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ORIGINAL CONTRIBUTION

Association Between the Seat Belt Sign and Intra-abdominal Injuries in Children With Blunt Torso Trauma in Motor Vehicle Collisions

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Abstract

Objectives: The objective was to determine the association between the abdominal seat belt sign and intra-abdominal injuries (IAIs) in children presenting to emergency departments with blunt torso trauma after motor vehicle collisions (MVCs).

Methods: This was a planned subgroup analysis of prospective data from a multicenter cohort study of children with blunt torso trauma after MVCs. Patient history and physical examination findings were documented before abdominal computed tomography (CT) or laparotomy. Seat belt sign was defined as a continuous area of erythema, ecchymosis, or abrasion across the abdomen secondary to a seat belt restraint. The relative risk (RR) of IAI with 95% confidence intervals (CIs) was calculated for children with seat belt signs compared to those without. The risk of IAI in those patients with seat belt sign who were without abdominal pain or tenderness, and with Glasgow Coma Scale (GCS) scores of 14 or 15, was also calculated.

Results: A total of 3,740 children with seat belt sign documentation after blunt torso trauma in MVCs were enrolled; 585 (16%) had seat belt signs. Among the 1,864 children undergoing definitive abdominal testing (CT, laparotomy/laparoscopy, or autopsy), IAIs were more common in patients with seat belt signs than those without (19% vs. 12%; RR = 1.6, 95% CI = 1.3 to 2.1). This difference was primarily due to a greater risk of gastrointestinal injuries (hollow viscous or associated mesentery) in those with seat belt signs (11% vs. 1%; RR = 9.4, 95% CI = 5.4 to 16.4). IAI was diagnosed in 11 of 194 patients (5.7%;

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95% CI = 2.9% to 9.9%) with seat belt signs who did not have initial complaints of abdominal pain or tenderness and had GCS scores of 14 or 15.

Conclusions: Patients with seat belt signs after MVCs are at greater risk of IAI than those without seat belt signs, predominately due to gastrointestinal injuries. Although IAIs are less common in alert patients with seat belt signs who do not have initial complaints of abdominal pain or tenderness, the risk of IAI is sufficient that additional evaluation such as observation, laboratory studies, and potentially abdominal CT scanning is generally necessary.

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Seat belt use during a motor vehicle collision (MVC) is the single most effective measure to decrease morbidity and mortality.[1,2] The use of lap/shoulder restraints reduces the risk of fatal injuries in occupants age 5 years and older by 45% and the risk of moderate-to-critical injury by 50%.[1] Seat belt use by occupants in vehicles saved an estimated 12,546 lives in 2010,[2] whereas MVC-related deaths and injuries from lack of safety belt use account for an estimated $26 billion in costs to society annually.[3]

Using the correct restraint system and proper positioning of lap belts in children (low across the thighs and not across the abdomen) is important to reduce injuries. Prospective studies[4–6] and a review of crash injury network data[7] in adults indicate an association between the presence of the "seat belt sign" and intra-abdominal injury, particularly involving the intestines or associated mesentery. Pediatric studies of this topic primarily consist of case series or retrospective reviews.[8–24] A single-center prospective study demonstrated an association between the seat belt sign and intra-abdominal injury in children, but was limited by its small sample size.[25] In contrast, one pediatric study failed to demonstrate any association between the seat belt sign and intra-abdominal injury.[26] A large, prospective multicenter study regarding the implications of the seat belt sign in children has not previously been conducted.

The objective of the current study was to determine the association between the seat belt sign and intra-abdominal injuries in children presenting to emergency departments (EDs) after MVCs. Furthermore, we also sought to determine the rate of intra-abdominal injury among the subset of children with seat belt signs who do not have abdominal pain or tenderness and have Glasgow Coma Scale (GCS) scores of 14 or 15 on initial examination.

METHODS

Study Design

This was a planned subanalysis of a large prospective observational multicenter study of children with blunt torso trauma. The human subjects research committees at each participating institution approved the study protocol.

