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Costal Margin Tenderness and the Risk for Intra-abdominal Injuries in Children with Blunt Abdominal Trauma

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Abstract

Background—The risk of radiation exposure from computed tomography (CT) imaging in children is well recognized. Patient history and physical examination findings, including costal margin tenderness (CMT), influence a physician's decision to image a child with blunt torso trauma. The objective of this study was to determine the importance of CMT for identifying children with intra-abdominal injuries (IAI) found on CT and IAI undergoing acute intervention.

Methods—We conducted an analysis of the Pediatric Emergency Care Applied Research Network (PECARN) IAI public use dataset, representing a large prospective multicenter cohort study from May 2007 to January 2010. Isolated CMT was defined as CMT without other identified PECARN risk factors for IAI (i.e., abdominal or thoracic wall trauma, abdominal tenderness or pain, decreased breath sounds, or vomiting). Logistic regression was used to calculate adjusted odds of IAI in children presenting with isolated and non-isolated CMT. Risk differences were calculated to estimate the risk of IAI independently attributable to CMT in the setting of isolated PECARN risk factors. Finally, CT use among exposure groups was estimated to quantify potentially avoidable imaging.

Results—Among 9,174 children with Glasgow Coma Scale scores of 14–15 who sustained blunt torso trauma, 1,267 (13.8%) had CMT. Among those with CMT, 177 (14.0%) had isolated CMT and 1,090 (86.0%) had non-isolated CMT. No children (0/177; 0%, 95% CI 0.0, 2.1%) with isolated CMT had IAI, compared to 17.2% (187/1090; 95% CI 15.0, 19.5%) of those with non-

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isolated CMT. The risk differences were not statistically significant. 36/177 (20.3%; 95% CI 14.7, 27.0%) children with isolated CMT underwent abdominal CT scans.

Conclusions—The risk of IAI associated with isolated CMT is minimal. For children with blunt abdominal trauma and isolated CMT, abdominal CT scan is of low yield.

Keywords

pediatric trauma; abdominal trauma; torso trauma; clinical prediction; computed tomography

Introduction

Injury is the leading cause of death and disability in children nationwide, and blunt trauma accounts for most fatal and nonfatal injuries.[1] Brain injury is the leading cause of traumatic death in children[2] and hemorrhage, from intra-thoracic or intra-abdominal injuries, is the next most common.[3] Accurate and efficient evaluation of children with blunt abdominal trauma is essential to provide optimal care and minimize delays in critical interventions. Detecting intra-abdominal injuries may be difficult even for the most experienced clinicians.[4] With technological advances over the past three decades, computed tomography (CT) has become the reference standard for evaluation of intra-abdominal injury. In children, however, abdominal CT scans are associated with a non-negligible lifetime attributable risk of cancer: at least one radiation induced malignancy is estimated to result from every 300 to 760 CT scans of the abdomen.[5–7] With the known risks of CT imaging, investigators have sought to identify patient history and physical examination findings, plus ultrasound and laboratory results, that identify children at very low risk for intra-abdominal injury and thus may not require CT scanning.[8–16] Prediction models have used a variety of physical examination components including subjective findings (e.g. abdominal tenderness or complaints of pain) and objective findings (e.g. seat belt sign or other evidence of abdominal or thoracic wall trauma).[15–17]

Costal margin tenderness is an important predictor of both hepatic and splenic injuries in adults;[18,19] however, it is not consistently used in predictive models for intra-abdominal injury in children. Investigators in the Pediatric Emergency Care Applied Research Network (PECARN) created a clinical prediction rule to identify children with blunt torso trauma at very low risk for intra-abdominal injuries undergoing acute intervention.[15] They evaluated costal margin tenderness; however, it was not found to be an independent predictor of injury undergoing acute intervention. Despite adult data supporting costal margin tenderness as a clinically important predictor of intra-abdominal injury, the PECARN findings question its clinical significance in children. Costal margin tenderness may still be important in children, however, and the PECARN prediction rule may have not captured its importance for a number of reasons (e.g., costal margin tenderness was masked by abdominal pain or tenderness variables, and in fact was used as a surrogate when those variables were missing, etc.). The risk of intra-abdominal injury in the setting of costal margin tenderness in children is unknown. Further understanding of and stratification in this arguably low-risk group may provide a potential target population for imaging-related risk reduction.

