The disparity between currently known best evidence and evidence-based practice has long been an issue in clinical medicine. Generating and validating definitive evidence appropriate for translation remains a particular challenge in emergency medicine (EM) research. Research into patient and parent shared decision-making and patient-centered outcomes may play a valuable role in implementing evidence-based practice in the emergency department (ED). This article will review the experience of the Pediatric Emergency Care Applied Research Network (PECARN) in deriving and validating the traumatic brain injury (TBI) prediction rules and how PECARN is working to translate the TBI prediction rules into clinical practice. In addition, we will mention how a group of investigators is studying patient and parent shared decision-making to improve patient-centered care regarding pediatric head trauma in the ED.

Trauma (unintentional injury) is the leading cause of death among children older than 1 year. TBI is the leading cause of childhood death and disability due to trauma, resulting in more than 6,000 deaths, 60,000 hospitalizations, and 600,000 ED visits annually in the United States. Computed tomography (CT) is the reference standard to emergently identify patients with clinically important TBI in the ED. Despite the low incidence of TBI requiring acute interventions such as neurosurgery in children with minor head trauma (defined from the Emergency Care Research Unit, Division of Population Health Sciences, Royal College of Surgeons in Ireland (AMMcC), Dublin, Ireland; and the Departments of Emergency Medicine and Pediatrics, University of California Davis School of Medicine (NK), Sacramento, CA.

Received June 28, 2015; accepted June 30, 2015.

This article is based on the keynote address delivered to the Academic Emergency Medicine consensus conference “Generation of Evidence and Translation Into Practice: Lessons Learned and Future Directions” by Nathan Kuppermann, San Diego, CA, May 12, 2015.

Funding for this conference was made possible (in part) by grant number 1R13HS023498-01 from the Agency for Healthcare Research and Quality (AHRQ) and grant number 1 R13 EB 019013-01 from the National Institute of Biomedical Imaging and Bioengineering. The views expressed in written conference materials or publications and by speakers and moderators do not necessarily reflect the official policies of the Department of Health and Human Services, nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government.

The authors have no potential conflicts of interest to disclose.

Supervising Editor: Christopher R. Carpenter, MD, MSc.

Address for correspondence and reprints: Nathan Kuppermann, MD, MPH; e-mail: nkuppermann@ucdavis.edu; Twitter: @nkuppermann.
here by Glasgow Coma Scale [GCS] scores of 14 to 15), there is significant practice variation in CT use in pediatric hospitals managing children with minor head trauma.\(^7\) Approximately 50% of children assessed in North American EDs for head trauma undergo CT.\(^9\) Studies suggest that the rate of CT use in children has increased substantially over the past decades,\(^3\) although the rate has plateaued and perhaps decreased in the past few years.\(^12\) While there is wide agreement that the benefits of an indicated CT scan far outweigh the risks, judicious use of CT is imperative to minimize cost, decrease unnecessary evaluation due to detection of inconsequential findings,\(^13\) minimize risks of pharmacologic sedation,\(^14\) and most importantly decrease the risk of ionizing radiation–induced malignancy.\(^12,15,16\)

There are several strategies to decrease unnecessary CT use and resultant radiation exposure. One strategy is to use radiation doses for CT imaging that are as low as reasonably achievable (“ALARA” principle) for image resolution.\(^17\) Another strategy is to follow evidence-based prediction rules to assist with CT decision-making. These rules limit use of CT to only those circumstances when it is truly necessary.\(^8,18,19\) As the radiology community has made substantial progress on the creation and validation of cranial CT imaging rules, the EM research community has focused its attention on the generalizability, ease of application, and sustainability of more than one million children treated annually (e.g., the evaluation of cranial, abdominal, and cervical spine trauma\(^8,31,32\), among many other topics.\(^23\) Of note, with regard to imaging in the ED, PECARN has produced a number of clinical prediction rules for the evaluation of traumatic conditions.\(^9,32,34\) PECARN leverages a combined population of more than one million children treated annually in 18 EDs throughout the United States to overcome many barriers inherent to pediatric emergency care research. These barriers include the infrequency of adverse outcomes in many pediatric conditions, the need for large numbers of children from varied backgrounds to achieve broadly representative study samples, the lack of an infrastructure to test the efficacy of pediatric emergency care, and the need for a mechanism to translate study results into clinical practice.\(^27,28\)