Study Setting and Population

The study was conducted between May 2007 and January 2010 at 20 pediatric EDs in the Pediatric Emergency Care Applied Research Network (PECARN), as part of a larger study to derive a clinical prediction rule for identifying children at low risk of intra-abdominal injuries undergoing acute intervention.[27] The current work builds on the prior study by providing detailed information on the importance of the seat belt sign.[27] In this substudy, we included patients younger than 18 years of age with histories of blunt abdominal trauma after MVCs, who were evaluated in the ED and had the presence or absence of seat belt sign documented during the initial evaluation. Children with both isolated abdominal trauma and abdominal trauma associated with multisystem injuries were included. We excluded children with preexisting neurologic disorders, traumatic injuries that occurred more than 24 hours prior to ED presentation, and those who were transferred to a study ED with prior abdominal computed tomography (CT) scanning.

Study Protocol

The ED clinician completed a history and physical examination on each enrolled patient. Clinical data were recorded onto a data collection form before CT scan results (if performed) or clinical outcomes were known. Abdominal CT scanning was obtained at the discretion of the treating physician and interpreted by the site radiologist.

We defined the "seat belt sign" as a continuous area of erythema, ecchymosis, or abrasion across the abdomen secondary to a seat belt restraint. This was explicitly stated on the data collection form. We considered abdominal pain present in those older than 2 years of age if the patient complained of pain in or over the abdomen. Abdominal pain was not evaluated in children younger than 2 years of age due to difficulty obtaining this information in the preverbal child. Abdominal tenderness was considered present if the child stated that palpation caused pain or if the patient grimaced on palpation of the abdomen.

Patients discharged to home after ED evaluation received telephone follow-up at least 1 week after ED discharge to determine if subsequent medical care was needed, abdominal imaging was obtained, or intra-abdominal injury was identified. Patients without symptoms of intra-abdominal injury at the telephone follow-up were considered not to have clinically important intra-abdominal injuries. We also conducted local reviews of trauma registries, medical records, and morgue reports for patients discharged from the ED who were not able to be contacted by telephone to ensure that intra-abdominal injuries were not subsequently identified.

Outcomes

Intra-abdominal injury was defined as any injury involving the spleen, liver, pancreas, urinary tract, adrenal glands, or gastrointestinal tract identified during the patient's ED stay, hospitalization, or at follow-up. Gastrointestinal tract injuries included any injury to the hollow viscous or associated mesentery from the stomach to the rectum. We defined solid organ injuries as those involving the liver, kidneys, or spleen. Patients were considered to have definitive abdominal testing for the diagnosis of intra-abdominal injury if they underwent abdominal CT scanning, laparotomy, laparoscopy, or autopsy.

The main outcome was intra-abdominal injury undergoing acute intervention defined by 1) therapeutic laparotomy, 2) angiographic embolization of an actively bleeding abdominal organ or other abdominal vascular structure, 3) blood transfusion for intra-abdominal hemorrhage, 4) administration of intravenous fluids for two or more nights in patients with pancreatic or gastrointestinal injuries, or 5) intra-abdominal injury resulting in death. The secondary outcome was intra-abdominal injury identified by any modality (e.g., CT, laparotomy, autopsy).

Data Analysis

We divided patients into two cohorts based on the presence or absence of the seat belt sign. For each cohort, we described patient demographics and therapies received using relative frequencies. We estimated the relative risk (RR) of intra-abdominal injury undergoing acute intervention for children with a seat belt sign compared to those without a seat belt sign. Additionally, we estimated the RR of intra-abdominal injury identified by any modality for children with a seat belt sign compared to those without. We restricted this analysis to patients undergoing definitive abdominal testing (abdominal CT, laparotomy, laparoscopy, or autopsy) and also estimated RRs for specific abdominal organs (gastrointestinal, spleen, liver, kidney, pancreas).

We performed multivariable regression analyses to identify the independent association of the seat belt sign with the two outcomes of interest. In these regression analyses, we selected covariates for consideration based on previous research on this topic and clinical sensibility. We adjusted for the following variables: vomiting, age-adjusted hypotension, GCS score less than 14, evidence of thoracic trauma, costal margin tenderness, decreased breath sounds, abdominal abrasion/contusion other than seat belt sign, and abdominal pain and/or tenderness. We used modified Poisson regression models fit to binary outcomes to estimate adjusted RRs.[28] To include all patients in regression models, we imputed missing data using chained regression models.[29,30] Separate models were fit for: 1) RR of intra-abdominal injury identified by any modality among all patients undergoing definitive abdominal testing, 2) RR of intra-abdominal injury undergoing acute intervention among all patients, 3) RR of intra-abdominal injury identified by any modality among restrained patients undergoing definitive abdominal testing, and 4) RR of intra-abdominal injury undergoing acute intervention among all restrained patients.