The objective of this study was to (1) determine the risk of intra-abdominal injury and the risk of intra-abdominal injury undergoing acute intervention in children presenting with isolated and non-isolated costal margin tenderness, (2) determine the risk of intra-abdominal injury and the risk of intra-abdominal injury undergoing acute intervention attributable to costal margin tenderness above and beyond established PECARN risk factors, and (3) describe potentially avoidable abdominal CT scans in patients with costal margin tenderness.

Methods

Study design, setting, population

We performed a planned secondary analysis using the dataset of a large prospective observational cohort study of children with blunt torso trauma, consisting of 20 PECARN centers nationwide (i.e. PECARN abdominal trauma study) from May 2007 to January 2010. The publicly available dataset contained no personal health information and was considered exempt from review by the Institutional Review Board. The study protocol and methods have been described in detail elsewhere.[15] Briefly, children younger than 18 years were included in the PECARN study if they presented within 24 hours of blunt trauma to the thorax and/or abdomen and at least one history or physical exam finding to suggest injury.[15] Exclusion criteria included penetrating trauma, pre-existing neurological disorders confounding the physical examination (e.g. profound mental retardation and/or cerebral palsy), transferred patients for whom an abdominal CT or diagnostic peritoneal lavage was already performed, and pregnancy. For this analysis, children with Glasgow Coma Scale (GCS) scores less than 14 were excluded due to concern the physical examination, including assessment of costal margin tenderness, would be unreliable.[20]

Definitions/Measures

The exposure of interest was costal margin tenderness ascertained by the provider evaluating the child in the emergency department. Costal margin tenderness was assessed on the right and left sides and considered present if tenderness was identified on palpation of ribs seven through 12. For the current analysis, isolated costal margin tenderness was defined by the composite of right, left, and/or bilateral costal margin tenderness only. To qualify as "isolated" all other PECARN clinical prediction rule variables, referred to from now on as PECARN risk factors, were required to be absent (evidence of abdominal wall trauma or seat belt sign, abdominal tenderness, complaints of abdominal pain, evidence of thoracic wall trauma, decreased breath sounds, or vomiting).[15] Thoracic wall trauma was defined as erythema, abrasions, ecchymosis, subcutaneous air, or lacerations to the thoracic wall. Abdominal wall trauma was similarly defined as any one of these findings on examination of the abdominal wall. Non-isolated costal margin tenderness was defined by the presence of costal margin tenderness in addition to one or more PECARN risk factors.[15] As with isolated costal margin tenderness, isolated PECARN risk factors were defined for each variable as *"PECARN risk factor X"* without costal margin tenderness *and* without any of the other PECARN risk factors.

The primary outcomes of interest were 1) intra-abdominal injury and 2) intra-abdominal injury undergoing acute intervention. Intra-abdominal injury included any radiographicallyor surgically-apparent injury to the intra-abdominal organs (i.e., spleen, liver, gallbladder, pancreas, kidneys, urinary bladder, gastrointestinal tract, adrenal gland), or injury to a vascular structure or a fascial defect. Acute intervention included therapeutic laparotomy, angiographic embolization of bleeding abdominal structures, blood transfusions to treat intra-abdominal injury related anemia, or intravenous fluid administration for two or more nights due to pancreatic or gastrointestinal injuries. The secondary outcome of interest was abdominal CT scan use in children with isolated and non-isolated costal margin tenderness.