Imaging in pediatric blunt head trauma is a high priority for national health organizations such as the American Academy of Pediatrics and the Emergency Medical Services for Children program of the Maternal and Child Health Bureau of the Health Resources and Services Administration.\(^5,33,34\) In light of the high prevalence of head trauma in children and the increasing use of CT scans, PECARN conducted a large multicenter study to generate high-quality evidence to guide CT decision-making.\(^8\) Two clinical prediction rules were derived and validated in a prospective cohort study of 42,412 patients younger than 18 years in 25 U.S. EDs: one rule for children younger than 2 years and a second rule for children between 2 and 18 years old. The overarching aim for that study was to identify children at very low risk for clinically important TBI (cTBI) for whom CT scans are typically unnecessary.\(^8\) As it was important to use simple and patient-oriented outcomes to improve generalizability, ease of application, and sustainability, a cTBI was defined in the study as death from TBI, neurosurgery, intubation for more than 24 hours for TBI, or hospital admission of two nights or longer for the head trauma associated with TBI on CT. The rules provide risk stratification for children in three risk groups: high-risk (4.4 and 4.3% risk of cTBI in children younger than 2 and those 2 years and older, respectively), for whom CT scans are typically recommended; intermediate-risk (0.9 and 0.8% risk), for whom CT decision-making is more complicated as the CT risk/benefit tradeoff is not as clear, with observation without CT appropriate for many children with certain isolated PECARN variables\(^37-39\) and shared decision making with parents/guardians frequently appropriate; and low-risk (<0.02 and <0.05% risk), for whom CT scans are typically not recommended. Overall, the negative predictive values for the low-risk groups in the validation samples were 100 and 99.95% for children younger than 2 and for those aged 2 years and older, respectively. Subsequently the rules were externally validated and compared favorably to other decision rules for children with minor head trauma.\(^40,41\)

In a planned secondary analyses of the PECARN study, the investigators found that the negative predictive value for neurosurgical intervention in children
with initial GCS scores of 14 or 15 and normal CT scan results was 100%. The authors concluded that hospitalization for head trauma for this cohort of patients is generally unnecessary, assuming normal mental status and no other indications for hospitalization. A further planned subanalysis of the PECARN TBI study data identified that 5,433 (14%) children were observed in the ED prior to decisions on whether CT scans should be performed. The rate of CT use was significantly lower in those observed before CT decision-making than in those not observed, while the rate of cTBI was similar and did not negatively affect cTBI outcomes. The children who were observed before the decisions of whether to obtain CT scans were younger; more likely to present with vomiting, altered mental status, or a history of loss of consciousness; and were more likely to have had severe mechanisms of injury. These findings suggest that clinical observation before CT decision-making is a safe and effective strategy to manage a particular cohort of children with minor head trauma, but further work is required to determine the appropriate TBI population for observation and duration of clinical observation and its effect on CT use rates and ED lengths of stay.

EVIDENCE TRANSLATION INTO CLINICAL PRACTICE

Translating validated definitive evidence into clinical practice remains a challenge as demonstrated by the inconsistent uptake of the Ottawa Ankle Rules into clinical practice over two decades. Dietvorst et al. recently described “algorithm aversion” as a barrier to knowledge translation, a phenomenon whereby people fail to use computer-based algorithms even when they are aware that these algorithms outperform human decision-making. Dietvorst et al. postulate that algorithm aversion occurs because people lose confidence more quickly in computerized algorithms after seeing them make the same mistakes as human forecasters. There remains a knowledge gap on how to reduce algorithm aversion and enhance implementation of clinical prediction rules. To this end, PECARN is striving to improve the translation of evidence-based care and its clinical delivery in EDs with an emphasis on knowledge translation projects.

