

Pediatric Solid Organ Injury Operative Interventions
at Harborview Medical Center, 2001 to 2012

Leslie A. Dervan

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Dr. Noel S. Weiss

Dr. Frederick Rivara

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Leslie A. Dervan

University of Washington

ABSTRACT

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Leslie A. Dervan

Chair of the Supervisory Committee:

Dr. Noel S. Weiss, Professor

Department of Epidemiology

Objectives: To evaluate the effectiveness of the Pediatric Solid Organ Injury Pathway at Harborview Medical Center (HMC): to determine what proportion of pediatric solid organ injury patients qualify for care under this pathway by having isolated injury, and to determine whether the proportion of patients receiving abdominal operative interventions, including splenectomy, changed at HMC after institution of the pathway in 2005.

Design: Retrospective cohort study

Setting: Harborview Medical Center, Seattle, Washington

Intervention: None

Subjects: Pediatric (0-18 years) trauma patients at HMC with solid organ (liver or spleen) injury during 2001-2012.

Methods and main results: Patients were identified in the Harborview Trauma Registry via ICD-9 codes for the presence of liver and spleen injuries. Demographic information, clinical characteristics and ICD-9 procedure codes were also obtained from the Harborview Trauma Registry. A minority of patients had isolated organ injury (less than 30%,) and were thus eligible for pathway care beginning in 2005.

The operative proportion was low before and after institution of the pathway in 2005; a slight decrease in the operative proportion was observed after adjusting for the increase in Injury Severity Score (ISS) observed over time. Among patients with isolated splenic injury, 3.1% received splenectomy in 2001-2004 (5.6% adjusted for ISS,) compared to 3.3% in 2005-2012. Among patients with isolated spleen or liver injury, 6.3% (adjusted for ISS; 6.1% unadjusted) underwent a related abdominal surgery (exploratory laparotomy, spleen or liver repair, or splenectomy) in 2001-2004, vs. 4.4% in 2005-2012.

Among patients with non-isolated splenic injury, who would not have been eligible for pathway care but whose care may have been influenced by a general change in practice over time, 9.8% (adjusted for ISS; 7.9% unadjusted) received splenectomy in 2001-2004, vs. 8.7% in 2005-2012. In patients with non-isolated liver or spleen injury, 11.5% (adjusted for ISS; 11.0% unadjusted) underwent abdominal surgery in 2001-2004, vs. 13.8% in 2005-2012.

Conclusions: The proportion of patients who had isolated splenic or hepatic injury, thereby qualifying for pathway care, was relatively low. In both time periods, receipt of splenectomy was infrequent, and appeared to meet nationally published guidelines for care of isolated splenic injury. Patient severity of injury increased over time. Adjusting for ISS, slightly fewer splenectomies occurred in the post-pathway period compared to the pre-pathway period.

BACKGROUND

The care of isolated solid organ injury to the liver and spleen has changed dramatically over the past several decades, as nonoperative management has been repeatedly shown to be a safe and successful approach to care in most cases. Review of this experience has led to the publication of benchmarks for solid organ injury care, including a splenectomy frequency of no more than 3% in patients with isolated splenic injuries, and of 5-11% in all children with splenic injury (1). This goal appears to be achievable in a variety of pediatric care settings (2-4) without subjecting patients to increased risk of transfusion, urgent surgery, late complications, or mortality (4-12). In nonoperatively managed patients, subsequent efforts aimed to decrease resource utilization showed that most may be successfully managed with relatively short ICU stays, relatively short hospital stays, limited lab draws, and limited repeat imaging tests (5-7,13-16).