Data Analysis

Descriptive statistics were performed on the entire study population and stratified by isolated and non-isolated costal margin tenderness. Counts and proportions were presented for categorical variables, and the medians with the associated interquartile ranges for continuous variables with non-normal distributions. Logistic regression was used to determine the relative odds of intra-abdominal injury with and without intervention associated with costal margin tenderness while controlling only for the PECARN risk factors, with significance level set at 0.05. In addition to the PECARN risk factors, additional adjusted analyses controlled for age, GCS, and mechanism of injury based on prior research,[18,20,21] data accuracy and completeness, and clinical sensibility, all while optimizing face validity and parsimony. Because we were interested in the role of costal margin tenderness with and without PECARN risk factors, we assessed the relationship of intra-abdominal injury with the following exposure groups: isolated costal margin tenderness, costal margin tenderness plus one or more PECARN risk factors, the presence of PECARN risk factors without costal margin tenderness, and no costal margin tenderness and no PECARN risk factors. Estimated proportions were calculated with binomial exact 95% confidence intervals (CI) and logistic regression was used to estimate odds of intra-abdominal injury for each exposure group. We tested model assumptions (using STATA *linktest* command) and goodness of fit (Hosmer Lemeshow p-value = .88). Prior to modeling the data, we plotted Pearson and deviance residuals in addition to Pregibon leverages to evaluate influential outliers. Risk differences were calculated to estimate the risk of intra-abdominal injury attributable to costal margin tenderness beyond that associated with each PECARN risk factor in isolation. For these analyses, children with each isolated PECARN risk factor were considered "unexposed," and children with each PECARN risk factor *plus* costal margin tenderness were considered the "exposed." The risk difference for each group then is the proportion of intra-abdominal injury in the exposed group that can arguably be attributed to the exposure. The proportion of children undergoing an abdominal CT scan among each exposure group was determined to estimate potentially low-yield CT scan use.

A complete case analysis was performed excluding all patients with missing data for costal margin tenderness or any of the PECARN risk factors. Subsequently, because missing data accounted for exclusion of 16.9% (1,871/11,045) of the children who qualified for study inclusion (i.e., with GCS scores of 14–15), an analysis using multiple imputation with chained equations and 10 imputations was completed to evaluate its impact.[22,23] Evaluation using the imputed data did not produce results significantly different from the complete case analysis and is thus presented in the supplemental appendix (see Appendix Figure 1 and Tables 1–4).

Results

A total of 9,174 children had complete data for costal margin tenderness and all the PECARN risk factors documented (Figure 1). Overall, nearly one-half of the children (n = 4,738, 42.9%) had CT scans of the abdomen and pelvis performed, with stratified proportions varying by constellation of symptoms and physical exam findings. Costal margin tenderness was documented in 1,267 (13.8%) children. Among them, 177 (14.0%) had *isolated* costal margin tenderness (i.e., costal margin tenderness with all other PECARN risk factors recorded as absent). Among the 1,090 children with *non-isolated* costal margin tenderness, 76.8% (n = 837) also had abdominal tenderness, 77.0% (n = 839) complained of abdominal pain, 40.8% (n = 445) had evidence of thoracic wall trauma, and 25% (n = 272) had evidence of abdominal wall trauma and/or seat belt signs. Only 10.9% (n = 119) vomited after their trauma and 5.1% (n = 56) had absent or decreased breath sounds. These are not mutually exclusive, and a child may have had any combination of the symptoms and physical exam findings described. Additional characteristics of children with isolated and non-isolated costal margin tenderness are presented in Table 1.

When controlling for all the PECARN risk factors, the relative odds of intra-abdominal injury in children with costal margin tenderness was twice that compared to children without costal margin tenderness (OR 2.1; 95 % CI 1.7, 2.6). Similarly, when controlling for PECARN risk factors, the relative odds of intraabdominal injury undergoing acute intervention in children with costal margin tenderness compared to those without costal margin tenderness was 1.7 (95 % CI 1.1, 2.6). Results did not change significantly when adjusting for age, mechanism of injury, and GCS score (adjusted OR 2.2; 95% CI 1.8, 2.8, for intraabdominal injury and adjusted OR 2.0; 95% CI 1.2, 3.1, for intraabdominal injury undergoing acute intervention). No child with *isolated* costal margin tenderness, however, had intra-abdominal injury (0/177; 0.0%, 95% CI 0.0, 2.1%; Table 2). In contrast, children with *non*-isolated costal margin tenderness not uncommonly had intra-abdominal injuries (187/1,090; 17.2%, 95% CI 15.0, 19.5%) and several had intra-abdominal injuries undergoing acute intervention (36/1,090; 3.3%, 95% CI 2.3, 4.5%). Using children without costal margin tenderness and without PECARN risk factors as the referent, the odds of intra-abdominal injury in children with non-isolated costal margin tenderness (i.e.; costal margin tenderness and one or more PECARN risk factors) was 19.5 (95% CI 13.7, 27.6), while it was only 6.9 (95% CI 4.9, 9.6) for children with one or more PECARN risk factors but without costal margin tenderness. Compared to children without costal margin tenderness or PECARN risk factors, the odds of intra-abdominal injury undergoing acute intervention was 21.6 (95% CI 9.1, 51.5) in children with non-isolated costal margin tenderness and was 11.1 (95% CI 4.8, 25.7) in children with PECARN risk factors but no costal margin tenderness, suggesting costal margin tenderness may augment the risk of IAI with and without intervention despite not playing a significant role alone. There was minimal change in parameter estimates after adjusting for age, GCS score, and mechanism of injury (Table 2).

