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After completing this exercise the participant will be able to describe the role of inter-observer agreement in the evaluation of pediatric patients with intra-abdominal injury.

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ORIGINAL RESEARCH CONTRIBUTION

CME

Interobserver Agreement in the Clinical Assessment of Children With Blunt Abdominal Trauma

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Abstract

Objectives: The objective was to determine the interobserver agreement of historical and physical examination findings assessed during the emergency department (ED) evaluation of children with blunt abdominal trauma.

Methods: This was a planned substudy of a multicenter, prospective cohort study of children younger than 18 years of age evaluated for blunt abdominal trauma. Patients were excluded if injury occurred more than 24 hours prior to evaluation or if computed tomography (CT) imaging was obtained at another hospital prior to transfer to a study site. Two clinicians independently recorded their clinical assessments of a convenience sample of patients onto data collection forms within 60 minutes of each other and prior to CT imaging (if obtained) or knowledge of laboratory results. The authors categorized variables as either subjective symptoms (i.e., patient history) or objective findings (i.e., physical examination). For each variable recorded by the two observers, the agreement beyond that expected by chance was estimated, using the kappa (κ) statistic for categorical variables and weighted κ for ordinal variables. Variables with 95% lower confidence limits (LCLs) $\kappa \geq 0.4$ (moderate agreement or better) were considered to have acceptable agreement.

Results: A total of 632 pairs of physician observations were obtained on 23 candidate variables. Acceptable agreement was achieved in 16 (70%) of the 23 variables tested. For six subjective symptoms, κ ranged from 0.48 (complaint of shortness of breath) to 0.90 (mechanism of injury), and only the complaint of shortness of breath had a 95% LCL $\kappa < 0.4$. For the 17 objective findings, κ ranged from –0.01 (pelvis instability) to 0.82 (seat belt sign present). The 95% LCL for κ was <0.4 for flank tenderness, abnormal chest auscultation, suspicion of alcohol or drug intoxication, pelvis instability, absence of bowel sounds, and peritoneal irritation.

Conclusions: Observers can achieve at least acceptable agreement on the majority of historical and physical examination variables in children with blunt abdominal trauma evaluated in the ED. Those variables are candidates for consideration for development of a clinical prediction rule for intra-abdominal injury in children with blunt trauma.

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PECARN sites and acknowledgements are listed in Appendix A.

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Trauma remains the leading cause of death and disability in children in the United States,[1] with intra-abdominal injury (IAI) the third leading cause of traumatic death (following injuries to the head and thorax).[2] Rapid and appropriate evaluation of children at risk for IAI is therefore critical to the evaluation of injured children.

The use of computed tomography (CT) has increased substantially over the past decade.[3,4] Inappropriate use of CT exposes children to unnecessary ionizing radiation,[3–6] and this exposure is linked to rises in the rates of leukemia and tumors.[7] To limit unnecessary abdominal CT scanning, clinical prediction rules can help identify which children are at nonnegligible risk of IAI and therefore should be considered for CT scan.

The first step in the development of a clinical prediction rule is the identification of historical and physical examination variables with acceptable reliability.[8] Limited data, however, exist regarding the interobserver agreement of clinical variables in children with blunt abdominal trauma. The objective of this study was to assess the interobserver agreement of historical and physical examination variables elicited during the emergency department (ED) evaluations of children with blunt abdominal trauma.

METHODS

Study Design

This was a planned substudy of a large, multicenter, prospective study of pediatric blunt trauma patients. The study was approved by the human subjects review boards at all participating institutions. Detailed methods of the parent study are published elsewhere.[9] Methodology specific for this manuscript is presented here.

Study Setting and Population

The study was conducted at 20 EDs participating in the Pediatric Emergency Care Applied Research Network (PECARN) and included both dedicated pediatric and general EDs across the United States.[10,11] Children younger than 18 years of age who were evaluated for blunt abdominal trauma at participating centers were enrolled in the parent study between May 2007 and January 2010.

Inclusion and exclusion criteria are listed in Table 1. Subjects in this analysis were a convenience sample of the parent study, as enrollment only occurred when two clinicians were available to perform independent clinical assessments.

