CHILD ABUSE OR ACCIDENT? BRINGING SCIENCE TO PEDIATRIC EMERGENCY DEPARTMENTS AND FORENSIC INVESTIGATIONS

BY **JIM DAWSON**

NIJ-funded researchers are developing a probability model to predict child head injuries in falls.

For physician Mary Clyde Pierce, it was a question asked in her first days as a pediatrician that "triggered the fire" in her. A detective working a case of an abused baby boy asked her how much force it would take to cause the bone fracture the infant had suffered.

"I couldn't answer it," said Pierce, now a professor of pediatrics at Northwestern University and an emergency medicine pediatrician at Lurie Children's Hospital of Chicago. "I thought it was just a hole in my medical education, so I started to read, and I couldn't find any answers."

She also became aware that while she was at the bedsides of injured and dying child abuse victims, other medical personnel were shying away from her. "They would just stick their heads in the sand because it is too ugly to deal with," she said. "That made me determined to change this story."

In one of the "ugly" cases she was handling, Pierce turned to Gina Bertocci, a professor of bioengineering at the University of Louisville, and asked a question similar to the one the detective had asked her. Bertocci remembers the call, and the question. "She contacted me to see if I could help her answer the question of how much force it would take for someone to fracture a child's femur," Bertocci said. That question, asked 23 years ago, "was the foundational question of our collaboration," she said. Together they established the Injury Risk Assessment and Prevention (iRAP) Laboratory at the University of Louisville.

The researchers' overarching goal has remained the same for more than two decades: using science to differentiate between abuse and accidental trauma in children.

The pediatrician and the bioengineer have been working together ever since, supported in part by a series of research grants from the National Institute of Justice (NIJ) dating back to a 2008 project to develop a system for detecting tell-tale bruising in infants.[1] Then there was their research into classic metaphyseal lesions, a fracture type commonly associated with abuse in infants,[2] and more recently, the biomechanical characterization of short-distance falls in children.[3] Currently Bertocci and Pierce, with mechanical engineers Angela Thompson and Raymond Dsouza of the iRAP Laboratory, are developing an injury risk curve that will help predict the likelihood of head injuries in pediatric falls.

Understanding Injuries

The need for their work is reflected in the high number of children brought into emergency departments in the United States each year and the difficulty doctors and nurses face in sorting the accidents from the abuse cases. As Bertocci and Pierce noted in a description of their current head injuries project, approximately 2.8 million children are brought to emergency departments for fall-related injuries annually.[4] "Although injuries from accidental falls in children are common," they wrote, the "history of a fall is the most commonly stated false scenario provided by caregivers to conceal physical abuse."[5]

Like the overall accident numbers, those that define the scope of the abuse problem are daunting. About 3.5 million children were reported to social services for abuse and neglect in 2017, and 670,000 of them were eventually identified as victims of child abuse.[6] Of those abuse victims, 1,720 died, making child abuse the leading cause of trauma-related deaths in children (see sidebar, "NIJ's Investment in Research on Pediatric Cause of Death"). More than 70% of the fatalities were younger than 3 years old.

The researchers' overarching goal has remained the same for more than two decades: using science to differentiate between abuse and accidental trauma. That differentiation "challenges clinicians, social workers, law enforcement personnel, biomechanics experts, and the judicial system on a daily basis," the researchers wrote.[7] By bringing the science of biomechanics to the world of pediatric medical assessment, Bertocci and Pierce are attempting to meet that challenge.

For the biomechanics experts, a key challenge is the lack of data on injury thresholds in children. The data that do exist, and that are often used in courts, come primarily from experiments that are based on primates and adults, then extrapolated to very young children. "Injury thresholds are largely based on scaled human adult thresholds and/or primate models," the researchers wrote. "Using head injury thresholds that are scaled from adults or primates can lead to inaccurate conclusions regarding whether or not a fall can generate serious or fatal head injury in a child. Since biomechanical analysis is a critical component in cases involving a fall history, these inaccuracies may translate into failure to prosecute a guilty perpetrator or failure to acquit an innocent suspect."[8]

Bertocci said her goal is to bring the concept of determining biomechanical compatibility between the stated history and the presenting injuries to the forensic assessment. "This allows more objective evaluation of children to determine if injuries are due to accident or abuse."