There were few cases of intra-abdominal injuries among children with costal margin tenderness *plus only one* PECARN risk factor (i.e., while all other PECARN risk factors were absent; Table 3). Two children underwent acute intervention for their injury in the setting of costal margin tenderness and only one PECARN risk factor: one child had costal margin tenderness and evidence of abdominal wall trauma or seat belt sign and one child had costal margin tenderness and thoracic wall trauma. For each PECARN risk factor, the risk difference for intra-abdominal injury between children presenting with an isolated PECARN risk factor (i.e.: the unexposed group) and children presenting with that variable *in addition to* costal margin tenderness (i.e., the exposed group) is presented in Table 3. While risk differences varied widely, from −4.2% to 5.6%, the attributable risk of intra-abdominal injury due to costal margin tenderness above and beyond that of each individual PECARN risk factor was not statistically significant.

Rates of abdominal CT scan use among exposure groups varied from 21.1% (95% CI 15.7, 27.4) for children with isolated costal margin tenderness to 70.6% (95% CI 68.2, 73.5%) for children with non-isolated costal margin tenderness (Table 4).

Discussion

In this study, children with blunt torso trauma and isolated costal margin tenderness (costal margin tenderness without any other PECARN risk factors) had only minimal risk of intra-abdominal injury. Although isolated costal margin tenderness had little role in identifying children with intra-abdominal injury, its presence significantly augmented the risk of intra-abdominal injury in those children who also had PECARN risk factors present. Furthermore, while controlling for PECARN risk factors, children with costal margin tenderness were at increased odds of injury compared to those without costal margin tenderness. However, when we stratified by each PECARN risk factor in isolation and evaluated the risk difference, the increased risk attributable with costal margin tenderness was not statistically significant. Despite the lack of intra-abdominal injury in the setting of isolated costal margin tenderness, approximately 20% of children with isolated costal margin tenderness still underwent abdominal CT imaging.

While the odds ratios calculated indicated a measurable effect of costal margin tenderness on intra-abdominal injury, the risk differences did not estimate a statistically significant increase in risk between those with costal margin tenderness and those without. The differences between these findings are likely explained not only by the difference between multiplicative and additive scales, but also by 1) bias introduced by unmeasured confounders in the logistic regression model, and 2) the small numbers and loss of statistical power when performing analyses isolated to specific PECARN risk factors in the absence of all others. Regarding the former explanation, it has been previously shown that the risk of intra-abdominal injury and that of intra-abdominal injury undergoing acute intervention increases as the number of PECARN risk factors increases.[15] For example, 1.4% of children in the parent study had intra-abdominal injuries undergoing acute intervention if only one PECARN risk factor was present, compared to 11.9% if four or more PECARN risk factors were present.[15] It is also likely that intra-abdominal injury increases in the setting of costal margin tenderness and other risk factors that were not identified in the PECARN analysis. The later explanation - the loss of statistical power when analyzing PECARN risk factors in isolation - may in part explain the negative findings of costal margin tenderness with only one PECARN risk factors in isolation. Stratifying by each PECARN risk factor removed all confounding introduced by other variables known (and not known) to increase the risk of intra-abdominal injury, which may have accounted for the effect size appreciated in the regression analysis. However, this also decreases the sample size available for analysis and thus compromises the statistical power and increases the chance of a type II error. Notably, the risk difference of intra-abdominal injury associated with costal margin and thoracic wall tenderness together compared to thoracic wall tenderness alone appeared to approach statistical significance. This finding is likely due to the significantly higher number of children in that group (653 compared to 200–300 in other exposure dyads). In fact, in the analysis on imputed data, the risk difference was 3.6% (95% CI 0.1, 7.0), achieving statistical significance. While inference on the effect size and direction of other dyads cannot be made with confidence, it is clear that an increased sample size within the stratified analyses would increase power and precision.