A number of issues impact whether this approach to care is consistently provided to patients. Questions remain about what measures should be undertaken to avoid operative interventions, and variability exists in the types of nonoperative care that patients actually receive (17). One aspect of this uncertainty is the criteria by which patients are deemed to “fail” nonoperative management. Hemodynamic instability or “excessive transfusion” is often given as the reason for failure, yet the magnitude of the operative risks versus the transfusion risks is unknown. Nonoperative management has been shown to be successful in patients with initial hypotension, if appropriate resuscitation is provided (3, 18). There is also variability in the amount of transfusion deemed “excessive”: 30% of adult surgeons polled disagreed that any blood should be transfused for hemodynamic instability before considering operative intervention (1). Adult surgeons were also more likely than pediatric surgeons to consider any transfusion a “failure” of nonoperative management (19). The volume of transfusion provided to patients with solid organ injury has also decreased over time, suggesting that providers have become more

comfortable with nonoperative management and permissive anemia (20-22). Even when hemodynamic instability is not present, there is evidence that some providers continue to base operative decision making on injury grade (23), despite other evidence that nonoperative management is frequently successful in high-grade injuries (3, 5, 9, 24-25). These differences suggest substantial variability in the care delivered to patients with solid organ injuries.

Management algorithms (also called pathways or clinical practice guidelines) are one measure used to address system variability in providing care. Many management algorithms for solid organ injury, some based on American Pediatric Surgical Association (APSA) guidelines and some based on other criteria, have been published and studied. The published algorithms vary widely in their patient selection and algorithmic goals, yielding different approaches to delivering patient care for isolated solid organ injury.

Given the known provider variability in practices, particularly surrounding decisions to abort nonoperative management and to use blood products in resuscitation, Harborview Medical Center (HMC) developed a management pathway in 2005 to standardize care for pediatric patients with isolated solid organ injury (hepatic and splenic injuries.) HMC is the only designated pediatric Level I trauma center for the states of Washington, Alaska, Montana, and Idaho. Compared to centers with smaller catchment areas, HMC cares for a high proportion of severely injured patients, with high grades of solid organ injury and with a greater likelihood of hemodynamic instability at presentation. Few published management pathways apply to this patient population, as there is historically a high level of concern using nonoperative management in hemodynamically unstable patients, or in those with high grades of injury. To address these specific needs of injured patients at HMC, the HMC Solid Organ Injury Pathway

is based on existing published pathways (5, 6) which emphasize hemodynamic status as the primary factor in decision making (Appendix).

Given the high proportion of trauma patients at HMC who suffer multiple injuries, it was unclear how many patients the pathway would apply to, as it is designed to be used in patients with isolated solid organ injury. It is possible that adopting this pathway—with its emphasis on hemodynamic status and standardized operative decision-making— also influenced the care provided to solid organ injury patients with multiple injuries, who on average have higher-grade organ injuries and higher Injury Severity Scores (ISS). We examined the use of this pathway by describing the patients who would be included in its care by having isolated solid organ injury, and to examine its possible broader effect by evaluating the proportion of patients (with both isolated and non-isolated injury) receiving operative interventions before and after 2005. We hypothesized that improved fluid resuscitation efforts and standardized operative decision-making would lead to a decrease in operative interventions over time.

METHODS

We conducted a review of the records of all pediatric patients (≤ 18 years of age) admitted to Harborview Medical Center with solid organ injury (hepatic or splenic injury) from 2001-2012. Solid organ injury was defined as having an ICD-9 code describing a hepatic or splenic injury (864.00-864.05, 864.09-864.15, 864.19, 865.00-865.04, 865.09-865.14, and 865.19.) Patients meeting this definition were identified by querying the Harborview Trauma Registry, and were included regardless of the presence of additional injuries. 10 records had duplicate identical entries, and one of each duplicate was deleted. Two additional duplicate HMC ID numbers occurred; these represented two separate admissions for the same individual and were

included. No records were subsequently excluded. The University of Washington Institutional Review Board approved this study, and the need for informed consent was waived.