Predicting Head Injuries

After years of gathering data on the dynamics of children falling, as well as bruising and fracture patterns, the researchers are focusing on developing a probability model to predict head injuries in falls. Their work aims to describe which head injuries are characteristic of various types of pediatric falls.

NIJ's Investment in Research on Pediatric Cause of Death

By **Danielle McLeod-Henning**

Research into the cause and manner of death in infants and children has been a high-priority research need of NIJ's Forensic Science Research and Development Technology Working Group.[1] NIJ has invested more than $9.7 million in research to further understand and determine intentional versus accidental trauma, or natural nontraumatic causes of death in infants and children. NIJ's first investment in this area was in 2007, with an award to Michigan State University titled "A Forensic Pathology Tool To Predict Pediatric Skull Fracture Patterns."[2] Since then, NIJ has made nearly 20 awards to academic institutions and medical examiners' offices, with studies focusing on finite element modeling of skull fractures, using advanced imaging technologies to capture minute injuries from suspected head trauma, and testing genetic markers that may lead to a sudden unexpected death, among other studies.[3]

About the Author

Danielle McLeod-Henning, M.F.S., is a program manager and physical scientist in NIJ's Office of Investigative and Forensic Sciences.

Notes

1. National Institute of Justice, "Forensic Science Research and Development Technology Working Group: Operational Requirements," https://nij.ojp.gov/topics/articles/forensic-science-research-and-development-technology-working-group-operational.

2. Brian J. Powell et al., "A Forensic Pathology Tool To Predict Pediatric Skull Fracture Patterns," Final report to the National Institute of Justice, award number 2007-DN-BX-K196, December 2012, NCJ 240683, https://www.ncjrs.gov/pdffiles1/nij/grants/240683.pdf.

3. National Institute of Justice, "Awards: Listing of Funded Projects," https://nij.ojp.gov/funding/awards/list?field_award_status_value=All&state=All&subtopic=12901,11361&field_fiscal_year_value=&combine_awards=&awardee=&city=&sort_by=field_fiscal_year_value&sort_order=DESC.

They began that research with a 2017 NIJ grant that involved using instrumented headbands on children in childcare centers and observing their activities using video surveillance.[9] Over many months, they recorded data on more than 3,000 falls. About a third of the falls were on playgrounds, while the others were indoors.[10] The researchers are currently analyzing the data from these falls and plan to create a website that includes a searchable repository of video-recorded falls based on their childcare center study.

The study measured such things as the dynamics of the falls (forward, rearward, feet- or head-first) and what part of the body made first impact (e.g., head, shoulder, hands). For falls that involved the head, the researchers then looked at which part of the head was impacted. For almost 40% of the falls, it was the face, with a slightly smaller percentage involving the occipital bone at the back of the head.[11] They also measured the height of each fall and cross-referenced the findings with the age and weight of the children.

Their key finding was that "across 3,256 falls, no children sustained moderate or severe head injuries."[12] Indeed, in all of the falls there were no serious injuries to any part of the body, they said. The researchers noted that the majority of the falls in the childcare center were ground-based falls occurring in a forward direction without head impact. This large collection of video-recorded falls is critical to understanding that common short-distance falls typically do not cause serious injuries in children.

As part of their effort to develop a probability model, the researchers are categorizing the injuries that are likely from a variety of falls, including information on head acceleration, force, and of critical importance, the height of the fall. "It's not as simple as saying a whole category of falls cause significant injury," said Thompson, an associate professor of engineering fundamentals at the University of Louisville. "As engineers, we really want to understand how children are injured based on what they fall into [such as the corner of a table], what type of surface they fall onto, and if they are running or are pushed by another child."

Their probability model will combine video fall data from the childcare center with data gathered from children brought into the Lurie Children's Hospital Emergency Department with head injuries resulting from falls. The hospital study will involve about 95 children injured in accidental falls; working with the parents or other caregivers, the research team will reconstruct the events surrounding each fall using computer simulation. The researchers will conduct virtual interviews with the caregivers to ensure accurate descriptions of the falls and will aid caregivers in collecting in-home measurements of fall heights when applicable.