Our findings regarding isolated costal margin tenderness are in contrast to the literature on costal margin tenderness in adults with blunt abdominal trauma and highlight the importance of not extrapolating and applying results from adult trauma studies to children. In a 2005 study of 876 adults with left costal margin tenderness after blunt trauma, 7.2% had splenic injuries and 2.3% had left renal injuries. In that study, 301 patients had "isolated" costal margin tenderness (defined as lack of abdominal or flank tenderness, femur fracture, gross hematuria, and hypotension) and 3.0% had splenic injuries, with one-third of those undergoing splenectomy.[19] Another study in adults found costal margin tenderness to be more common in patients with intra-abdominal injuries compared to those without intra-abdominal injuries (risk ratio 1.9; 95% CI 1.5, 2.3).[14] In that study, a clinical prediction model was built and costal margin tenderness was shown to be a significant variable in the model.[14] In a retrospective review of 476 hospitalized adults with rib fractures, lower rib fractures increased the risk of both hepatic and splenic injuries.[18] While one may argue that rib fractures are likely associated with costal margin tenderness, in that study, costal margin tenderness was not evaluated in isolation of other complaints. Most importantly, these studies are from injured adults. The costal margin protects a smaller portion of the abdominal viscera (particularly the spleen and liver) in children compared to adults,[24] and thus costal margin tenderness may be more of a risk factor for intra-abdominal injury in adults than in children.

In addition to the PECARN prediction rule, additional independent prediction models for intra-abdominal injury in children have been developed, all with the goal of identifying children at low-risk for injury who can forgo abdominal CT imaging.[11,13] These studies, however, were limited by their small sample sizes and the failure to definitively address the importance of costal margin tenderness.[11,13] Streck et al studied 2,188 children after blunt injury and found that an abnormal abdominal examination, defined as "abdominal wall trauma, tenderness or distension," to be predictive.[16] While helpful, the definition combines many different and potentially variable presentations. Neither the prediction rule by Streck and colleagues nor the PECARN prediction rule drill down on costal margin tenderness in their evaluation for risk of intra-abdominal injury.[15,16] The PECARN study also does not address the importance of costal margin tenderness in those patients with co-existing PECARN risk factors. Our study is the first to quantitatively describe the attributable risk of intraabdominal injury due to costal margin tenderness alone and due to costal margin tenderness in addition to other previously identified and validated risk factors. Our findings support that costal margin tenderness should not be included as an independent variable in predictive models for intra-abdominal injury after blunt torso trauma in children. Moreover, in children with PECARN risk factors present on initial physical examination, the additional presence of costal margin tenderness likely only minimally increases the risk of intra-abdominal injury.

In efforts to "do no harm" and to not miss injuries, physicians obtain abdominal CT scans after blunt injury for many reasons. CT scans are readily available and have a high sensitivity and specificity for detection of intra-abdominal solid organ injuries. The negative predictive value of a CT scan approaches 100%, often making it safe to discharge patients from the emergency department following a normal abdominal CT scan.[25] Furthermore, in the setting of intra-abdominal injury, CT scans are often important in identifying the type and extent of injury, and guiding treatment.[4,26,27] However, the risks of radiation and the costs to patients and health systems are not inconsequential. To optimize quality care at the lowest cost, physicians must proceed cautiously in identifying children for whom CT scans can be avoided without introducing undue risk of missed injury, delayed diagnosis, or compromised outcomes. That being said, in this study, 20% of children with isolated costal margin tenderness, and no other identified risk of intra-abdominal injury as defined by PECARN risk factors, still underwent CT imaging of their abdomen. All these children could have reasonably been spared the radiation and associated risks and costs.