In a final subanalysis, we described those patients with the seat belt sign who did not have abdominal pain or tenderness at the time of initial ED evaluation and had GCS scores of 14 or 15. For this subgroup we described the rate of abdominal CT and the risk of intra-abdominal injury and intra-abdominal injury undergoing acute intervention.

We conducted all analyses using SAS/STAT software, version 9.3, and imputed missing values for regression models using IVEware. Statistical testing was considered significant for p-values < 0.05. No adjustments were made for multiple comparisons.

RESULTS

In the primary study, 12,044 patients with blunt torso trauma were enrolled. A total of 3,832 (32%) children sustained blunt torso trauma after MVCs and were the focus of this subanalysis. Ninety-two (2%) patients were further excluded due to missing data on the presence or absence of the seat belt sign. Therefore, the study population consisted of the 3,740 patients eligible for analysis (Figure 1). The median age was 12.2 years (interquartile range [IQR] = 6.4 to 16.3 years) and 1,951 (52%) were female.

Of the 3,740 patients, 249 (6.7%) had intra-abdominal injuries, and 88 (2.4%) had intra-abdominal injuries undergoing acute intervention. A total of 585 (16%) patients had seat belt signs: 84 (14.4%) of these patients had intra-abdominal injuries and 40 (6.8%) had intra-abdominal injuries undergoing acute intervention. Characteristics of the two study cohorts are described in Table 1.

A total of 1,864 (50%) patients underwent definitive abdominal testing. Of those with seat belt signs and definitive abdominal testing performed, 84 (18.8%, 95% confidence interval [CI] = 15.4% to 22.8%) had intra-abdominal injuries, and 40 (9.0%, 95% CI = 6.5% to 12.0%) had intra-abdominal injuries undergoing acute intervention. The rate of abdominal CT scanning was higher among those with the seat belt sign (443 out of 585, 76%) compared to those without the seat belt sign (1,415 out of 3,155; 45%), with an absolute difference in rates of 31% (95% CI = 27% to 35%).

Of the 249 patients with intra-abdominal injuries, 176 (71%) had solid organ injuries, 63 (25%) had gastrointestinal injures (hollow viscous or associated mesentery), and 15 (6%) had pancreatic injuries. Table 2 describes the types of intra-abdominal injuries identified for those with and without a seat belt sign among those who underwent definitive abdominal testing. Overall, intra-abdominal injuries were more likely to occur in those patients with a seat belt sign, primarily due to a greater rate of gastrointestinal injuries. Table 3 presents the rates of patients undergoing acute intervention for their intra-abdominal injuries. Overall, those with a seat belt sign were more likely (RR = 4.5, 95% CI = 3.0 to 6.8) to undergo intervention for their intra-abdominal injuries than those without a seat belt sign.

We modeled the risk of intra-abdominal injury adjusted for physical examination findings in those patients who underwent definitive abdominal testing (Table 4). Rates of imputation for missing variables are presented in Data Supplement S1 (available as supporting information in the online version of this paper). After adjusting for other important patient history and

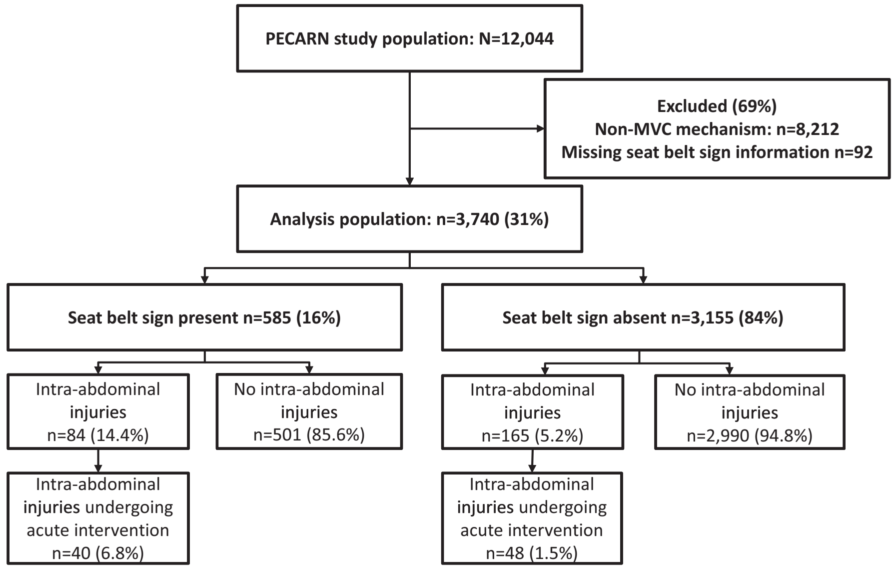

Figure 1. Flow diagram of study population.

