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The benefits of limiting scheduled blood draws in children with a blunt liver or spleen injury

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ABSTRACT

Background: Nonoperative management protocols of blunt liver and spleen injury in children usually call for serial monitoring of the child's hemoglobin and hematocrit (H/H) at scheduled intervals. We previously demonstrated that the need for emergent intervention is triggered by changes in vital signs, not the findings of scheduled blood draws and changed our protocol accordingly. The current aim is to evaluate the safety of this change.

Methods: We performed a retrospective review of all children admitted following blunt liver or spleen injury during two periods; the historic cohort 1/09–12/13 and the protocol cohort 8/15–7/17. Data evaluated included the need for intervention, number of H/H checks, and outcomes.

Results: 330 children were included (216 historic; 114 protocol). Groups did not differ in percentage of male patients, injury severity score, or GCS. Median age in the historic cohort was younger than the protocol cohort (9 vs 12 years; $p = 0.02$). More children in the protocol group had a grade 5 injury (1% vs 9%; $p < 0.0001$). Groups did not differ in the number who required intervention or discharge disposition (including mortality). The protocol group had fewer H/H checks (median 5 vs 4, $p < 0.0001$); the two groups did not differ in their nadir H/H. The historic group had a longer median hospital length of stay (3 days vs 2, $p = 0.0007$).

Conclusions: Decreasing the number of scheduled blood draws following a blunt liver or spleen injury in children is safe. Additional benefits include a decrease in the number of blood draws and a decrease in length of hospital stay.

Study type: Cost-effectiveness.

Level of evidence: Level III.

Blunt abdominal trauma remains a significant cause of morbidity and mortality in the pediatric population. Abdominal solid organ injury accounts for 10%–15% of all pediatric trauma [1]. Nonoperative management (NOM) has become the standard of care for these children with failure rates around 5%–7% [2,3]. The widespread use of a nonoperative strategy preceded any prospective data to help guide the development of these management protocols. Starting in 2000, The American Pediatric Surgical Association (APSA) Trauma Committee began publishing evidence-based guidelines for the nonoperative management of blunt liver and spleen injuries [4]. These guidelines dictate the length of intensive care unit (ICU) and hospital stay, pre- and postdischarge imaging as well as length of activity restrictions based on grade of injury. Although missing from the guidelines, many institutions, including Children's Hospital Colorado (CHCO), include in their institution specific protocols, scheduled blood draws to measure a child's hemoglobin and hematocrit at standard times following injury to determine the presence or absence of ongoing bleeding and potential need for intervention [5,6]. We previously reviewed our institutional data to determine the relationship between scheduled blood draws and need for intervention in the form of packed red blood cell (PRBC) transfusion, angioembolization, or operative intervention to treat a blunt liver or spleen injury [7]. We found that the need for operative intervention happened early, a median of 4 h after injury. Additionally, we found that children who required any of the three interventions had other signs of bleeding such as hypotension or tachycardia, and the scheduled hemoglobin and hematocrit measures did not predict the need for intervention, making them potentially unnecessary [7]. Based on these data, the protocol for the management of a blunt liver and spleen injury at CHCO was changed to limit the number of scheduled hemoglobin and hematocrit checks. The aim of the

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current study is to compare children who were managed before and after the change, to determine the effect of our change in protocol on patient outcomes.

1. Methods

This study was reviewed and approved by the Colorado Multiple Institution Review Board. We performed a retrospective review of the medical records of all children ages 4–16 years old admitted to Children's Hospital Colorado (CHCO) during two different time periods, prior to protocol change (historic) and after protocol change (protocol) with any grade blunt liver or spleen injury. The original protocol is shown in Fig. 1 with the updated protocol in Fig. 2. The historic group included children admitted between 1/09 and 12/13. The protocol group included children admitted 8/15–7/17. The aim of the current study is to evaluate the impact of a change in