Limitations

This study has several potential limitations. Although it was a planned secondary analysis, the primary purpose of the dataset was not to assess the importance of costal margin tenderness. The sample size was large but the number of patients with outcome events and the number of children qualifying for each stratified exposure group were limited and thus the ability to identify significant risk differences between groups was limited. Some data were missing, however the imputed analysis demonstrated minimal differences from the main analysis. Many of the elements of the patient history and physical examination are subjective in nature, as suggested by a prior report documenting inter-observer agreement (κ=0.63) for costal margin tenderness,[28,29] although this still represents substantial agreement. As always with retrospective data, there is also the possibility of unmeasured confounders which were not obtained or included in our analysis, and caution must be taken when inferring risk as causal relationships are not definitive.

Conclusions

Children with costal margin tenderness without any PECARN risk factors are at very low risk of having intra-abdominal injuries. The attributable risk due to costal margin tenderness for intra-abdominal injury beyond the PECARN risk factors is minimal. Among children with isolated costal margin tenderness after blunt trauma, abdominal CT scans can likely be avoided.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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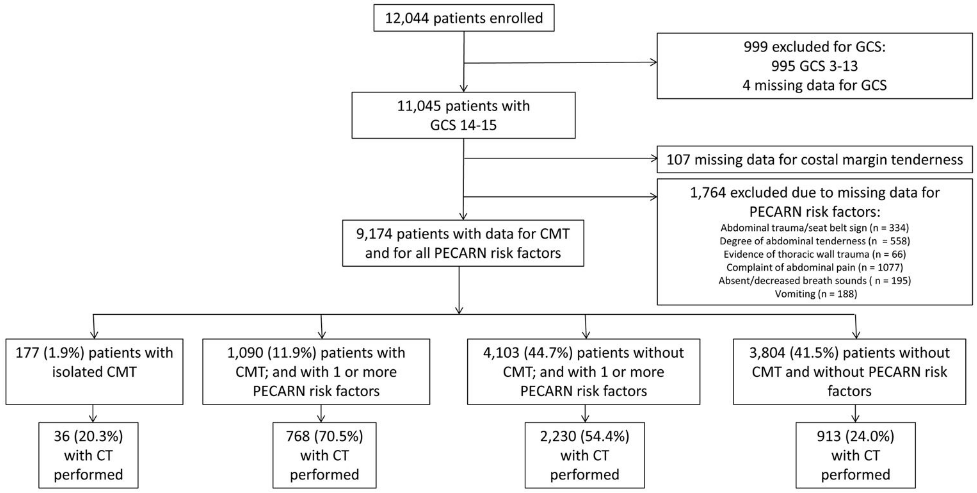

Figure 1.

Flow diagram of study population

GCS = Glasgow Coma Scale

PECARN = Pediatric Emergency Care Applied Research Network

CMT = costal margin tenderness

CT = computed tomography

Table 1

Clinical characteristics of children with isolated[*] and non-isolated[†] costal margin tenderness, n (%) unless otherwise indicated

	Isolated costal margin tenderness (n = 177)	Non-isolated costal margin tenderness (n = 1090)
Demographics		
Age in years, median (IQR)	14 (10, 16)	13 (10, 16)
Male	112 (63.3)	712 (65.3)
Mechanism of Injury		
Motor vehicle collision	52 (29.4)	263 (24.1)
Pedestrian/Bicycle struck by moving vehicle	14 (7.9)	117 (10.9)
ATV/motorcycle/scooter collision	5 (2.8)	55 (5.1)
Bicycle collision or fall from bicycle	6 (3.4)	86 (7.9)
Fall from elevation	18 (10.2)	119 (10.9)
Fall down stairs	7 (4.0)	20 (1.8)
Abdomen struck by object	23 (13.0)	206 (18.9)
Other	51 (28.8)	221 (20.3)
Unknown mechanism	1 (0.6)	3 (0.3)

IQR = interquartile range

ATV = all-terrain vehicle

[*]Isolated costal margin tenderness defined as costal margin tenderness with documented absence of all other PECARN risk factors (evidence of abdominal wall trauma or seat belt sign, abdominal tenderness on exam, complaints of abdominal pain, evidence of thoracic wall trauma, decreased breath sounds, and vomiting).

[†]Non-isolated costal margin tenderness defined as costal margin tenderness with one or more PECARN risk factors.