Knowledge translation describes any process that contributes to the effective and timely incorporation of evidence-based information into the practices of health professionals in such a way as to effect optimal health care outcomes and maximize the potential of the health care system. The Institute of Medicine’s “Crossing the Quality Chasm: A New Health System for the 21st Century” and “Future of Emergency Medicine” seminal reports have been instrumental in advancing the knowledge translation agenda. In an era of increased demand on health care costs, value, and efficiency, health research funding agencies such as the Agency for Healthcare Research and Quality are supporting knowledge translation research initiatives. In EM, the 2007 Academic Emergency Medicine consensus conference “Knowledge Translation in Emergency Medicine” spawned and inspired a number of federally funded and nationally sponsored innovative programs in research and education.

There are many factors that contribute to the inefficient translation of well-substantiated research into clinical emergency medical care. Glaziou and Haynes described the contributing elements in a research-to-practice pipeline model. The model is divided into two interconnected domains to represent the two concepts: “getting the evidence straight” and “getting the straight evidence used,” respectively, in Figure 1.

Lang et al. further described the knowledge translation process as encompassing four major disciplines (resource development and access, bedside evidence-based medicine, clinical quality improvement, and use of decision aids). To continue the research-to-practice pipeline analogy, there are many ways in which “water can be lost from the pipe” before it reaches the patient (and affects clinical outcomes). To ensure that the pipe is kept full, it is important to fill it with high-quality evidence, which is accepted by stakeholders and is easy to translate. Then, to prevent “leakage from the pipe” before the evidence reaches the patient, it is essential to ensure good engagement with multiple stakeholders. The first step involves getting the evidence straight, drawn from valid and important clinical research and represented in the 4S hierarchal pyramid (Figure 1). Three important aspects of evidence-based care (bedside evidence-based medicine, clinical quality improvement, and use of decision aids) have been advocated as key components of the awareness-to-adherence model of Pathman et al. along the evidence-to-practice pipeline. However, as the focus on engaging key stakeholders needs to start and finish with the bedside clinician, knowledge translation must find a way for the end-user bedside clinician to identify these decision aids as practice-worthy.

As an example of a simple diagnostic aid to overcome some of these knowledge translation barriers, the California American College of Emergency Physicians has produced pocket cards with the PECARN TBI rules to help the implementation for ED clinicians in a simple, nontechnologic format (Figure 2).

The role of interventions such as decision aids and clinical decision support systems is currently being evaluated to assess adherence to the TBI prediction rules. The overall goal of these efforts is to reduce unnecessary CT use in children with minor head trauma without missing clinically important TBI. PECARN investigators recently completed an implementation study of the TBI prediction rules by developing and testing an electronic health record (EHR)-based computerized clinical decision support system. Computerized clinical decision support systems are information systems designed to improve clinical decision-making by matching characteristics of individual patients to a computerized knowledge base. Software algorithms then generate patient-specific recommendations to improve practitioner performance. The systematic review by Kawamoto et al. of 70 studies suggests that clinical decision support systems improved clinical practices in 68% of trials. Independent predictors of improved clinical practice identified in this systematic review included: automatic provision of deci-
tion support as part of clinician workflow, provision of decision support at time and location of decision-making, provision of recommendations rather than just risks, and providing the decision support via computer. In their study, PECARN researchers developed and implemented a chief complaint-based process to trigger data collection for appropriate patients in the EHR, an EHR blunt head trauma data collection tem-

Figure 1. The research to practice pipeline. (Reproduced, with permission, from Glasziou P, Haynes B. “The paths from research to improved health outcomes.” Evidence Based Nursing 2005;8(2):36–8, copyright 2015, with permission from BMJ Publishing Group Ltd.)

Figure 2. California ACEP Choosing Wisely—Pediatric head trauma CT decision guide for children 2 years and older. (Reproduced, with permission, from California American College of Emergency Physicians.)
plate, and a data transfer process to translate the data from the template into real-time, patient-specific decision support (cITBI risks and CT recommendations). Data analysis from this study is currently ongoing, with the main outcome of interest being change in CT use and patient outcomes after implementation of computerized decision support within and across sites.