From the trauma registry, demographic and injury-related information was obtained, including: age, sex, ISS, emergency room vital signs, emergency room disposition, hospital length of stay, mortality, discharge ICD-9 codes, organ injury Abbreviated Injury Scale (AIS) codes, and ICD-9 procedure codes, dates, and times. AIS codes were only available for the years 2005-2012. Patients were classified as being “hemodynamically unstable” per the HMC solid organ injury pathway if their vital signs in the emergency department (according to the trauma registry) were outside the range delineated in the pathway (Appendix). Injuries were classified as high-grade if they were grade IV or grade V by either ICD-9 criteria (26) or AIS scoring. ISS was further categorized into clinically relevant categories of ≤ 9 , 10-15, and >15 .

No standard definition of isolated organ injury based on ICD-9 coding was identified in the literature. Additionally, the pathway itself does not define isolated injury. For the purposes of this investigation, patients were classified as having isolated organ injury if no ICD-9 codes were present identifying either multiple solid organ injuries or any additional severe injuries. Severe injuries were considered to include: cerebral edema (ICD-9 348-350), traumatic brain injury (ICD-9 850-852 & 854-855), myocardial contusion or depression, or pulmonary vascular injury (ICD-9 410-429), cerebral infarct (ICD-9 433-444), pneumo/hemothorax or penetrating thoracic trauma (ICD-9 511-518, 860-863, 875-876, & 901-903), peritonitis or penetrating abdominal trauma (ICD-9 567-568 & 868.1-868.19), intracranial hemorrhage or cerebral laceration (ICD-9 800.1-802, 852-854, & 803-805), spinal cord injury (ICD-9 806-807), and pelvic fracture or long-bone fracture (ICD-9 808-809, 821-822, & 812-813.)

The primary operative outcome of interest was receipt of splenectomy (ICD-9 procedure code 41.5). An additional operative outcome of interest was defined as one or more of the following abdominal surgeries: spleen surgery (ICD-9 41.5, 41.93, and 41.95), liver surgery (50.2, 50.22, 50.3, 50.6, 50.61, and 50.69), or exploratory laparotomy (54.11, 54.1, and 54.19), given that many patients who receive splenectomy do so after an exploratory laparotomy is performed for other indications (typically peritonitis, ongoing bleeding, or hemodynamic instability.)

Both ISS and AIS injury severity scores are typically reported, to describe overall severity of injury as well as organ-specific injury severity. However, AIS scores were separately calculated in the Harborview Trauma Registry only beginning in 2005, and so were only available for a portion of the years under study. AIS scores have better specificity for injury grade than do ICD-9 scores (26,) and the two were not comparable among records in our sample for which both were available. We were therefore unable to evaluate the trend in high-grade injury over time. Additionally, given that the ISS captures both injury grade and the severity of concomitant injuries that may influence operative decision-making, we chose to use the ISS alone as an indicator of severity of injury for the purposes of this evaluation.

Statistical analysis

The proportion of patients classified as having isolated injury was calculated by year and by period. The proportion of both isolated and non-isolated injury patients classified as hemodynamically unstable was calculated by period. Within these categories, the injured population was described for the pre-pathway period (2001-2004) and the post-pathway period (2005-2012) using descriptive statistics for age, gender, ISS, proportion of high-grade injury, hospital length of stay (LOS), and mortality.

We evaluated the proportion of isolated and non-isolated solid organ injury patients receiving splenectomy by period, and of isolated and non-isolated spleen injury patients receiving an abdominal surgery of interest by period. From the descriptive statistics, ISS was noted to increase over time, and higher ISS was also associated with the occurrence of both surgical interventions. To address confounding by ISS over time, we calculated pre-pathway proportions of splenectomy and abdominal surgery (among isolated and non-isolated populations) based on post-pathway ISS quartiles, thereby adjusting the pre-pathway operative proportion for the post-pathway level of severity. STATA SE 12 was used for all analyses.