Table 1
Characteristics of the 3,740 Motor Vehicle Collision Study Patients

Characteristic	Seat Belt Sign (*n* = 585)	No Seat Belt Sign (*n* = 3,155)
Age (yr), median (IQR)	10.2 (6.8–15.2)	12.6 (6.3–16.5)
Sex (male)	287 (49)	1,502 (48)
Restrained*	552 (99)	2,086 (73)
Abdominal CT	443 (76)	1,415 (45)
Hospital admission†	351 (60)	1349 (43)
Laparotomy	38 (6)	26 (1)

Data are reported as *n* (%) unless otherwise noted.
IQR = Interquartile range.
*Missing restraint use information for 29 with seat belt sign and 312 with no seat belt sign; missing values not included in the calculation of percentages.
†Hospital admission for one or more nights.

physical examination findings, the presence of a seat belt sign was an independent predictor of intra-abdominal injury (adjusted RR = 1.8, 95% CI = 1.3 to 2.4). We modeled the risk of intra-abdominal injury undergoing acute intervention adjusted for the same factors as above, but among the entire 3,740 patients in this cohort (Table 5). Again, the presence of a seat belt sign was an independent predictor for intra-abdominal injury undergoing acute intervention (adjusted RR = 5.5, 95% CI = 3.0 to 10.0).

The multivariable analyses in which we modeled 1) the risk of intra-abdominal injury among the 1,377 patients who were restrained and underwent definitive abdominal testing and 2) the risk of intra-abdominal injury undergoing acute intervention among the 2,835 patients who were restrained are presented in Data Supplement S2 (available as supporting information in the online version of this paper) and Table 6, respectively. The presence of a seat belt sign was an independent predictor for intra-abdominal injury and a very strong predictor for intra-abdominal injury undergoing acute intervention.

A total of 194 (33%) patients with seat belt signs did not have complaints of abdominal pain on initial history or abdominal tenderness on initial physical examination and had GCS scores of 14 or 15. Patient history and physical examination findings among these 194 patients

Table 2
Types of Intra-abdominal Injuries in Study Patients Undergoing Definitive Abdominal Testing (*N* = 1,864)*

Injury	Seat Belt Sign (*n* = 445)	No Seat Belt Sign (*n* = 1,419)	RR (95% CI)
Any IAI	84 (19)	165 (12)	1.6 (1.3–2.1)
Gastrointestinal	47 (11)	16 (1)	9.4 (5.4–16.4)
Solid organ	38 (9)	138 (10)	0.9 (0.6–1.2)
Spleen	22 (5)	75 (5)	0.9 (0.6–1.5)
Liver	19 (4)	71 (5)	0.9 (0.5–1.4)
Kidney	13 (3)	23 (2)	1.8 (0.9–3.5)
Pancreas	6 (1)	9 (1)	2.1 (0.8–5.9)

Data are reported as *n* (%)
IAI = intra-abdominal injury; RR = relative risk.
*Definitive abdominal test defined as abdominal CT, laparotomy, laparoscopy, or autopsy.

Table 3
Types of Acute Interventions in Patients With Intra-abdominal Injuries Among Study Patients (N = 3,740)

Outcome	Seat Belt Sign (n = 585)	No Seat Belt Sign (n = 3,155)	RR (95% CI)
Any IAI undergoing acute intervention	40 (7)	48 (2)	4.5 (3.0–6.8)
IV fluids ≥ 2 days*	27 (5)	10 (0.3)	14.6 (7.1–29.9)
Therapeutic laparotomy	37 (6)	21 (1)	9.5 (5.6–16.1)
Blood transfusion	17 (3)	32 (1)	2.9 (1.6–5.1)
Angiographic embolization	1 (0.2)	5 (0.2)	1.1 (0.1–9.2)
Death related to the IAI	1 (0.2)	5 (0.2)	1.1 (0.1–9.2)

Data are reported as n (%).
*In only one of the 27 patients with seat belt signs receiving IV fluids ≥ 2 days was the IV fluid their only acute intervention. Three of the patients without seat belt signs had IV fluids ≥ 2 days as their only acute intervention.
IAI = intra-abdominal injury; IV = intravenous; RR = relative risk.