Study Protocol

A clinician (faculty physician, pediatric emergency medicine fellow, resident, nurse practitioner, or physician assistant) performed a history and clinical examination and recorded results on a standardized data collection form. The initial evaluation was supervised and verified by the faculty or fellow physician (if performed by one of the other clinician types). A second faculty or fellow physician, who was blinded to the evaluation of the first clinician, performed an independent evaluation within 60 minutes of the first evaluation and documented findings on a second form. The faculty and fellow physicians could have received any type of specialty training. All clinical evaluations were performed prior to knowledge of the results of laboratory results and abdominal imaging studies, if performed. Although all clinicians were aware of the study and oriented to the data collection forms, the clinicians did not undergo special, standardized training in completion of the forms. IAI was considered present if an injury to an

Table 1
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
1. Blunt torso trauma resulting from a significant mechanism of injury, such as: • Motor vehicle collision: high speed, ejection, or rollover; • Automobile versus pedestrian or bicycle: automobile moderate to high speed ($\geq$5 mph); • Falls $\geq$ 20 feet in height; • Crush injury to the torso; • Physical assault involving the abdomen. 2. Decreased level of consciousness (GCS score < 15 or below, age-appropriate behavior) in association with blunt torso trauma. 3. Blunt traumatic event with any of the following (regardless of the mechanism): • Extremity paralysis; • Multiple long bone fractures at multiple sites (e.g., tibia and humerus fracture). 4. History or physical examination suggestive of IAI following blunt torso trauma of any mechanism (including mechanisms of injury of less severity than mentioned above).	1. Penetrating trauma. 2. Preexisting neurologic disorders seriously confounding physical examination assessment (e.g., profound mental retardation and/or cerebral palsy). 3. Traumatic injury occurred more than 24 hours prior to the time of presentation to the ED. 4. Transfer of the patient to the participating center from an outside facility with abdominal CT or diagnostic peritoneal lavage already performed. 5. Patient is pregnant. 6. Patient has a documented IAI < 30 days prior to ED presentation.

GCS = Glasgow Coma Scale; IAI = intra-abdominal injury.

abdominal organ was identified by CT, laparotomy, or autopsy.

We evaluated and documented 23 clinical variables, including those pertaining to the history (subjective symptoms) and physical examination (objective findings). The variables considered were selected based on both a priori hypothesis of association with IAI and biologic plausibility.

Sample Size Calculation

To be considered for the prediction rule, variables are required to have at least moderate agreement (κ with a lower bound of the 95% CI of ≥ 0.4).[8,12] We used standard formulas for the sample size needed for a given standard error of κ.[13] The assumed κ coefficients and the proportion of subjects with the predictor present were based on prior data.[14,15] Using one-sided hypothesis testing with 80% power, calculations demonstrated that with 400 patients, we would be able to test all predictors except for flank tenderness. To adequately test flank tenderness, we estimated 4,583 patients would be needed, which was not feasible. This sample size estimate for κ measurements is similar to that from a previous large, multicenter study of pediatric head trauma.[16]

Data Analysis

We performed all analyses using SAS 9.2 (SAS Institute, Cary, NC). Chance-adjusted agreement between physician observers was calculated using the κ statistic. A patient with a missing value for a variable from either physician observer was excluded from the analysis for that variable. For ordinal variables, we used the Fleiss-Cohen weighted κ, with standard quadratic weights. We calculated the lower one-sided 95% lower confidence limit (LCL) using normal approximation methods. We considered agreement to be acceptable if the LCL for the κ value was ≥ 0.4, indicating moderate agreement or better, consistent with guidelines for clinical prediction rules.[12,17]

RESULTS

We enrolled 12,044 patients in the parent cohort study (81% capture rate). The current study sample consists of the 632 patients (5.2%) who had second physician observers complete independent clinical evaluations and data collection forms. At each study site, between 2 and 21% of enrolled patients had second evaluations performed. The primary specialties of the physician observers are displayed in Table 2. Two-thirds of the observer pairs were two pediatric emergency medicine physicians.

The mechanisms of injury for the patients in the interobserver study sample and the parent study are listed in Table 3A. The distribution of mechanisms of injury was similar between the two samples. Patient demographic and clinical characteristics (Table 3B) were also similar between the groups.

