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Nonoperative management of penetrating abdominal solid organ injuries in children

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ABSTRACT

Background: Nonoperative management (NOM) of penetrating solid organ injuries (SOI) has not been well described in the pediatric population. The objective of this study was to characterize the epidemiology, injury patterns, and factors associated with trial and failure of NOM.

Methods: This is a retrospective cohort analysis of the National Trauma Data Bank for the period of 2007-2014. The study population included patients ≤18 y with penetrating injury to the liver, spleen, or kidney. NOM was defined as no operative intervention (exploratory laparotomy or operation involving the liver, spleen, or kidney) < 4 h of emergency department arrival. Failed NOM was defined as operative intervention ≥4 h after emergency department arrival. Multivariate logistic regression explored clinical factors potentially associated with trial and failure of NOM.

Results: Of 943,000 pediatric trauma patients included in the National Trauma Data Bank, 3005 (0.32%) met our inclusion criteria. Median age was 17.0 y; 88.8% were male. Gunshot wounds (GSW) accounted for 71.7% of injury mechanisms and stab wounds accounted for the remaining 28.3%. Median injury severity score was 9 (interquartile range: 5-13). Two thousand one hundred and twenty-one (70.6%) patients sustained kidney injury, 1210 (40.3%) liver injury, and 159 (5.3%) splenic injury. NOM was pursued in 615 (20.5%) patients. Factors significantly associated with immediate operative intervention included GSW, hypotension, and associated hollow viscus injury. Failed NOM was identified in 175 patients (28.5%). Factors significantly associated with failed NOM included GSW, high-grade SOI, and associated hollow viscus injury. Overall mortality was 26 (0.9%).

Conclusions: NOM can be safe in a carefully selected group of pediatric patients with penetrating SOI. Future prospective studies are warranted to validate its feasibility.

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Over the past few decades, the selective nonoperative management (NOM) of solid organ injuries (SOI) has become a widely accepted practice in pediatric patients following blunt abdominal trauma.[1,2] Selective NOM in blunt SOI has led to a decrease in nontherapeutic laparotomies, associated complications, hospital length of stay (LOS), and costs.[1,3,4] As a result, a significant decrease in operative intervention for pediatric blunt SOI has been observed in the United States.[4]

Historically, mandatory exploration of penetrating injuries was considered standard of care for the adult population. However, a high incidence of negative laparotomy was reported following abdominal penetrating injury.[5] Further, contemporary data have led to a major paradigm shift such that selective NOM is now considered the appropriate management for adult patients sustaining penetrating abdominal trauma, who are hemodynamically stable without signs of peritonitis.[6-10] To date, little data have examined whether the use of selective NOM in pediatric patients with SOI following penetrating abdominal trauma is an appropriate management strategy. In contrast to adult patients, selection principles for NOM for penetrating SOI are not well defined in children, and there are conflicting reports on the need for mandatory exploration.[9,11,12] Furthermore, no previous studies have assessed for clinical factors associated with failure of NOM for penetrating SOI in pediatric population.[6]

The aims of this study were to characterize the epidemiology, injury patterns, and patient-level factors associated with trial and failure of NOM for penetrating abdominal SOI in the pediatric population and to characterize outcomes in this specific group of trauma patients. We hypothesized that selective NOM would be safe in carefully selected pediatric patients who sustain penetrating abdominal SOI.

Methods

Study design and patient selection

We performed an 8-y (2007-2014) retrospective analysis of the National Trauma Data Bank (NTDB). The NTDB is a nationwide trauma database maintained by the American College of Surgeons and contains data on more than 5 million patients, with contributions from more than 900 trauma centers across the United States. Our study was approved as exempt by the institutional review board of the University of Southern California.