GUIDELINE

	Grade I	Grade II	Grade III	Grade IV
Admit to:	Floor	Floor	Floor / ICU x 24 hrs (depending on need for ↑monitoring capability) then floor if stable	ICU x 24 hrs then floor if stable
Hospital LOS	2 days	3 days	3-4 days	4-5 days
Lab Tests	HCT 12hrs & 24hrs post injury	HCT 12hrs & 24hrs post injury	HCT 12hrs, 24hrs, & 48hrs post injury	HCT 6hrs, 12hrs, 24hrs, 48hrs post injury
Clinical Assessment & Monitoring	VS q 2hrs x 8 hrs, then q 4hrs; C/R/Pox monitoring x 24hrs; Strict I & O	VS q 2hrs x 8 hrs, then q 4hrs; C/R/Pox monitoring x 24hrs; Strict I & O	VS q 2hrs x 8 hrs, then q 4hrs; C/R/Pox monitoring x 24hrs; Strict I & O	VS q 1hrs x 12hrs, then q 2hrs x 12hrs, then q 4hrs; C/R/Pox monitoring x 24hrs; Strict I & O
Treatments & Procedures	Incentive Spirometry prn	Incentive Spirometry prn	Incentive Spirometry q 2hrs until ambulatory; NG / Foley as indicated	Incentive Spirometry q 2hrs until ambulatory; NG / Foley as indicated
Nutrition	NPO x 12hrs, clears, then ADAT	NPO x 12hrs, clears, then ADAT	NPO x 24hrs, clears x 8hrs, then ADAT	NPO x 24hrs, clears x 8hrs, then ADAT
Activity	Bedrest x 24hrs then OOB to toilet only. Ambulation 12hrs	Bedrest x 24hrs then OOB to toilet only. Ambulation 12hrs	Bedrest x 24hrs then OOB to toilet only. Ambulation 12hrs	Bedrest x 48hrs then OOB to toilet only. Ambulation 12hrs
	prior to discharge	prior to discharge	prior to discharge	prior to discharge
IV Fluids	Maintenance IV while NPO then saline lock with good PO intake	Maintenance IV while NPO then saline lock with good PO intake	Maintenance IV while NPO then saline lock with good PO intake	Maintenance IV while NPO then saline lock with good PO intake
Medications	Mild pain- Tylenol 15mg/kg po/pr q 4hrs prn	Mild pain- Tylenol 15mg/kg po/pr q 4hrs prn Moderate pain- Oxycodone 0.05-0.15 mg/kg po q 4hrs prn Severe pain- Morphine 0.1mg/kg IV q 2-4hrs prn	Mild pain- Tylenol 15mg/kg po/pr q 4hrs prn Moderate pain- Oxycodone 0.05-0.15 mg/kg po q 4hrs prn Severe pain- Morphine 0.1mg/kg IV q 2-4hrs prn	Mild pain- Tylenol 15mg/kg po/pr q 4hrs prn Moderate pain- Oxycodone 0.05-0.15 mg/kg po q 4hrs prn Severe pain- Morphine 0.1mg/kg IV q 2-4hrs prn
Pre and post discharge imaging	None	None	None	None
Restricted activity for normal age appropriate activities	3 weeks	4 weeks	5 weeks	6 weeks
Restricted activity for full-contact/competitive sports or play	*6 weeks	*8weeks	*12weeks	*16weeks
Return to school	1 week	1 week	1-2 weeks	1-2 weeks
Follow-up clinic or PCP visit	None	None	2 weeks	1-2 weeks

Fig. 1. The protocol for the management of blunt liver or spleen injury at the Children's Hospital Colorado that was used during the historic cohort (prior to August 2015). The protocol contains guidelines for the management of these children based on grade of injury.

GUIDELINES

	Grade I/II	Grade III	Grade IV/V	Active bleeding noted on imaging
Admit to:	Floor	Floor (ICU if clinically warranted)	Floor (ICU if clinically warranted)	ICU; Consider angioembolization
Hospital LOS	1 night (total 24 hours observation)	2 nights (total 48 hours observation)	2-3 nights	2-3 nights
Laboratory tests	H/H on admit, at 24 hours post-injury, and for clinical instability	H/H on admit, at 24 hours post-injury, and for clinical instability, Repeat H/H at 48 hours post injury if greater than 6 drop in HCT	T&S, H/H on admit, at 24 hours and 48 hours post injury, and for clinical instability	T&S, H/H on admit, and at 2-4 hours post-injury, at 24 hours and 48 hours post-injury
Clinical Assessment & Monitoring	VS q4h until d/c	VS q4h until d/c	Continuous C/R/Pox x24h, then q4h	Continuous C/R/Pox x24h, then q4h
Treatment & Procedures	IS Q2H while non-ambulatory and prn	IS Q2H while non-ambulatory and prn	IS Q2H while non-ambulatory and prn	IS Q2H while non-ambulatory and prn
Nutrition	NPO overnight, then REG diet HD 2	NPO overnight, then CLD on HD 2 & ADAT	NPO overnight, CLD on HD 2, REG diet HD 3	NPO overnight, CLD on HD 2, REG diet HD 3
Activity	Bathroom privileges overnight, full ambulation on HD 2	Bedrest overnight bathroom privileges HD 2, full ambulation HD 3	Bedrest x 2 nights , then full ambulation HD 3	Bedrest x 2 nights , then full ambulation HD 3
IVF	MIVF while NPO	MIVF while NPO	MIVF while NPO	MIVF while NPO
Medications	Mild pain: Tylenol	Mild pain: Tylenol Moderate to severe: Oxycodone Severe/NPO: Morphine	Mild pain: Tylenol Moderate to severe: Oxycodone Severe/NPO: Morphine	Mild pain: Tylenol Moderate to severe: Oxycodone Severe/NPO: Morphine
Pre/post discharge imaging	None	None	None	None
Activity Restrictions: normal	Grade I: 3 weeks Grade II: 4 weeks	5 weeks	6 weeks	Per injury grade
Activity restrictions: contact	Grade I: 6 weeks Grade II: 8 weeks	12 weeks	16 weeks	Per injury grade
Return to school	1 week	1-2 weeks	1-2 weeks	1-2
Follow-up clinic/PCP	None	2 weeks	1-2 weeks	1-2