Of the 632 pairs of observations in the current study, acceptable agreement (95% LCL for $\kappa \geq 0.4$) was achieved in 16 (68%) of the 23 candidate variables. For the historical variables, κ ranged from 0.48 (complaints of shortness of breath) to 0.90 (mechanism of injury). The only historical variable with a 95% LCL $\kappa < 0.4$ was patient complaint of shortness of breath (0.35; Table 4). For the physical examination variables, κ ranged from –0.01 (pelvis instability) to 0.82 (seat belt sign present). Eleven of the 17 physical examination variables had acceptable κ statistic values. The six variables with 95% LCLs for $\kappa < 0.4$ include flank tenderness, abnormal chest auscultation findings, pelvis instability, absence of bowel sounds, suspicion of alcohol or drug intoxication, and peritoneal irritation (Table 5).

DISCUSSION

In this large multicenter study of children evaluated after blunt abdominal trauma, we found agreement between physician observers was acceptable for the majority of historical and physical examination variables. These variables can serve as candidates for the development of a clinical prediction rule for the evaluation of children with blunt abdominal trauma.

Although moderate agreement or better was found for most variables, several variables did not reach sufficient threshold for acceptable interobserver agreement. We anticipated poor agreement for some variables, such as suspicion of alcohol or drug intoxication and complaint of shortness of breath. These variables are not well defined and therefore specific training of clinicians on how to assess these variables may improve reliability among investigators, but the results would not be replicated by clinicians using these variables on a day-by-day basis. Therefore, these variables are

Table 2
Characteristics of Observer Pairs Completing Evaluations

	Second Evaluation				
Initial Evaluation	EM	General/Trauma Surgery	Pediatrics	PEM	Pediatric Surgery
EM	24 (3.8)	0	0	41 (6.5)	0
General/trauma surgery	0	33 (5.2)	0	0	0
Pediatrics	5 (0.8)	0	16 (2.5)	7 (1.1)	0
PEM	52 (8.2)	0	6 (0.9)	421 (66.6)	15 (2.4)
Pediatric surgery	0	0	0	7 (1.1)	0

Values reported as *n* (%).
Five pairs not included in table due to rarity (internal medicine/family practice/other).
PEM = pediatric emergency medicine.

Table 3A
Mechanisms of Injury of Patients in the Interobserver Cohort Compared to the Parent Study Cohort

Mechanism of Injury	Sample for Interobserver Agreement Analysis (n = 632)	Total Study Sample (N = 12,044)
Occupant in MVC	216 (34.2)	3,830 (31.8)
Pedestrian/bicyclist struck by moving vehicle	142 (22.5)	2,272 (18.9)
Fall from elevation	73 (11.6)	1,623 (13.5)
Fall down stairs	12 (1.9)	281 (2.3)
Bike collision/fall from bike	41 (6.5)	758 (6.3)
Motorcycle/ATV/motorized scooter collision	33 (5.2)	602 (5.0)
Object struck abdomen	33 (5.2)	793 (6.6)
Other	76 (12.0)	1,691 (14.0)
Unknown	6 (1.0)	194 (1.6)

All values *n* (%).
ATV = all-terrain vehicle; MVC = motor vehicle collision.

Table 3B
Characteristics of Patients in the Interobserver Cohort Compared to the Parent Study Cohort

Patient Characteristics	Sample for Interobserver Agreement Analysis (n = 632)	Total Study Sample (N = 12,044)
Mean (SD) age, yr	10.1 (5.3)	10.3 (5.4)
Age < 2 yr	59 (9.3)	1,167 (9.7)
Sex, male	382 (60.4)	7,384 (61.3)
Race, white	325 (51.4)	6,489 (53.9)
Discharged home from ED	314 (49.7)	6,036 (50.1)
CT performed	300 (47.5)	5,508 (45.7)
Positive for IAI diagnosed by any method	37 (5.9)	761 (6.3)

Values reported as *n* (%) unless otherwise noted.
IAI = intra-abdominal injury.

not appropriate for consideration into a clinical prediction rule. Furthermore, low prevalence also contributed to some variables (e.g., suspicion of alcohol intoxication or pelvis instability) having poor interobserver agreement.