Patients ≤18 y of age were included. Penetrating solid organ (liver, kidney, spleen) injuries were identified using the International Classification of Disease (ICD)-9 diagnosis and external cause of injury codes. Patients were excluded if they were pronounced dead on arrival or if they were lost to follow-up following the index hospitalization (hospital disposition: left against medical advice) or if they had associated severe injuries defined as abbreviated injury scale ≥3 to the head, neck, chest, spine, or extremity. The primary outcome included initial trial of NOM and NOM failure. The definition of NOM was time dependent and consisted of no emergent operative intervention for abdominal injuries <4 h after arrival to emergency department (ED) based on previous data in adult patients.[10] NOM failure included any major abdominal operations ≥4 h of ED arrival, including diagnostic laparoscopy. Major abdominal operations were defined by ICD-9 procedure codes and included exploratory laparotomy (54.11) as well as operations on the spleen (41.00-41.99), esophagus (41.20-42.19, 42.30-42.80, 42.84-42.92), hollow viscus (43.00-43.99, 44.00-44.09, 44.30-44.61, 44.63-44.99, 45.00-47.99, 48.60-48.99), liver (50.00-50.09, 50.20-50.89, 50.99), hepatobiliary (51.00-51.09, 51.20-51.99), pancreas (52.00-52.09, 52.20-52.99), kidney (55.00-55.19, 55.30-55.99), urinary system (56.00-56.29, 56.40-56.99), and vascular (38.04, 38.06, 38.07, 38.14, 38.16, 38.34, 38.36, 38.37, 38.44, 38.46, 38.47, 38.84, 38.86, 38.87, 39.10, 39.24, 39.26, 39.30-39.35, 39.79, 39.93, 39.98, 39.99). Angiography and angioembolization (39.79, 88.40, 88.45, 88.47, and 88.49) were considered separately and did not constitute NOM failure.

We abstracted the following variables: patient demographics, ED vital signs and Glasgow coma scale, mechanism of injury, injury severity using injury severity score and abbreviated injury scale, mechanical ventilation support, intensive care unit (ICU) admission, hospital LOS, ICU LOS, and in-hospital mortality. Tachycardia was defined as a pulse rate >120. Hypotension was defined according to age as follows: systolic blood pressure (SBP) < 90 mmHg if age ≥10 otherwise SBP < (70 + 2 × age) if age <10.[13] We also calculated shock index, pediatric age-adjusted (SIPA: heart rate/SBP).[14] Cutoffs used to define increased SIPA were following: 1.2 (age 1-6), 1.0 (age 7-12), and 0.9 (age 13-18) as defined by Acker *et al*.[14]

Statistical analysis

Descriptive statistical analysis was performed for the study population. Values were reported as mean with standard deviation for continuous variables with normal distributions, median with interquartile range (IQR) for continuous variables with nonnormal distributions, and as frequencies for categorical variables. Bivariate analysis was performed using chi-square to test differences in proportions and unpaired Student's *t*-test or Wilcoxon test to compare differences between means and medians, respectively. Mantel–Haenszel chi-square was used to test for the significance of a linear relationship between ordinal variables. Univariate logistic regression was performed to assess for the association between clinically relevant variables and trial and failure of NOM. Variables that were significantly associated with the outcome of interest were then included in a multivariable model with results reported as raw and adjusted odds ratios (OR) and 95% confidence intervals (CIs). A two-sided *P* value of 0.05 was considered statistically significant, and no adjustments were made for multiple comparisons. Statistics were performed using SAS software (Version 9.4; SAS Institute, CARY, NC).

Results

A total of 63,716 pediatric patients with SOI were identified in the NTDB during our study period. Of these, 7330 (11.5%) were due to a penetrating mechanism of injury. After excluding 3936 patients that had severe concomitant injuries and 389

patients that arrived dead on arrival, 3005 patients were included in the analysis. Patient characteristics are summarized in Table 1. Our study patients were more likely to be male (88.8%), and median age was 17 (IQR: 15-18). The median injury severity score was nine (IQR: 5-13) with 28.3% of the injuries due to stab wounds (SW) and 71.7% due to gunshot wounds (GSW). Overall, 11.2% presented to the ED with tachycardia and 4.8% were hypotensive. The distribution of injuries was following: 40.3% liver, 70.6% kidney, and 5.3% spleen, and 15.6% of patients had multiple SOI. Associated hollow viscus injuries were found in 67.4% of patients, and 77.5% of these patients underwent an operation within 4 h of ED arrival.

