly identify 95% of patients with the condition, but would miss 5% who have the condition. A highly sensitive test casts a broad net in order to minimize missed cases (false negatives). Good screening tests have high sensitivity.

Specificity. Again, for an imaginary screening test, if specificity were 95%, the test would correctly identify those without the condition, but would fail to identify 5% who had the condition. A highly specific test casts a net with precise aim, to minimize those who do not have the condition, but are incorrectly identified as positive (false positives). Good screening tests have high specificity.

Screening tests are not diagnostic. Once a person has been identified as having a high probability of having the condition, then doctors will apply a good diagnostic test to confirm the symptoms of the condition.

Relationships between Condition and Test Results

	Persons with the Condition	Persons Without the Condition
Positive Test Result	True Positives Persons with condition and test positive	False Positives Persons without condition but test positive
Negative Test Result	False Negatives Persons with condition, but test negative	True Negatives Persons without condition and test negative

Sensitivity equals

$$\frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$$

Specificity equals

$$\frac{\text{True Negatives}}{\text{True Negatives} + \text{False Positives}}$$

In summary, what we are trying to do is use evidence to inform two key decisions that doctors have to make in these cases — “Do I work them up?” and then later, “Do I diagnose and report?”

multicenter study to measure the predictive properties of the variables and find out what combination works best to accomplish your goal, which in this case is to develop a screen. You call that a *derivation* study; you are deriving the rule (Hymel et al., 2013). Second, you then have to complete a second multicenter study and demonstrate that in an equivalent patient population, that it performs just as well as you said it would in the first study. You are validating its performance and so we call that a *validation* study. We completed the validation study (Hymel et al., 2014). The third expected step in the development of a clinical prediction rule is called the *implementation* or *impact study*, which is currently underway. We are now for the first time trying to get doctors to apply the screen in PICU settings. We have four PICU sites where we are deploying these strategies and working to get doctors to use the screening tool and follow its recommendations. We also have four matched sites where the doctors are practicing screening and making decisions to workup or not workup children in their usual way without the screen rules. We are hoping that doctors at our intervention sites will apply the criteria significantly more frequently than the doctors at the control sites. If they do that, we may be able to demonstrate that the tool has a positive impact on patients. If that is accomplished, we expect to see a lower frequency of what we call missed cases.

Let's move on to the next step: the clinical *prediction* rule research. Whereas the purpose of the four-variable rule was to inform and direct doctors to work up a head-injured child for abuse, the second rule was developed to allow doctors to predict the probability that the child's injuries were due to abuse. This second rule has seven variables. The seven included the same four variables that we used to make the rule to inform doctors to perform the evaluation for AHT. We then added three additional variables. These are (1) a retinal exam (by an ophthalmologist) of the photoreceptor layers in the back of the eye to look for retinal hemorrhages; (2) a skeletal survey to look for associated fractures; and (3) any brain hypoxia, ischemia, or swelling hypoxia/ischemia of the brain. This third variable the supply of oxygen to the brain was inhibited or cut off by the abuse.

The seven variables did the trick. The real surprise for me was that the four variables that were included in the original screening tool ended up included in the seven-variable rule.

This adds a significant level of simplicity to the whole process. So now, if you think of the timeline of a child's hospitalization, doctors can apply the screening rule at the time of admission using just four variables to decide if they should do a workup. They then wait a while and get back the results of the tests performed as part of the evaluation and then they apply the seven-variable rule to inform their decision, “Ok, now do I diagnose or report based on these results?” In summary, what we are trying to do is use evidence to inform two key decisions that doctors have to make in these cases — “Do I work them up?” and then later, “Do I diagnose and report?” You could describe the screening tool as a more *directive* decision rule. It's directing behavior. It is saying, work him up if you have one or more. The seven-variable rule is a prediction tool. It is giving you an estimate of the probability in order to *inform* rather than *direct* their decision to diagnose or report.

Dr. McCarroll: That is very interesting.

Dr. Hymel: The beauty of it is that it can all be made simple because it is manageable with a hand-held phone app. At the intervention sites the doctors have access to the prediction tools. If they ask the question, “Which of those variables are present?” it gives them a number, an estimate of probability.

Dr. Whalen: You talked about the ongoing impact study. Will you be able to go back and look at the clinical decision-making on the missed cases?

Dr. Hymel: Yes. These results are preliminary, but it turns out that there are site-specific, physician-specific, and patient-specific variables that appear to be impacting decisions by doctors whether to apply the screening tool and follow its recommendations or not. The preliminary look at the data suggests that smaller sites are adopting it more readily than larger sites. Perhaps that is because at the large sites there are more physicians and therefore each of them has fewer opportunities to consider applying it to a patient. The larger sites are a bigger challenge, a more diverse physician population. What I am learning now is that change comes slowly. But, we are only in the beginning of the third year of a five-year study.

Dr. McCarroll: Thank you for the interview and for your research. We will certainly inform our audience of some of the many complexities of AHT and AHT research.

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Dr. Hymel: Thank you for your interest in this research.

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Websites of Interest

A Center for Disease Control and Prevention (CDC) website describes abusive head trauma (AHT). It includes definitions of AHT as well as ICD-9 and ICD-10 codes diagnosing non-fatal and fatal AHT. This document can be helpful for emergency room physicians as well as researchers.
<https://www.cdc.gov/violenceprevention/pdf/pedheadtrauma-a.pdf>

This American Academy of Pediatrics (AAP) website gives background information on AHT for reporters. It includes facts about AHT and emphasizes prevention, the validity of the diagnosis, and supporting medical references about these issues.
<https://www.aap.org/en-us/about-the-aap/aap-press-room/aap-press-room-media-center/Pages/Abusive-Head-Trauma-Fact-Sheet.aspx>

Another and more extensive AAP document entitled “Understanding Abusive Head Trauma in Infants and Children” gives extensive descriptions of what is AHT, how it is identified, and a discussion and refutation of the argument that the diagnoses of AHT and Shaken Baby Syndrome (SBS) are not valid. It is important that readers understand that AHT/SBS is a valid and well supported medical diagnosis.
https://www.aap.org/en-us/Documents/cocan_understanding_aht_in_infants_children.pdf

The National Center on SBS website gives extensive data on SBS including statistics on its incidence, costs, and outcomes. It includes statements of consensus from major international health organizations on the diagnosis and impact of SBS/AHT on children. It also contains an extensive reference list on SBS and AHT.
<https://www.dontshake.org/learn-more/itemlist/category/13-facts-info>

Period of Purple Crying website contains information about the program that helps parents understand that crying by an infant is usually a normal part of their development. In addition to other resources, it includes a video featuring Dr. Ronald Barr who describes program and the importance of preventing AHT/SBS.
<http://www.purplecrying.info/what-is-the-period-of-purple-crying.php>

The Pediatric Brain Injury Research Network (PediBIRN) is a research consortium that has included 18 hospitals in which pediatricians have contributed to the research. Dr. Hymel is the founder, principal investigator, and director of this project. The PediBIRN website describes the ongoing study to implement the clinical decision tool (CDR) for estimates of the probability of abusive head trauma. The website contains a video by Dr. Hymel in which he explains the PediBIRN project. For pediatricians who join the research, the website has data forms that physicians can use to input data to the study as well as the AHT probability calculator that physicians are urged to use in evaluating head-injured children for the probability of abuse.
<http://www.pedibirn.com/>

A CDC website Preventing Abusive Head Trauma in Children gives facts about AHT as well as addition resources including a 52-page manual for preventing child abuse and neglect.
<http://www.cdc.gov/violenceprevention/childabuseandneglect/Abusive-Head-Trauma.html>