RESULTS

We identified 890 patients who met the inclusion criteria. This included 303 from the pre-pathway period (2001-2004) and 587 from the post-pathway period (2005-2012), with a range of 64 to 111 cases per year. (25 cases were present in the partial year of data in 2012). There was no clear trend in the annual number of cases observed over the years studied, with an average of 75.8 cases per year from the pre-pathway period and 80.3 cases per year from the post-pathway period (excluding the partial year of data in 2012).

We estimated that 28.8% of patients had isolated solid organ injury, based on the definition above, with 32.3% in the pre-pathway period and 26.9% in the post-pathway period. There was no clear trend in the proportion by year, ranging from 18.5% to 39.1%. (Table 1)

The proportion of patients qualifying as hemodynamically unstable, based on emergency room vital signs and per the pathway guidelines, was extremely low among patients with isolated organ injury (1% in the pre-pathway period, 0% in the post-pathway period.) The proportion of non-isolated injury patients who qualified as hemodynamically unstable was also low, and this was also similar over time (3.9% in the pre-pathway period, 4.7% in the post-pathway period.)

(Table 1) Hemodynamic instability was uncommon among those who ultimately received splenectomy and/or abdominal operative intervention: 5 out of 36 patients (13.9%) who received splenectomy and 10 out of 94 patients (10.6%) who underwent abdominal surgery qualified as being hemodynamically unstable. However, those who were hemodynamically unstable had a high likelihood of being severely injured; these patients had a mean ISS of 48.9 (range: 10-75) and a mortality of 48.3%. Among those with hemodynamic instability who survived (n=15), mean ISS was 46.2, length of stay was an average 23 days, 40% required an abdominal surgery, and 22% of those with spleen injury required splenectomy.

Descriptive statistics of the population studied are presented in Table 2. These were notable for a higher average ISS in the post-pathway period for both isolated and non-isolated organ injury groups (10.6 vs. 12.6 and 25.9 vs. 32.0, respectively). When ISS was categorized into three clinically relevant levels of injury, a sizeable proportion of isolated injury patients were “seriously” injured, with 35.4% having an ISS >15. The post-pathway period had a higher proportion of patients in the moderate (10-15) and severe (>15) injury categories, consistent with the observation that mean ISS was higher in the post-pathway period (Table 3.) In evaluating severity of injury by organ injury grade, a substantial proportion of isolated organ injury patients had high-grade injury in the post-pathway period (grade IV or V; 34%; Table 2.)

Among isolated spleen-injured patients, splenectomy occurred in 3.1% of patients in the pre-pathway period, compared to 3.3% in the post-pathway period. Patients undergoing splenectomy had a much higher average ISS than those who did not receive splenectomy (40.3 vs. 24.8.) The association of ISS with splenectomy as well as with time period raised a concern for confounding; therefore, an estimate adjusted for ISS quartile was calculated. Adjusted for post-pathway ISS quartile, 5.6% of isolated spleen-injured patients underwent splenectomy in the pre-pathway period (vs. 3.1% unadjusted). Similarly, among isolated spleen- and liver-

injured patients, combined abdominal operations of interest (including spleen procedure, liver procedure, or exploratory laparotomy) occurred in 6.3% (adjusted for ISS; 6.1% unadjusted) of pre-pathway patients, vs. 4.4% of post-pathway patients.

Among non-isolated splenic injury patients, 9.8% (adjusted for ISS; 7.9% unadjusted) received splenectomy in the pre-pathway period, vs. 8.7% in the post-pathway period. Among non-isolated liver and spleen injury patients, combined abdominal operations of interest occurred in 11.5% pre-pathway (adjusted for ISS; 11.0% unadjusted), compared to 13.8% post-pathway.

Length of stay was similar among both injury groups pre- and post- pathway, but was substantially longer among those with non-isolated injury (9.0 days vs. 3.0 days, post-pathway.)