Operative interventions are detailed in Table 2. NOM was initiated in 615 (20.5%) patients with 71.5% (440 of 615) success. There were no significant differences in the rate of NOM trial and successful NOM between each age group[1-18] (Table 3). The median time to NOM failure was 8 h from ED arrival (IQR: 5-25). Of 1210 liver injuries, 298 (24.6%) underwent a trial of NOM with 80.5% success. Of 2121 kidney injuries, 361 (17.0%) underwent a trial of NOM with a 65.9% success. Of 159 splenic injuries, 35 (22.0%) were treated nonoperatively with a 48.7% success. NOM was more frequently attempted in patients with SW compared to GSW (36.0% *versus* 14.3%, $P < 0.001$), and NOM was more likely to be successful with SW (83.7% *versus* 59.4%, $P < 0.001$). An elevated SIPA was significantly associated with NOM failure (OR: 1.53, 95% CI: 1.00-2.36, $P = 0.048$) but not with immediate operation (OR: 0.86, 95% CI: 0.70-1.08, $P = 0.20$) in the univariate analysis. However, elevated SIPA was not significantly associated with NOM failure in the multivariate analysis (OR: 1.08, 95% CI: 0.44-2.66, $P = 0.86$). Angiography or angioembolization was attempted in 5.0% (31/615) of patients undergoing NOM. Diagnostic laparoscopy was performed in 14 patients after a trial of NOM. All cases demonstrated positive findings that required further procedures. Rates of NOM did not change significantly over the study period ($P = 0.21$) nor did rates of NOM failure ($P = 0.47$).

Table 4 shows the results of logistic regression analysis for trial of NOM. Significant independent factors associated with immediate operative intervention were GSW (OR: 0.51, 95% CI: [0.41-0.62], $P < 0.001$), hypotension (OR: 0.34, 95% CI: [0.17-0.67], $P = 0.002$) and associated hollow viscus injury (OR: 0.25, 95% CI: 0.21-0.31, $P < 0.001$). A separate univariate logistic regression model modeling the association between hospital trauma center designation and the likelihood of operative management found that pediatric trauma centers are more likely to undergo a trial of NOM compared to adult trauma centers (OR: 1.65, 95% CI 1.11-2.45, $P = 0.01$), although no effect was observed between mixed designation trauma centers and pediatric trauma centers (OR 1.11, 95% CI 0.75-1.66, $P = 0.60$).

Table 5 shows the results of logistic regression analysis for failure of NOM. Factors significantly associated with failed NOM included GSW (OR: 2.01, 95% CI: 1.29-3.13, $P = 0.002$), associated hollow viscus injury (OR: 6.42, 95% CI: 4.18-9.84, $P < 0.001$), and high-grade SOI (OR: 2.16, 95% CI: 1.13-4.10, $P = 0.02$). On univariate analysis, pediatric trauma center designation was not associated with a decreased risk of NOM failure compared to adult trauma centers (OR 0.82, 95% CI 0.40-1.68, $P = 0.58$) or mixed adult-pediatric trauma centers (OR 0.63, 95% CI 0.30-1.31, $P = 0.22$). Hospital outcomes data are detailed in Table 6. The median hospital LOS was 7 d in patients requiring an immediate operation, 7 d in patients with NOM failure, and 3 d in patients successfully treated nonoperatively. Overall mortality was 26 (0.9%). Only 1/175 (0.6%) patient died following failed NOM.

Table 1 – Demographics, injury and trauma center characteristics.

Variable	Total ($n = 3005$)
Age, median (IQR)	17 (15-18)
Age groups, *n* (%)	
1-4	78 (2.6)
5-9	67 (2.2)
10-13	131 (4.5)
14-18	2729 (90.8)
Male gender, (%)	2669 (88.8)
ISS, median (IQR)	9 (5-13)
Injury mechanism, (%)	
Stab wound	852 (28.3)
GSW	2153 (71.7)
ED vital signs, (%)	
Tachycardia	327 (11.2)
Hypotension	139 (4.8)
High SIPA	616 (20.5)
Solid organ injured, (%)	
Liver	1210 (40.3)
Kidney	2121 (70.6)
Spleen	159 (5.3)
Severe solid organ injury (AIS ≥4), (%)	325 (10.8)
Multiple solid organ injury, (%)	468 (15.6)
Associated hollow viscus injury, (%)	2024 (67.4)
Trauma center characteristics	
Pediatric	140 (4.7)
Adult	1713 (57.4)
Mixed	1078 (36.1)
Unknown	160 (1.8)

Table 2 – Surgical intervention rates.

	Immediate operation ($n = 2390$)	NOM failure ($n = 175$)
Exploratory laparotomy, (%)	1585 (66.3)	148 (84.6)
Laparotomy, *n* (%)		
Nephrectomy	118 (4.9)	16 (9.1)
Splenectomy	66 (2.8)	13 (7.4)
Liver procedures	22 (0.9)	2 (1.1)
Hollow viscus procedures	1684 (70.4)	147 (84.0)
Vascular procedures	398 (16.7)	38 (21.7)
Diagnostic laparoscopy, (%)	69 (2.9)	14 (8.0)
Angiography, (%)	23 (1.0)	22 (12.6)

Table 3 – Trial of nonoperative management and success rate by age group.