Fig. 2. The protocol for the management of blunt liver or spleen injury at the Children's Hospital Colorado that was implemented in August 2015. The protocol contains guidelines for the management of these children based on grade of injury. This protocol was used for the care of the protocol cohort.

protocol to children admitted with a blunt liver or spleen injury. This protocol is specific to CHCO; for this reason, those children treated at Denver Health Medical Center, who were part of the initial cohort, were excluded from the current analysis. All children with a blunt liver or spleen injury were included, not only those with isolated solid organ injuries, but also those children with multisystem trauma. Exclusion criteria included those children suffering penetrating trauma. Data collected include demographic information, vital signs, and laboratory studies on arrival, grade of liver and/or spleen injury, and need for intervention in the form of a laparotomy, PRBC transfusion, and/or angioembolization, as well as the indication for intervention and the time from injury to intervention(s). We also reviewed each child's nadir hemoglobin and hematocrit during hospitalization, and the total number of times the hemoglobin and hematocrit were measured.

Statistical analysis was conducted in Prism 7d (by GraphPad Software, Inc. La Jolla, CA, USA). Categorical variables were compared between the groups using a Chi-Square test. Continuous variables were compared using the t test for normally distributed data or Wilcoxon two sample test for nonparametric data. Differences were considered significant when $P < 0.05$.

2. Results

A total of three hundred thirty children were included, 216 in the historic cohort and 114 children in the protocol cohort. Table 1 demonstrates the demographic characteristics of the two cohorts. The two groups did not differ in percentage of male patients, injury severity score (ISS), or Glasgow Coma Scale (GCS) score. Median age in the historic cohort was younger than the protocol cohort (9 vs 12 years; $p = 0.02$). More children in the protocol group had a grade 5 injury (1% vs 9%; $p < 0.0001$). A total of 36 patients in the historic cohort and 28 patients in the protocol cohort required an intervention. Among these children, the median time to intervention did not differ between the two groups (median 5.5 h in the historic cohort vs 6 h control cohort; $p = 0.42$).

Table 2 compares the clinical outcomes among children in the historic and protocol groups. These two groups did not differ in the number who required intervention (laparotomy, angioembolization, or PRBC transfusion). Additionally, there was no difference in discharge disposition (including mortality) between the two groups. The historic group had more hemoglobin and hematocrit checks than the protocol group (median 5 vs 4, $p < 0.0001$) yet there was no difference in their nadir

Table 1
Demographic characteristics of those children admitted following blunt liver or spleen injury before or after protocol change.

	Historic (n = 216)	Protocol n = 114)	*p value*
Age, median (IQR)	9 (6–13)	12 (7–13)	0.02
Male, n (%)	146 (67.6%)	74 (64.9%)	0.63
ISS, median (IQR)	12 (9–17)	16 (9–25)	0.26
GCS on presentation, median (IQR)	15 (15–15)	15 (15–15)	0.22
Liver injury, n (%)	122 (56%)	64 (56%)	1
Spleen injury, n (%)	113 (52%)	61 (54%)	0.57
Both, n (%)	19 (9%)	11 (10%)	0.84
Grade 5 injury, n (%)	2 (1%)	10 (9%)	0.0007

hemoglobin and hematocrit during hospitalization. The historic group had a longer median hospital length of stay than the protocol group (median 3 days vs 2 days, p = 0.0007).