Mortality was zero among patients with isolated organ injury; it was similar among those with non-isolated injury pre- and post-pathway (10.8% vs. 8.1%.) (Table 2)

Discussion

This review evaluated abdominal operative frequency in 890 pediatric patients suffering spleen and liver injuries who received medical care at HMC from 2001-2012. A minority of patients present with isolated injuries at HMC, limiting the applicability of the HMC Pediatric Solid Organ Injury Pathway. This pathway also aims to classify patients based on hemodynamic status to help guide resuscitation and operative decision-making. However, very few patients qualified as hemodynamically unstable, and very few patients requiring operative intervention were hemodynamically unstable, limiting the clinical utility of this parameter as currently defined.

Adjusted for ISS, the proportion of isolated organ injury patients undergoing splenectomy and the proportion undergoing a related abdominal surgery (spleen/liver repair and/or exploratory laparotomy) showed a slight decline after the introduction of a solid organ injury care pathway in

2005. The mean ISS of the isolated injury patients in this sample (12.6, with 35.4% having ISS \geq 15) is higher than that reported in published literature evaluating similar pathways, which report a mean ISS of between 7.7 and 11.6, and an ISS range of 4-26 (5-7, 13.) The proportion of patients with grade IV and V injury among those with isolated injury (34%, post-2005) in the HMC population is also higher than that reported in this literature; these studies include no more than 13% grade IV and V injuries, with a mean organ injury grade of between 2.3 and 2.8 (5-7, 13.)

Despite the fact that HMC cares for a population of isolated solid organ injury patients with higher grades of injury and higher overall injury, the proportion who receive splenectomy and related abdominal surgeries was low, and was close to published benchmarks (1). Studies including patients with multiple trauma show a higher proportion of patients who receive splenectomy; 15.1% in one study (3). The estimated frequency of splenectomy of 7.3% among all pediatric splenic injury patients at HMC is comparable to these reports, and falls well within published benchmarks of 5-11% in the non-isolated injury population (1, 27).

By basing our patient selection on ICD-9 codes from an established trauma registry, we potentially missed cases that were mistakenly not entered into the registry or cases where the ICD-9 code identifying the liver/spleen injury was entered incorrectly. To evaluate this, we searched for AIS codes for liver and spleen injury among a population of patients with ICD-9 codes for renal injury, for the years 2005-2012. Only 10 patients were identified as having an AIS code for spleen injury without a corresponding ICD-9 code (out of 522 total identified spleen injuries), and 10 patients were identified as having an AIS code for liver injury without a corresponding ICD-9 code (out of 478 total liver injuries.) This would suggest that the number of missed cases should be small.

Using ICD-9 procedure codes to classify the outcome may also have led to bias by incorrect coding or missing codes for procedures that were, in fact, done on patients. This is impossible to estimate but is likely of low magnitude, given that ICD-9 codes allow the hospital to bill for procedures that it performed; additionally, it should be nondifferential, as any such miscoding should have not have happened selectively.

In summary, this review shows a slight decline in operative procedures for patients with isolated solid organ injury, before and after institution of the Pediatric Solid Organ Injury Pathway at HMC in 2005, despite our observation that the current pathway has limited applicability to the patients encountered at HMC. This may represent an opportunity to expand pathway care to the remainder of the HMC pediatric solid organ injury population, depending on the availability of evidence to guide standard care for those with non-isolated and more severe injury.

TABLES

Table 1. Proportion of pediatric solid organ injury patients at Harborview Medical Center qualifying for care under the Pediatric Solid Organ Injury Pathway, 2001-2012

	Isolated solid organ injury (N=256, 28.8%)		Non-isolated solid organ injury (N=634, 71.2%)	
	Pre-pathway (2001-2004)	Post-pathway (2005-2012)	Pre-pathway (2001-2004)	Post-pathway (2005-2012)
Total cases	98	158	205	429
Hemodynamically unstable*	1/95 (1.1%)	0/157 (0%)	8/203 (3.9%)	20/427 (4.7%)

*excluding 8 patients (0.9%) missing hemodynamic data.