Table 4
Multivariable Analysis Modeling the Relative Risk of Intra-abdominal Injury in Motor Vehicle Collision Patients Undergoing Definitive Abdominal Testing (n = 1,864)*

Characteristic	Multivariable Risk Ratio (95% CI)	p-value
Vomiting	1.4 (1.0–2.0)	0.06
Hypotension	2.4 (1.7–3.5)	< 0.01
GCS score < 14	2.5 (1.8–3.5)	< 0.01
Decreased breath sounds	1.6 (1.1–2.4)	0.01
Evidence of thoracic trauma	1.4 (1.1–1.8)	0.02
Costal margin tenderness	1.4 (1.0–2.0)	0.02
Abdominal pain and/or tenderness	1.6 (1.2–2.2)	< 0.01
Restrained	0.8 (0.6–1.0)	0.09
Abdominal abrasion/contusion		
Seat belt sign	1.8 (1.3–2.4)	< 0.01
Other abrasion/contusion	1.3 (0.9–1.9)	0.11
None		Reference

GCS = Glasgow Coma Scale.
*Definitive abdominal test defined as abdominal CT, laparotomy, laparoscopy, or autopsy.

Table 5
Multivariable Analysis Modeling the Relative Risk of Intra-abdominal Injury Undergoing Acute Intervention in All Study Patients (n = 3,740)

Characteristic	Multivariable Risk Ratio (95% CI)	p-value
Vomiting	2.3 (1.3–4.0)	< 0.01
Hypotension	5.0 (2.8–8.9)	< 0.01
GCS score < 14	10.1 (5.9–17.3)	< 0.01
Decreased breath sounds	2.1 (1.1–4.1)	0.02
Evidence of thoracic trauma	1.0 (0.6–1.8)	0.93
Costal margin tenderness	2.0 (1.1–3.7)	0.03
Abdominal pain and/or tenderness	3.1 (1.9–5.2)	< 0.01
Restrained	0.6 (0.3–1.2)	0.14
Abdominal abrasion/contusion		
Seat belt sign	5.5 (3.0–10.0)	< 0.01
Other abrasion/contusion	2.1 (1.1–3.9)	0.02
None		Reference

GCS = Glasgow Coma Scale.

included high-risk mechanism of injury (55), hypotension (2), presence of thoracic trauma (79), absent/decreased breath sounds (4), vomiting (5), and femur fracture (8). Of the 194 patients, 101 (52%, 95% CI = 45% to 59%) had abdominal CT scans performed. Table 7 shows the clinical details for 11 (5.7%, 95% CI = 2.9% to 9.9%) of the 194 patients who had intra-abdominal injuries diagnosed, including the four (2.1%, 95% CI = 0.6% to 5.2%) having intra-abdominal injuries undergoing acute intervention. None of these 11 patients had their intra-abdominal injuries identified after discharge from the ED or hospital.

A total of 1,714 patients did not have a seat belt sign, complaints of abdominal pain on initial history, or abdominal tenderness on initial physical examination and also had GCS scores of 14 or 15. Of these patients, 488 (28%, 95% CI = 26% to 31%) underwent abdominal CT scanning. Thirty-two (1.9%, 95% CI = 1.3% to 2.6%) of these 1,714 patients had intra-abdominal injuries identified and five (0.3%, 95% CI = 0.1% to 0.7) underwent acute intervention (three solid organ angiographic embolizations and two blood transfusions).