The generalizability of our results is enhanced by the fact that this was conducted at 20 ED settings across the United States. Although the EDs involved tended to be in academic centers, they represent both pediatric-specific and general EDs, including those located in urban, suburban, and more rural settings. We also had a diverse group of faculty and fellow physicians with regard to type of training (general trauma surgeons, general emergency physicians, pediatric surgeons, pediatric emergency physicians, and pediatricians). These aspects are important to create a robust clinical prediction rule, useful in multiple settings and by multiple types of providers.

Although the relevant literature is limited, our results are similar to those of the few studies offering data on the reliability of the symptoms and signs important to

Table 4
Interobserver Agreement for Patient Historical Variables

Trait per First Rater	% With Characteristic Present per First Rater	κ	One-sided 95% LCL
Injury mechanism			
Occupant in MVC	34.7	0.9	0.88
Fall from an elevation	11.8		
Fall down stairs	1.9		
Pedestrian or bicyclist struck by moving vehicle	22.8		
Bike collision or fall from bike	6.6		
Motorcycle/ATV/ motorized scooter collision	5.3		
Object struck abdomen	5.1		
Other	11.7		
Does patient complain of abdomen pain	36.5	0.71	0.66
Vomiting/retching	6.8	0.67	0.57
Location of abdominal pain			
None/unable to assess	64.4	0.64	0.58
Diffuse	14.1		
Localized	21.5		
Does the patient have a distracting painful injury	26.4	0.53	0.46
Does patient complain of shortness of breath/ difficulty breathing	5.9	0.48	0.35

All subjects (*n* = 632).
ATV = all-terrain vehicle; LCL = lower confidence level; MVC = motor vehicle collision.

the clinical evaluation of children with blunt abdominal trauma. For example, the interobserver reliability of abdominal tenderness in this study (κ = 0.74) was similar to that from a single-center, prospective study of injured children (κ =0.63, 95% CI = 0.50 to 0.76).[15]

In a large prospective study of adult patients with blunt trauma, interobserver agreement was evaluated in a convenience sample of 720 patients.[18] The lower bound of the 95% CI for κ was ≥ 0.4 for the following variables: GCS < 14, intoxication, abdominal tenderness, costal margin tenderness, abdominal seat belt sign, and distracting painful injury. Variables with unacceptable κ values included flank tenderness, abdominal distension, and peritoneal irritation. The calculated κ values in our study were similar for abdominal tenderness, costal margin tenderness, seat belt sign, distracting painful injury, peritoneal irritation, and flank tenderness. Our κ values for abdominal distension and alcohol intoxication, however, were considerably different than those reported in the adult study. Abdominal distension may be easier to assess in children as there is generally less central obesity. Alcohol intoxication is rare in children such that the κ value may be falsely lowered.

Our study is similar to two multicenter pediatric studies conducted as part of the development of separate clinical predication rules for traumatic brain injury and seizures. One group of investigators evaluated the interobserver agreement of historical and physical

Table 5
Interobserver Agreement for Physical Examination Findings

Trait per First Rater	% with Characteristic Present per First Rater	κ	One-sided 95% LCL
Seat belt sign present	4.5	0.82	0.73
Abdominal tenderness	35.8	0.74	0.69
Degree of abdominal tenderness		0.73	0.69
None	64.4		
Mild	16.7		
Moderate	14.9		
Severe	4.0		
Abdominal wall trauma	19.0	0.70	0.63
Absent/decreased breath sounds	1.8	0.66	0.46
Thoracic trauma	17.0	0.64	0.57
Left or right costal margin tenderness	12.9	0.63	0.55
Abdominal distention	2.6	0.61	0.43
Pelvic bone tenderness	10.5	0.60	0.50
Location of abdominal tenderness		0.58	0.53
None	64.8		
Diffuse	12.2		
Above the umbilicus	12.0		
Below the umbilicus	8.0		
Periumbilical	3.0		
Thoracic tenderness	15.4	0.56	0.48
Flank tenderness	10.4	0.46	0.36
Abnormal chest auscultation findings	2.4	0.43	0.23
Suspicion of intoxication	1.2	0.42	0.15
Peritoneal irritation	1.7	0.42	0.15
Bowel sounds absent	7.4	0.08	−0.04
Pelvis unstable	1.0	−0.01	−0.02