Although the emergency department injury portion of the research was on hold as of July 2020 because of COVID-19 issues, Pierce said she was not concerned about recruiting parents to report the details of how injuries to their children occurred. "Parents actually love to be in these studies," she said. "It's so different than it was 20 years ago, probably because of Google and the ability of people to understand research so much better than they used to."

Bruising, a Tell-Tale Sign

In addition to the video data and injury information from a hospital, the probability model will include 3D human child computer models. Thompson and Dsouza, working with Bertocci, will create virtual models of 18- and 36-month-old children that will be used in simulating falls and measuring associated biomechanical data such as head acceleration.

The team has developed and validated numerous 3D computer models simulating pediatric falls and other injurious events. One model developed by Dsouza allows them to predict potential bruising patterns in children, whether from abuse or an accident. "Bruising is the earliest sign of physical abuse," the researchers wrote.[13] The custom 3D model incorporates 132 virtual sensors to enable the prediction of bruising patterns and level of force applied.

The bruising model is important, Pierce said in an interview, because her research has shown that "the most common thing that is misinterpreted prior to a child having a more serious injury, like a fracture or brain injury, is just bruising." In addition to being a warning sign of the early stages of abuse, bruising combined with other injuries can point to abuse. "We are used to bruises not being serious, so if you have, for example, an ear bruise and a fracture, nobody notices the ear bruise. But that is the tell-tale sign. That is the actual difference between an accidental injury and abuse," she said.

Pierce explained that a small bruise on an ear could indicate that a child was struck on the side of the head. "If you're struck on the side of the head generating an ear bruise and you fly across the room, versus just running and you fall and don't have an ear bruise. It is putting the combination of injuries together that is important. You don't think anything about it because bruises are boring and as a physician you don't have to do anything to a bruise."

Many times in her career, she has talked to experienced physicians who said they examined a child and did not find any bruises, Pierce said. However, when she examines the same child, she may find a dozen bruises that the other doctor missed. "Maybe there is one on the ear, or inside the mouth. It's interesting to teach people to think about the little details that we've been taught don't matter, so it's really a big shift in thinking, and that's why I started collaborating with engineers."

Pierce and Bertocci are developing an app for medical personnel that helps them find bruises in children, as well as other tools to allow them to evaluate injuries more objectively and to answer the fundamental question the detective asked Pierce years ago: Was the infant's bone fracture caused by an accident or abuse?

"That's why I'm so passionate about developing a more science-based way to understand whether a caregiver's history [regarding the cause of injury] is plausible given presenting injuries," she said. "That's where implicit bias can really play a role, and it has to do with how to conduct a good physical exam and pay attention to the marks on the body or understand the fracture biomechanics. But physicians are not trained in this, so we're trying to develop tools that can help them think in a more sophisticated way."

The researchers are optimistic that they can develop tools to help physicians delineate injuries due to physical child abuse versus those due to accidents. "There is a whole area of implementation science," Pierce said, "and once we have the tools ready, we'll start doing implementation studies, which is the best way to affect clinical practice."

The research underscores the critical importance of multidisciplinary collaborative science, they noted — building a multidisciplinary team of engineers and physicians has advanced the understanding of pediatric injuries and how they occur, through objective science. Their research, Bertocci said, has the potential to influence clinical and forensic investigations in distinguishing between accidental and abusive causes of pediatric injuries.

About the Author

Jim Dawson is a forensic science writer and contractor with Leidos supporting the National Institute of Justice.