DISCUSSION

In this large, multicenter prospective study, we confirm the independent association between the seat belt sign and intra-abdominal injuries in pediatric patients presenting to EDs after MVCs. Children with seat belt signs were substantially more likely to incur intra-abdominal injuries, primarily due to increased risks of gastrointestinal injuries, compared to those without seat belt signs. Similar to previous work, no increased risk of solid organ injuries (spleen, liver, or kidney) was identified in those with seat belt signs.[25] Furthermore, patients with seat belt signs were 4.5 times more likely to undergo acute intervention for their intra-abdominal injuries, and 9.5 times more likely to undergo therapeutic laparotomy,

Table 6
Multivariable Analysis Modeling the Relative Risk of Intra-abdominal Injury Undergoing Acute Intervention in Restrained Motor Vehicle Collision Patients (n = 2,835)

Characteristic	Multivariable Risk Ratio (95% CI)	p-value
Vomiting	2.7 (1.5–5.0)	<0.01
Hypotension	5.7 (2.6–12.8)	<0.01
GCS score < 14	10.0 (5.0–20.1)	<0.01
Decreased breath sounds	2.8 (1.1–7.0)	0.03
Evidence of thoracic trauma	0.9 (0.5–1.8)	0.80
Costal margin tenderness	1.3 (0.6–3.0)	0.50
Abdominal pain and/or tenderness	4.7 (2.6–8.7)	<0.01
Abdominal abrasion/contusion		
Seat belt sign	4.7 (2.6–8.7)	<0.01
Other abrasion/ contusion	2.0 (0.8–4.9)	0.15
None		Reference

GCS = Glasgow Coma Scale.

than those without seat belt signs. Finally, 2% of patients with seat belt signs but without initial abdominal pain or tenderness and with GCS scores of 14 or 15 had intra-abdominal injuries that underwent acute intervention.

This study demonstrates an increased risk of intra-abdominal injuries in patients with seat belt signs, consistent with prior research. The exact rates of injuries, however, were lower than prior studies. The rate of intra-abdominal injury in the current study was 19% of those with seat belt sign who underwent definitive abdominal testing. This finding is substantially lower than the 30% identified in the only prior prospective study on this topic.[25] This may in part be due to more selective CT scanning in the current study. A large retrospective study suggested the rate of intra-abdominal injury to be 21% in the presence of the seat belt sign; however, that study was subject to selection bias as it only included hospitalized patients.[20]

In addition, the rate of gastrointestinal injuries in those with seat belt signs (11% of those undergoing definitive abdominal testing) was lower compared to the nearly 25% identified in prior studies.[24,25] The rate of pancreatic injuries in those with seat belt signs was only 1% in the current study, which is lower than the 7% in the prior prospective study.[25] The 9% rate of solid organ injuries in those with seat belt signs was identical to that in the prior prospective study,[25] but less than the rate of 21% reported in a retrospective study.[24]

Overall, the seat belt sign was associated with an increased risk of intra-abdominal injuries in our population, especially due to gastrointestinal injuries, which has previously been demonstrated and described.[25,31] Another study, however, suggested that the seat belt sign was not associated with abdominal injuries.[26] That study, however, consisted of a retrospective chart review that relied on physician documentation of a seat belt sign in the medical record. Prospective documentation of the seat belt sign likely increases the reliability of the findings and thus likely reflects a closer representation of the truth. In addition, other studies suggest that seat belt use is not a stand-alone factor that increases the risk for intra-abdominal injuries, but rather changes the spectrum and patterns of injuries.[32,33] The current study indicates that the seat belt sign is associated with a higher rate of gastrointestinal injuries whereas the rate of solid organ injuries remains unchanged. In addition, proper restraint at the time of the crash is important, as the risk of intra-abdominal injury is higher in children whom are suboptimally restrained.[34,35]

The laparotomy rate of 6% in the study population with seat belt signs was lower than the rate reported in most prior pediatric reports, ranging from 19% to 37%.[21,24,25] One prior study, however, reported a similarly low rate of pediatric laparotomy as the current study.[26] The differences in the laparotomy rates noted in prior studies are likely due to different patient populations, study protocols (prospective vs. retrospective data collection), study definitions, and surgical practices. The laparotomy rate reported in the current study is from 20 different participating institutions and thus likely represents a more generalizable estimate during

Table 7
Characteristics of the 11 Children With Intra-abdominal Injuries and Seat Belt Signs Who Did Not Have Abdominal Pain or Tenderness on Initial Evaluation

Age (yr)	Mechanism	Abdominal Injury	Intervention
3	>40 mph, lap belt only	GI	None
5	>40 mph, booster seat	GI	None
10	20–40 mph, lap and shoulder	Spleen	None
14	>40 mph, lap and shoulder	Adrenal	None
16	20–40 mph, lap and shoulder	Adrenal	None
16	Rollover, lap and shoulder	Liver	None
17	Lap and shoulder	Liver, kidney	None
3	Unknown speed, booster seat	Urinary bladder	Laparotomy
4	>40 mph	GI, pancreas	NPO, IVF
8	>40 mph, ejected	Spleen	Transfusion
17	Unknown speed, lap and shoulder	GI, Spleen	Embolization

GI = gastrointestinal; MPH = miles per hour; NPO = not by mouth; IVF = intravenous fluids.

an era in which nonsurgical management of most pediatric abdominal injuries is favored. Regardless, the risk of intra-abdominal injuries undergoing laparotomy remains substantial in children with the seat belt sign.