All subjects (n = 632).
LCL = lower confidence level.

examination finding in pediatric blunt head trauma,[19] while another group evaluated those in children with first unprovoked seizures.[20] Like these studies, we were also able to identify numerous historical and physical examination variables with good clinical plausibility and adequate interobserver agreement. Unlike our study, the study to identify candidate variables for children with first-time seizures had many physical examination variables that were infrequently present and had relatively low κ values.[20] A low κ value can be an artifact of a low prevalence for a particular clinical finding, despite high raw agreement.[21,22] Only two variables were evaluated both in our study and in the study of children with blunt head trauma. The reported κ values for mechanism of injury (κ = 0.83; one-sided 95% LCL = 0.81) and vomiting (κ = 0.91; one-sided 95% LCL = 0.89) were similar to those of our study.[19]

Prior studies have evaluated interobserver agreement in pediatric patients with acute abdominal pain from nontraumatic reasons (most commonly appendicitis).[23–25] These prior studies agree with the current study that the variables of vomiting and location of abdominal pain have at least moderate agreement, and guarding and peritoneal signs have poor agreement. These studies, however, disagree in the interobserver agreement of abdominal tenderness and the presence or absence of abdominal tenderness. The different findings for abdominal tenderness are not surprising given the reasons for pain and structures affected may be different in traumatic and nontraumatic conditions. Trauma more likely causes somatic pain compared to medical reasons, which more likely cause dull, poorly localized, splanchnic (visceral) pain. The differences in findings highlight the need for specific assessment of variables for the condition of interest and not relying on interobserver agreement for different medical conditions.

LIMITATIONS

The sample, although large, was a convenience sample. The characteristics of the study sample, however, closely match that of the parent study, limiting any bias from the sampling method. The study was conducted mostly in academic settings; however, this is the setting in which many, if not most, pediatric patients with serious abdominal trauma present (American College of Surgeons designated Level I and II trauma centers). In addition, most paired assessments occurred between pediatric emergency physicians, although there is no reason to believe that this would bias the results. This distribution is similar to that of our prior work regarding the interobserver assessment of children with blunt head trauma.[19] In addition, a prior study has demonstrated substantial agreement between physician types when examining children.[25] Nevertheless, the results may not be generalizable to all centers and physicians providing care to injured children. Although the two clinicians were asked to conduct their examinations as close as possible to each other, there is the potential that the physical examination findings changed between the times of the two examinations. Finally, some of the physical examination findings were uncommon, contributing to lower κ values and wide CIs of some of the κ values, even though agreement between observers may have been high.

CONCLUSIONS

Observers can achieve acceptable agreement on most historical and physical examination variables collected from the evaluation of children with blunt abdominal trauma in the ED. Such variables are candidates for the development of clinical prediction rules for intra-abdominal injury in children after blunt abdominal trauma.

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APPENDIX A
PARTICIPATING CENTERS AND SITE INVESTIGATORS

Participating centers and site investigators are listed below in alphabetical order: Bellevue Hospital Center (M. Tunik); Children's Hospital Boston (L. Lee); Children's Hospital of Michigan (P. Mahajan); Children's Hospital of New York–Presbyterian (M. Kwok); Children's Hospital of Philadelphia (F. Nadel); Children's National Medical Center (S. Atabaki); Cincinnati Children's Hospital Medical Center (B. Kerrey); DeVos Children's Hospital (J. Kooistra); Howard County Medical Center (D. Monroe); Hurley Medical Center (D. Borgialli); Jacobi Medical Center (S.Blumberg) Medical College of Wisconsin/Children's Hospital of Wisconsin (K. Yen); Nationwide Children's Hospital (B. Bonsu); University of California Davis Medical Center (N. Kuppermann, J. Holmes); University of Maryland (J. Menaker); University of Michigan (A. Rodgers); University of Rochester (M. Garcia); University of Utah/Primary Children's Medical Center (K. Adelgais); Washington University/St. Louis Children's Hospital (K. Quayle); Women and Children's Hospital of Buffalo (K. Lillis).

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