	Age 1-4	Age 5-9	Age 10-13	Age 14-18	P-value
Total patients	78	67	131	2729	-
Trial of NOM	14 (17.9%)	16 (23.9%)	32 (24.4%)	553 (20.3%)	0.55
NOM success	11/14 (78.6%)	9/16 (56.3%)	19/32 (59.4%)	401/553 (72.5%)	0.19

Discussion

The present study using a nationwide trauma database showed that selective NOM was attempted in 20.5% of pediatric patients who sustained penetrating abdominal SOI. The results of trial and failure rates of NOM are similar to those from previous studies in adults.[8-10] Furthermore, the results in the logistic regression suggest that NOM was appropriately selected using clinical factors associated with increased risk of NOM failure (hemodynamic instability and associated hollow viscus injury). Overall success rate of NOM was 71.5% without increased mortality. To our knowledge, this is the largest series to characterize selective NOM of penetrating SOI in the pediatric population, and our results confirm the hypothesis that selective NOM can be considered in children sustaining penetrating SOI who are hemodynamically stable and without signs of peritonitis.

Although the selective NOM of patients with abdominal penetrating wounds has been accepted in adults, there is still a need to characterize the role of selective NOM in children. In the 1990s, Dicker *et al.*[11] evaluated the feasibility of selective NOM of penetrating liver injury in children using the National pediatric trauma registry. Of 132 patients (24% SW and 76% GSW), only six patients (5%) were managed nonoperatively. The incidence of nontherapeutic laparotomy was 16%, which is comparable to the data in adults.[8] Although no data were shown regarding trial and failure of NOM in this study, the authors concluded that aggressive surgical intervention is recommended for penetrating liver injury in children. In contrast, Cigdem, *et al.*[12] demonstrated, in a single-center retrospective study, that 56.6% of patients sustaining penetrating abdominal trauma (67% SW and 33% GSW) were selected for NOM with only two patients failing NOM (96% success). Patients who were hemodynamically stable without signs of peritonitis were selected for NOM. Of note, abdominal ultrasonography was performed in NOM patients, and only 19.6% of patients were found to have SOI.

In recent literature, the utility of SIPA as a predictor for operative intervention was evaluated in blunt trauma. A retrospective study by Acker *et al.*[14] showed that 30% and 53% of pediatric patients (age 4-16) with an increased SIPA required operative intervention and blood transfusion, respectively. Arbuthnot *et al.*[15] reported that 95% of children with high-grade isolated blunt SOI, who required ICU-level interventions (transfusion, vasopressor use, intubation, or operation) had either an elevated SIPA or a hematocrit <30%. In the present study, an increased SIPA was not significantly associated with immediate operation or NOM failure following penetrating abdominal trauma.

In adults, it is suggested that NOM is contraindicated in patients with (1) hemodynamic instability, (2) diffuse abdominal pain or signs of peritonitis, or (3) unevaluable mental status.[16] In a prospective study at LAC + USC Medical Center, 40% of study patients with penetrating abdominal trauma did not meet these criteria for immediate operation.[9] However, an additional 15 patients underwent an exploratory laparotomy for the findings on computed tomography

Table 4 – Factors associated with trial of nonoperative management.

Variable	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Age group				
1-4	0.92 (0.53-1.61)	0.77	0.88 (4.67-1.67)	0.68
5-9	1.19 (0.68-2.08)	0.54	1.07 (0.56-2.02)	0.84
10-13	1.60 (1.09-2.33)	0.02	1.50 (0.98-2.30)	0.06
14-18	(reference)		(reference)	
Male gender	0.86 (0.66-1.11)	0.25	0.80 (0.60-1.08)	0.12
Hypotension	0.25 (0.13-0.49)	<0.001	0.34 (0.17-0.67)	0.002
Injury mechanism				
GSW	0.31 (0.26-0.37)	<0.001	0.51 (0.41-0.62)	<0.001
Stab wound	(reference)		(reference)	
High-grade SOI	1.01 (0.77-1.33)	0.96	1.09 (0.76-1.57)	0.63
Multiple SOI			0.78 (0.58-1.03)	0.08
Hollow viscus injury	0.19 (0.16-0.23)	<0.001	0.25 (0.21-0.31)	<0.001

Table 5 – Factors associated with failure of nonoperative management.