We found that children with the seat belt sign were more likely to have intra-abdominal injuries undergoing acute intervention, including intravenous fluids administration, therapeutic laparotomies, and blood transfusions. Children with the seat belt sign, however, were not at an increased risk for angiographic embolization or death from their intra-abdominal injuries. Overall, approximately one-half of the patients with seat belt signs and intra-abdominal injuries underwent acute interventions. This important finding has implications on the management of, and resource utilization for, these children. These patients in general require more diagnostic testing and periods of ED observation and/or hospitalization and occasionally specific therapeutic interventions.

Patients with seat belt signs and abdominal pain or tenderness on examination are at higher risk for intra-abdominal injuries and warrant additional diagnostic evaluation (observation, laboratory studies, or CT imaging) depending on the clinical scenario. In the current study, 89% of those with seatbelt signs and abdominal pain, abdominal tenderness, or a GCS score less than 14 underwent abdominal CT scanning.

The risk of intra-abdominal injuries in children with seat belt signs but without abdominal pain and tenderness on initial evaluation, however, is less, and the approach to these patients is less clear. One study suggested that the rate of intra-abdominal injuries in children with the seat belt sign but without abdominal pain or tenderness is low and that additional diagnostic evaluation may not be necessary.[25] In the current study, however, we found a small but important proportion of patients with seat belt signs but without initial abdominal pain or tenderness who had intra-abdominal injuries, including 2% who underwent acute intervention. Furthermore, the multivariable analyses confirm the independent association of the seat belt sign with both intra-abdominal injuries and intra-abdominal injuries undergoing acute intervention. Therefore, it appears that despite the relatively lower risk of intra-abdominal injuries in these patients, additional evaluation is usually warranted, which could include observation, laboratory screening, or CT scanning. Of note, however, only one-half of these asymptomatic patients with seat belt signs underwent CT scanning in the current study, suggesting that clinicians safely evaluate and manage many of these patients without CT scanning.

LIMITATIONS

The rate of abdominal CT use among those with the seat belt sign was higher compared to those without, suggesting a certain degree of evaluation bias. In addition, some of those patients with the seat belt sign who were not imaged with CT in the current study may have had "clinically silent" intra-abdominal injuries, which could explain some of the differences in injury proportions between this and previous studies. Furthermore, patients discharged from the ED may have had undiagnosed intra-abdominal injuries. Several modes of follow-up, however, were performed to identify such patients,[27] and the primary outcome of intra-abdominal injury undergoing acute intervention was assessable in all patients regardless of abdominal CT use. Finally, patients classified as having intra-abdominal injuries undergoing acute intervention due to receiving intravenous fluids for two or more nights to maintain hydration because of gastrointestinal or pancreatic injuries may have received more extensive workups than those without such treatment. Further research is needed to determine the appropriate evaluation of pediatric patients with seat belt signs and no pain or tenderness on evaluation.

CONCLUSIONS

Pediatric patients with seat belt signs after motor vehicle crashes are at a greater risk of intra-abdominal injuries than those without seat belt signs, primarily due to a greater risk of gastrointestinal injuries. In addition, these patients are also more likely to undergo acute interventions than those without seat belt signs. Although intra-abdominal injuries are uncommon in patients with seat belt signs and no initial complaints of abdominal pain or abdominal tenderness on examination, the risk of intra-abdominal injury is such that additional evaluation with observation, laboratory studies, and potentially abdominal computed tomography is generally necessary.

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APPENDIX A

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 (A. Ellison); 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 (J. Holmes, N. Kuppermann); 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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Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1. Missing variables and rates of imputation.

Data Supplement S2. Multivariable analysis modeling the relative risk of intra-abdominal injury in restrained MVC patients undergoing definitive abdominal testing (n = 1,377).