**PATIENT-CENTERED OUTCOMES RESEARCH AND SHARED DECISION-MAKING**

Patient-centered outcomes research aims to improve health outcomes by developing and disseminating evidence-based information to patients, clinicians, and other decision-makers while incorporating the values of patients and other stakeholders. This information is in response to patients’ expressed needs about which clinical and health system design interventions are most effective for specific patient cohorts with particular health care needs. The Patient Protection and Affordable Care Act of 2010 created the Patient-Centered Outcomes Research Institute (PCORI) to support conduct of research leading to evidence-based, patient-centered health interventions.

Shared decision-making is a method of promoting evidence-based, patient-centered, high-quality decisions. Shared decision-making has several key features and, in particular, educating patients (or parents, in a pediatric setting) such that they are empowered to apply their values and preferences to management decisions. The process includes inviting patients (parents) to comfortably participate in informed decision-making and arriving at a consensus (between clinician and patient/parent) on the best management approach, such that risk-informed patient/parental preferences are taken into consideration. Shared decision-making promotes respect for patient’s autonomy and provides clinicians with opportunities to rapidly develop rapport, educate, and meaningfully connect with their patients. Similarly, there are numerous potential benefits for the health care system, including improved health outcomes, reductions in unwarranted variation in care and costs, and greater alignment of care with patients’ values. U.S. emergency physicians understand that shared decision-making is both feasible and likely to provide high-yield alternatives to overtreatment, but believe that significant patient-level barriers must be overcome for shared decision-making to succeed.

In a systematic review of shared decision-making in the ED setting, the authors found that decision support interventions had a positive effect on outcomes such as patient knowledge and satisfaction and reduced health care utilization without evidence of harm or lack of feasibility. Shared decision-making is suited to those preference-sensitive health care decisions where there are two or more medically reasonable options available with no professional consensus, and a mutualistic clinician–patient relationship exists. Mutuality is characterized by active patient involvement where both parties share information, take steps to build consensus about the preferred treatment, and reach agreement about which treatment to implement. In relation to the PECARN TBI rules, and in particular to the large number of children with minor head trauma who are categorized in an “intermediate-risk group,” the PECARN rules suggest that either observation for a period of time or immediate CT scan is a reasonable option for many patients. The decision rests on several issues, including clinician experience, whether the patient has only one finding in isolation versus more than one PECARN finding, whether the patient has worsening symptoms or signs after ED observation (for which a CT scan would be indicated), and parental preferences. The authors of the PECARN TBI study offered no explicit recommendations for clinicians on how to weigh each of these factors and engage in the decision-making process. Shared decision-making appears to be a promising tool for arriving at patient-centered decisions and reducing unnecessary CT scans, particularly for patients in the PECARN “intermediate-risk group.”

There is a current knowledge gap regarding the role that shared decision-making and its associated tools, such as patient decision aids and structured decision support interventions, play in particular clinical scenarios in the ED. Two large systematic reviews have shown that decision aids improve knowledge, reduce decisional conflict, and stimulate patients and parents to be more active in decision-making without increasing their anxiety. Hess et al. are currently conducting a multicenter clinician-level randomized trial to compare an intervention group receiving a decision aid, “Head CT Choice,” to a control group receiving usual care. The goal is to test the effectiveness of a decision aid to facilitate shared decision-making with parents regarding whether to obtain a head CT scan or to further observe their child after minor head trauma. The investigators hypothesize that use of “Head CT Choice” will significantly increase parents’ knowledge, engagement, and satisfaction and safely decrease the rate of head CT and 7-day health care utilization.

**CONCLUSIONS**

Limiting inappropriate computed tomography imaging is a top priority in the ED. To effect sustainable and safe decreases in emergent imaging in ED practice, one must first generate and validate definitive evidence and have a planned knowledge translation program. After the evidence is “ripe,” it must be disseminated and implemented at the point of patient care, with minimal interruption to clinical care, typically using computerized decision support. Shared decision-making is a powerful tool to facilitate patient-centered care and may be appropriate when clinical decision-making regarding emergent imaging is ambiguous; further studies are required to generate the evidence base for the utility of shared decision-making and patient-oriented decision aids.
References