This analysis was repeated after excluding those children who required an intervention. Among children who did not require an intervention in the form of PRBC transfusion, laparotomy, or IR embolization to manage their blunt liver or spleen injury, the historic and protocol cohorts did not differ with regard to ISS, GCS, or the percentage of children who were male. Children in the protocol cohort were older (median 12 years vs 9 years; p = 0.04), than those in the historic cohort. Additionally, there were more grade 5 injuries in the protocol cohort (n = 4, 5% vs n = 1, 0.5%; p = 0.04) than in the historic cohort. Table 3 compares outcomes between the protocol and historic cohorts among children who did not require intervention. Children in the protocol cohort had a shorter hospital length of stay (median 2 vs 4 days, p < 0.0001) and fewer number of H and H checks (median 3 vs 4, p < 0.0001). However, there was no difference in the nadir hemoglobin or hematocrit between the two cohorts.

Among children who did not require intervention, there was one death secondary to nonaccidental head trauma leading to brainstem herniation and death less than 24 h after admission. There were seven additional deaths in the protocol group who did undergo an intervention. Mechanism of injury in these cases included motor vehicle collision in six and a skiing accident in one. Six of these children had a GCS of 3 on arrival and one had a GCS of four. Four of these deaths were attributed to severe intracranial injury and three were because of hemorrhagic shock.

To better understand why the protocol was not followed routinely, we looked specifically at the group of children in the protocol group who did not require an intervention, comparing those children who had the prescribed number of blood draws (prescribed group) and those who had additional H/H checks beyond what was ordered in the protocol (additional group). There were 86 children in the protocol group who did not require an intervention with 32 in the prescribed group and 54 in the additional group. These groups did not differ in terms of basic demographics (Table 4). Children in the additional group were more likely to be admitted to the ICU (p = 0.017) and there was a trend towards higher ISS in the additional group (p = 0.08). Children in the additional group were also more likely to have a grade 4 or 5 injury, although this did not reach statistical significance (p = 0.08).

Table 3
Clinical outcomes of those children admitted following blunt liver or spleen injury who did not require an intervention.

	Historic (n = 180)	Protocol (n = 86)	*p value*
Hospital length of stay (days), median (IQR)	4 (3–5)	2 (1–3)	<0.0001
Number H/H checks, median (IQR)	4 (4–6)	3 (2–4)	<0.0001
Nadir Hemoglobin, median (IQR)	12 (11–13)	12 (11–13)	0.74
Nadir Hematocrit, median (IQR)	33 (30–36)	34 (31–37)	0.11
Discharge disposition, n (%)			0.37
Home	178	84	
Rehabilitation	0	1	
Death	0	1	
Care of social services	2	0	

3. Discussion

We found that a change in protocol that decreases the number of scheduled hemoglobin and hematocrit checks following blunt liver or spleen injury in children is safe. When comparing those children who were admitted prior to the protocol change to those admitted after, there was no difference in the rate of any of the three interventions evaluated including PRBC transfusion, IR angioembolization, or laparotomy. More importantly, no child suffered a delay in intervention because there was no scheduled lab draw. As we showed with the previous cohort [7], all children in the protocol cohort who required an urgent intervention had a change in their hemodynamics that alerted the clinicians to the need for intervention. Our data demonstrate that limiting scheduled blood draws is safe in this population. Additionally, among those children who did not require an intervention, median hospital length of stay was decreased by two days following protocol change.

Since the original publication by the APSA Trauma Committee in 2000, many groups have evaluated the safety and benefit of limiting various aspects of the APSA NOM protocol recommendations. This

Table 2
Clinical outcomes of children of those children admitted following blunt liver or spleen injury before or after protocol change.

	Historic (n = 216)	Protocol n = 114)	*p value*
Hospital length of stay (days), median (IQR)	4 (3–6)	2 (1–5)	<0.0001
Need for Intervention, n (%)	36 (17%)	28 (25%)	0.11
Need for Laparotomy, n (%)	8 (4%)	9 (8%)	0.12
IR embolization, n (%)	0 (0%)	1 (1%)	0.35
PRBC Transfusion, n (%)	35 (16%)	27 (9%)	0.1
Number H/H checks, median (IQR)	5 (4–7.8)	4 (2.8–6)	<0.0001
Nadir Hemoglobin, median (IQR)	11 (9.7–13)	11 (8.8–13)	0.29
Nadir Hematocrit, median (IQR)	32 (28–36)	32 (26–37)	0.83
Discharge disposition, n (%)			0.33
Home	192 (89%)	99 (87%)	
Rehabilitation	14 (6%)	6 (5%)	
Death	7 (3%)	8 (7%)	
Care of social services	3 (1%)	1 (1%)	

Table 4
Characteristics of children admitted following blunt liver or spleen injury after protocol change in whom the protocol was followed and those who had additional blood draws.