This article discusses the following awards:

- "Development of a Surrogate Bruising Detection System To Describe Bruising Patterns Associated with Common Childhood Falls," award number 2008-DD-BX-K311
- "Development of Scientific and Objective Methods To Detect Physical Child Abuse," award number 2009-DD-BX-0086
- "Utility of Postmortem X-Ray Computed Tomography (CT) in Supplanting or Supplementing Medicolegal Autopsies," award number 2010-DN-BX-K205
- Development of a Computer Simulation Model To Predict Potential Bruising Patterns Associated With Common Childhood Falls," award number 2014-DN-BX-K006
- "Biomechanical Investigation of the Effect of Bone Disorders on Pediatric Femur Fracture Potential," award number 2015-DN-BX-K018
- "Biomechanical Characterization of Video Recorded Short Distance Falls in Children," award number 2017-DN-BX-0158
- "Development of a Probability Model To Predict Head Injury Risk in Pediatric Falls," award number 2019-DU-BX-0029

Notes

1. Gina Bertocci and Raymond Dsouza, "Development of a Surrogate Bruising Detection System To Describe Bruising Patterns Associated With Common Childhood Falls," Final report to the National Institute of Justice, award number 2008-DD-BX-K311, April 2013, NCJ 242018, https://www.ncjrs.gov/pdffiles1/nij/grants/242018.pdf.
2. Office of Juvenile Justice and Delinquency Prevention funding award description, "Development of Scientific and Objective Methods To Detect Physical Child Abuse," at the University of Louisville Research Foundation, award number 2009-DD-BX-0086, https://ojjdp.ojp.gov/funding/awards/2009-dd-bx-0086.
3. National Institute of Justice funding award description, "Biomechanical Characterization of Video Recorded Short Distance Falls in Children," at the University of Louisville Research Foundation, award number 2017-DN-BX-0158, https://nij.ojp.gov/funding/awards/2017-dn-bx-0158. Additional related NIJ awards are "Development of a

Computer Simulation Model To Predict Potential Bruising Patterns Associated With Common Childhood Falls," at the University of Louisville Research Foundation, award number 2014-DN-BX-K006, https://nij.ojp.gov/funding/awards/2014-dn-bx-k006; "Biomechanical Investigation of the Effect of Bone Disorders on Pediatric Femur Fracture Potential," at the University of Louisville Research Foundation, award number 2015-DN-BX-K018, https://nij.ojp.gov/funding/awards/2015-dn-bx-k018; and "Development of a Probability Model To Predict Head Injury Risk in Pediatric Falls," at the University of Louisville Research Foundation, award number 2019-DU-BX-0029, https://nij.ojp.gov/funding/awards/2019-du-bx-0029.

4. National Institute of Justice funding award description, "Development of a Probability Model To Predict Head Injury Risk in Pediatric Falls."
5. National Institute of Justice funding award description, "Development of a Probability Model To Predict Head Injury Risk in Pediatric Falls."
6. All data in this paragraph are from Children's Bureau, Administration on Children, Youth and Families, *Child Maltreatment 2017,* Washington, DC: U.S. Department of Health and Human Services, Administration for Children and Families, January 2019, https://www.acf.hhs.gov/cb/resource/child-maltreatment-2017.
7. National Institute of Justice funding award description, "Development of a Probability Model To Predict Head Injury Risk in Pediatric Falls."
8. National Institute of Justice funding award description, "Development of a Probability Model To Predict Head Injury Risk in Pediatric Falls."
9. National Institute of Justice funding award description, "Biomechanical Characterization of Video Recorded Short Distance Falls in Children."
10. Gina Bertocci, Angela Thompson, and Karen Bertocci, "Biomechanical Characterization of Video Recorded Short Distance Falls in Children," semiannual progress report (July-December 2019) submitted for NIJ award number 2017-DN-BX-0158.
11. Bertocci, Thompson, and Bertocci, "Biomechanical Characterization of Video Recorded Short Distance Falls in Children."
12. All data in this paragraph are from Bertocci, Thompson, and Bertocci, "Biomechanical Characterization of Video Recorded Short Distance Falls in Children."
13. National Institute of Justice funding award description, "Development of a Computer Simulation Model To Predict Potential Bruising Patterns Associated With Common Childhood Falls.".

Image source: SDI Productions/iStock.

NCJ 255644

Cite this article as: Jim Dawson, "Child Abuse or Accident? Bringing Science to Pediatric Emergency Departments and Forensic Investigations," *NIJ Journal* 283, October 2021, https://nij.ojp.gov/topics/articles/child-abuse-or-accident-bringing-science-pediatric-emergency-departments.