Variable	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Age group				
1-4	0.72 (0.20-2.60)	0.61	0.47 (0.11-1.96)	0.30
5-9	2.04 (0.75-5.58)	0.17	1.67 (0.52-5.34)	0.38
10-13	1.80 (0.87-3.73)	0.11	1.82 (0.77-4.31)	0.17
14-18	(reference)		(reference)	
Male gender	0.69 (0.42-1.14)	0.15	0.70 (0.40-1.24)	0.22
High SIPA	1.53 (1.00-2.36)	0.048	1.08 (0.44-2.66)	0.86
Injury mechanism				
GSW	3.52 (2.41-5.14)	<0.001	2.01 (1.29-3.13)	0.002
Stab wound	(reference)		(reference)	
High-grade SOI	1.98 (1.16-3.36)	0.01	2.16 (1.13-4.10)	0.02
Multiple SOI	0.98 (0.58-1.66)	0.94	0.73 (0.38-1.41)	0.35
Hollow viscus injury	7.98 (5.39-11.82)	<0.001	6.42 (4.18-9.84)	<0.001

(CT) suspicious for hollow viscus injury or diaphragm injury. As a result, 28.3% of all patients underwent a trial of NOM. This number is slightly higher than the result in our study (20.5%), likely due to differences in experience and resources available for selective NOM at each trauma center. However, it is important to note that, in our logistic regression model for a trial of NOM, the absence of hypotension and associated hollow viscus injury were factors significantly associated with a trial of NOM. These results suggest that the criteria for selective NOM in adult penetrating SOI are applicable to pediatric patients.

In addition to close monitoring of patients receiving NOM with serial abdominal examinations, the use of abdominal CT is advocated in previous literature.[9,10] As reported in our study, the most common reason for NOM failure is associated hollow viscus injury. Although the sensitivity of CT for hollow viscus injury is not very high, the CT findings suggestive of hollow vicus injury can be found early on and may be useful to minimize the delay in surgical intervention.[17] Also, a high-grade SOI with a CT finding of contrast blush (active arterial extravasation, pseudoaneurysm, or arteriovenous fistula) can be managed with angioembolization.[9] In the present study, we were unable to collect the data for diagnostic imaging performed in patients undergoing NOM. Given our results showing that 5.0% (31/615) of NOM patients underwent angiography or angioembolization, CT might be performed in selected patients who underwent NOM. In future studies, the utility of CT or alternative diagnostic modalities, such as ultrasound needs to be evaluated in pediatric patients.

Several aspects of this study create limitations on data interpretation. First, given its retrospective and epidemiologic approach, true causation could not be assessed. Although the number of trauma centers contributing patient data to the NTDB has been increasing annually, it still underrepresents the true number of cases because of the limited participation of U.S. trauma centers. Missing data and miscoding have also been a limitation with NTDB-based studies. We relied on NTDB ICD-9 diagnosis and procedure codes and had no way to verify that patients were correctly diagnosed and treated. Second, no standardized protocol has been proposed, at least in pediatric population, for trial of NOM. While we defined NOM failure as a major abdominal operation >4 h after ED arrival based on the data in previous literature, any institutions with different level of experience in NOM may require a different definition of NOM failure.[8,10,18] Third, due to our strict inclusion and exclusion criteria, the sample size in our study, particularly in the age 1-13 group, might not be large enough to show significant results. Although the NTDB is

Table 6 – Outcomes.

Outcome	Immediate operation ($n = 2390$)	NOM success ($n = 440$)	NOM failure ($n = 175$)	P value
Hospital LOS				
Days, median (IQR)	7 (5-10)	3 (2-6)	7 (5-13)	<0.001
ICU LOS				
No. Admitted (%)	1260 (47.2)	202 (45.9)	73 (41.7)	0.001
Days, median (IQR)	3 (2-5)	2 (1-3)	3 (2-4)	<0.001
Mechanical ventilation				
Days, median (IQR)	2 (1-4)	2 (1-6)	2 (1-3.5)	0.34
In-hospital mortality (%)	24 (1.0)	1 (0.2)	1 (0.6)	0.25

the largest trauma database in the United States, the possibility of a type II error cannot be excluded. Finally, due to the data limitations in the NTDB, we could not distinguish indications for a delayed operation in each patient who underwent NOM. In the absence of this detailed information, it would not be possible to determine whether the delay in operation could have an impact on patient outcome. Furthermore prospective studies are warranted to investigate significant factors associated with NOM failure and its impact on patient outcomes.