	Prescribed (n = 32)	Additional (n = 54)	*p value*
ISS, median (IQR)	9 (8–15.25)	11.5 (9–18)	0.08
ICU admission, n (%)	5 (16%)	22 (41%)	0.017
Grade 4 or 5 injury, n (%)	5 (16%)	19 (35%)	0.08
Age, median (IQR)	10 (8–13)	12 (6.75–14)	0.29
Male sex, n (%)	17	37	0.67
GCS, median (IQR)	15 (15–15)	15 (15–15)	0.99
Mechanism			0.81
Motor vehicle or ATV related, n (%)	11 (34%)	14 (26%)	
Auto vs pedestrian or bike, n (%)	6 (19%)	10 (19%)	
Fall, n (%)	4 (13%)	5 (9%)	
Snow sport, n (%)	5 (16%)	13 (24%)	
Other sport, n (%)	4 (13%)	8 (15%)	
Nonaccidental trauma, n (%)	0	2 (4%)	
Other, n (%)	2 (6%)	2 (4%)	

began when St. Peter et al. validated the safety of an abbreviated bedrest protocol for these patients, demonstrating the safety of a shortened length of hospital stay [8]. These findings have been confirmed by Dadou et al. who showed that an abbreviated bedrest protocol is associated with early mobilization, fewer blood draws, and decreased LOS without any change in patient outcomes [6]. More recently, there has been a move towards hemodynamic driven protocols. A multi-institution study by Cunningham, et al. demonstrated that implementation of a hemodynamic driven protocol that uses stable vital signs along with stable hematocrit to guide care was associated with shorter hospital and ICU lengths of stay, a decrease in total phlebotomy, and a decrease in hospital costs with similar complication rates [5], adding to the work of previous groups, which have similarly advocated for hemodynamic driven protocols [9,10]. Of note, each of the adjustments to the APSA protocol is based on the treatment of stable patients without evidence of ongoing bleeding.

The concern with limiting NOM protocols, whether by admitting fewer children to the ICU for monitoring, abbreviating the period of required bedrest, or limiting the number of scheduled lab draws, is the fear of missing ongoing bleeding in an injured child. The rate of failure of NOM protocols is known to be quite low in the range of 5%–7% [2,3]. For this reason, there are few data characterizing this population. Multiple groups have shown, however, that hemodynamic markers can be used to accurately identify children at high risk of ongoing bleeding, without the need for prolonged bedrest or multiple blood draws. Arbuthnot et al., showed that the addition of hemodynamic based criteria, namely an elevated pediatric age adjusted shock index (SIPA) [11] combined with anemia on presentation, could be used to identify children for ICU admission, and doing so would significantly decrease ICU admission rates [12]. They found that those children with a normal SIPA and hematocrit on presentation had a very low risk of ongoing bleeding and could be safely monitored on the ward [12]. A recent review by Notrica and Linnaus advocates for serial vital signs, clinical exam, and monitoring of SIPA without serial hemoglobin checks to accurately identify those children in need of a transfusion [13]. Our data support this move towards hemodynamic monitoring of children with blunt liver and spleen injuries.

The limitations of our study include the fact that it is retrospective in nature, comparing two groups of children who were treated during different time periods. Differences in total blood draws could also potentially be explained by a general trend towards cost consciousness. Additionally, the adherence to the protocol was not 100%. The protocol recommends two total hemoglobin and hematocrit checks for otherwise stable children with grade 2 or 3 injuries and three checks for those with grade 4 or 5 injuries; however, the median number of checks in our protocol group who did not require intervention was three. For this reason, we can only conclude that our protocol was associated with fewer blood draws and no adverse events; the validity of the protocol itself cannot be verified. We did attempt to identify factors associated with additional blood draws and while only ICU admission reached statistical significance, grade 4 and 5 injury as well as higher ISS also may be associated with additional draws. We plan to use the current data to advocate for stricter protocol adherence and will again plan to examine the effect of our protocol after this education.

Additionally, our data come from a single institution, potentially limiting the generalizability of our findings. Our data are, however, consistent with the published literature [14], offering further support to our conclusions. In order to verify the safety and benefits of the many variations of abbreviated NOM protocols, future work will require a prospective, multicenter study. Future work at our institution will focus on education and protocol adherence.

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