Table 2

Association between isolated and non-isolated costal margin tenderness and a) Intra-abdominal injury and b) Intra-abdominal injury undergoing acute intervention

a) Intra-abdominal injury

	No./No.	% (95% CI)	OR (95% CI)	AOR3* (95% CI)
Isolated CMT	0/177	0.0 (0.0, 2.2)	--	--
CMT with 1+ PECARN risk factors	187/1,090	17.2 (15.0, 19.5)	19.5 (13.7, 27.6)	21.5 (15.1, 30.7)
No CMT, 1+ PECARN risk factors	280/4,103	6.8 (6.1, 7.6)	6.9 (4.9, 9.6)	6.7 (4.8, 9.4)
No CMT, no PECARN risk factors	40/3,804	1.1 (0.8, 1.4)	Reference	Reference

b) Intra-abdominal injury undergoing acute intervention

	No./No.	% (95% CI)	OR (95% CI)	aOR‡ (95% CI)
Isolated CMT	0/177	0.0 (0.0, 1.8)	--	--
CMT with 1+ PECARN risk factors	36/1,090	3.3 (2.3, 4.5)	21.6 (9.1, 51.5)	27.8 (11.5, 67.1)
No CMT, 1+ PECARN risk factors	71/4,103	1.7 (1.4, 2.2)	11.1 (4.8, 25.7)	10.8 (4.7, 24.9)
No CMT, no PECARN risk factors	6/3,804	0.2 (0.0, 0.3)	Reference	Reference

PECARN = Pediatric Emergency Care and Research Network

CMT = costal margin tenderness

IAI = intra-abdominal injury

CI = confidence interval

OR = odds ratio

aOR = adjusted odds ratio

*Adjusted for age, Glasgow Coma Scale score, and mechanism of injury.

Table 3

Risk of intra-abdominal injury in children with costal margin tenderness (CMT) and each PECARN risk factor compared to children with only that PECARN risk factor in isolation

	N	Risk exposed (with CMT)		Risk unexposed (no CMT)		Risk difference
		No./No.	**% (95% CI)**	**No/No.**	**% (95% CI)**	**% (95% CI)**
Abdominal trauma/seatbelt sign	304	1/12	8.3 (0.2, 38.5)	8/292	2.7 (1.2, 5.3)	5.6% (−10, 21)
Abdominal tenderness	197	3/38	7.9 (1.7, 21.4)	7/159	4.4 (1.8, 8.9)	3.5% (−5.7, 13)
Complaint of abdominal pain	243	2/38	5.3 (0.6, 17.7)	4/205	2.0 (0.5, 4.9)	3.3% (−4.0, 11)
Thoracic wall trauma	653	4/119	3.4 (0.9, 8.4)	5/534	0.9 (0.3, 2.2)	2.4% (−0.9, 5.8)
Absent/decreased breath sounds	29	0/5	0 (0.0, 45.1)	1/24	4.2 (0.1, 21.1)	−4.2% (−12, 3.8)
Vomiting	274	0/8	0 (0.0, 31.2)	5/266	1.9 (0.6, 4.3)	−1.9% (−3.5, −0.2)

PECARN = Pediatric Emergency Care and Research Network

CI = confidence interval

Table 4

Rate of overall abdominal CT scan use and abdominal CT scan use in children without intra-abdominal injuries among those with isolated and non-isolated costal margin tenderness

	Overall CT scan use		CT scan use in children without intra-abdominal injury	
	No./No.	**(%; 95% CI)**	**No./No.**	**(%; 95% CI)**
Isolated CMT	36/177	(20.3; 14.7, 27.0)	36/177	(20.3; 14.7, 27.0)
CMT with 1+ PECARN risk factors	768/1090	(70.5; 67.7, 73.2)	582/903	(64.5; 61.2, 67.6)
No CMT, 1+ PECARN risk factors	2,230/4,103	(54.4; 52.8, 55.9)	1,951/3,823	(51.0; 49.4, 52.6)
No CMT, no PECARN risk factors	913/3,804	(24.0; 22.7, 25.4)	873/3,764	(23.2; 21.9, 24.6)

CT = computed tomography

CMT = costal margin tenderness