Conclusions

NOM may be considered in a carefully selected group of pediatric patients with penetrating SOI. Hemodynamically stable patients without signs of peritonitis may be candidates for trial of NOM. Once NOM is initiated, patients should be closely monitored for any signs of ongoing hemorrhage from SOI or associated hollow viscus injury.

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Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

REFERENCES

1. Haller Jr JA, Papa P, Drugas G, Colombani P. Nonoperative management of solid organ injuries in children. Is it safe? *Ann Surg*. 1994;219:625–628.
2. Sims CA, Wiebe DJ, Nance ML. Blunt solid organ injury: do adult and pediatric surgeons treat children differently? *J Trauma*. 2008;65:698–703.
3. Frumiento C, Vane DW. Changing patterns of treatment for blunt splenic injuries: an 11-year experience in a rural state. *J Pediatr Surg*. 2000;35:985–988.
4. Dodgion CM, Gosain A, Rogers A, St Peter SD, Nichol PF, Ostlie DJ. National trends in pediatric blunt spleen and liver injury management and potential benefits of an abbreviated bed rest protocol. *J Pediatr Surg*. 2014;49:1004–1008.
5. Como JJ, Bokhari F, Chiu WC, et al. Practice management guidelines for selective nonoperative management of penetrating abdominal trauma. *J Trauma*. 2010;68:721–733.
6. Velmahos GC, Demetriades D, Toutouzas KG, et al. Selective nonoperative management in 1,856 patients with abdominal gunshot wounds: should routine laparotomy still be the standard of care? *Ann Surg*. 2001;234:395–402.
7. Navsaria PH, Nicol AJ, Edu S, Gandhi R, Ball CG. Selective nonoperative management in 1106 patients with abdominal gunshot wounds: conclusions on safety, efficacy, and the role of selective CT imaging in a prospective single-center study. *Ann Surg*. 2015;261:760–764.
8. Peponis T, Kasotakis G, Yu J, et al. Selective nonoperative management of abdominal gunshot wounds from heresy to adoption: a multicenter study of the research consortium of New England centers for trauma (ReCoNECT). *J Am Coll Surg*. 2017;224:1036–1045.
9. Demetriades D, Hadjizacharia P, Constantinou C, et al. Selective nonoperative management of penetrating abdominal solid organ injuries. *Ann Surg*. 2006;244:620–628.
10. Velmahos GC, Constantinou C, Tillou A, Brown CV, Salim A, Demetriades D. Abdominal computed tomographic scan for patients with gunshot wounds to the abdomen selected for nonoperative management. *J Trauma*. 2005;59:1155–1160.
11. Dicker RA, Sartorelli KH, McBrids WJ, Vane DW. Penetrating hepatic trauma in children: operating room or not? *J Pediatr Surg*. 1996;31:1189–1191.
12. Cigdem MK, Onen A, Siga M, Otcu S. Selective nonoperative management of penetrating abdominal injuries in children. *J Trauma*. 2009;67:1284–1286.
13. ECC Committee, Subcommittees and Task Forces of the American Heart Association. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2005;112:IV1–IV203.
14. Acker SN, Ross JT, Partrick DA, Tong S, Bensard DD. Pediatric specific shock index accurately identifies severely injured children. *J Pediatr Surg*. 2015;50:331–334.
15. Arbuthnot M, Armstrong LB, Mooney DP. Can we safely decrease intensive care unit admissions for children with high grade isolated solid organ injuries? Using the shock index, pediatric age-adjusted and hematocrit to modify APSA admission guidelines. *J Pediatr Surg*. 2017;52:989–992.
16. Inaba K, Demetriades D. The nonoperative management of penetrating abdominal trauma. *Adv Surg*. 2007;41:51–62.
17. Matsushima K, Mangel PS, Schaefer EW, Frankel HL. Blunt hollow viscus and mesenteric injury: still underrecognized. *World J Surg*. 2013;37:759–765.
18. Peev MP, Chang Y, King DR, et al. Delayed laparotomy after selective non-operative management of penetrating abdominal injuries. *World J Surg*. 2015;39:380–386.