Table 2. Descriptive statistics and outcomes for isolated and non-isolated solid organ injury patients at Harborview Medical Center by time period, 2001-2012

	Isolated solid organ injury		Non-isolated solid organ injury	
	Pre-pathway (2001-2004) N=98	Post-pathway (2005-2012) N=158	Pre-pathway (2001-2004) N=205	Post-pathway (2005-2012) N=429
<i>Characteristics</i>				
Age, years (\pm SD)	11.8 (\pm 4.9)	11.2 (\pm 4.8)	13.9 (\pm 4.9)	13.5 (\pm 5.0)
% Male	75%	75%	62%	66%
Mean ISS (\pm SD)	10.6 (\pm 6.1)	12.6 (\pm 6.5)	25.9 (\pm 13.0)	32.0 (\pm 15.0)
High-grade solid organ injury (IV-V)*	-	34%	-	36%
<i>Outcomes</i>				
Splenectomy**	3.1%	3.3%	7.9%	8.7%
ISS-adjusted***	5.6%	-	9.8%	-
Abdominal operation****	6.1%	4.4%	11.0%	13.8%
ISS-adjusted	6.3%	-	11.5%	-
Hospital length of stay	3.7 days	3.0 days	8.7 days	9 days
Mortality	0.0%	0.0%	10.8%	8.1%

*AIS grades corresponding to grade of injury only available for years 2005-2012.

**Among patients with a spleen injury only.

***Pre-pathway proportions, adjusted for post-pathway ISS distribution (ISS quartile.)

****Combined outcome including at least one of: liver repair, spleen repair or splenectomy, or exploratory laparotomy.

Table 3. Distribution of categorized ISS by isolated vs. non-isolated injury and time period.

ISS	Isolated solid organ injury		Non-isolated solid organ injury	
	Pre-pathway (2001-2004) N=99	Post-pathway (2005-2012) N=158	Pre-pathway (2001-2004) N=204	Post-pathway (2005-2012) N=429
<10	56 (56.6%)	42 (26.6%)	24 (11.8%)	14 (3.3%)
10-15	15 (15.2%)	60 (38.0%)	21 (10.3%)	39 (9.1%)
>15	28 (28.3%)	56 (35.4%)	159 (77.9%)	376 (87.7%)

Appendix. Harborview Medical Center Solid Organ Injury Pathway

Solid Organ Injury Pathway for Pediatrics^{1,2}

OBJECTIVE: Optimal management of isolated spleen and liver injuries.

PATHWAY:

- 1) Following initial assessment of the injured pediatric patient (age < 17 years), isolated liver and spleen injuries follow either the HEMODYNAMICALLY STABLE or HEMODYNAMICALLY UNSTABLE pathway based on hemodynamics. Hemodynamic instability is based on age inappropriate heart rate and hypotension (Refer to Table1).
- 2) During the initial assessment appropriate management of the airway is maintained. In patients with age inappropriate heart rate and hypotension then resuscitation is initiated with both crystalloid and blood as indicated in the HEMODYNAMICALLY UNSTABLE algorithm with notification of the surgical attending. If stabilization occurs the patient is admitted to the PICU for management as indicated in the HEMODYNAMICALLY STABLE algorithm. If the patient has an inappropriate response to initial resuscitation efforts or demonstrates any evidence of peritonitis immediate operative intervention is to be taken.
- 3) For patients with hemodynamic stability or those that obtain hemodynamic stability following initial resuscitation with crystalloid and blood, the HEMODYNAMICALLY STABLE algorithm is followed. Initially in the PICU the patient is closely monitored with serial HCT, hemodynamic assessment, and abdominal exams.
 - a. If the HCT drops below 21 the surgical attending is notified and the patient is transfused with 10 mL/kg PRBCs, if appropriate response occurs the patient is watched for an additional 24 hours in the PICU with serial HCT. Prior to or during transfusion, angioembolization or operative intervention may occur based on surgeon discretion. If stability continues the patient is transferred to the acute care floor.
 - b. If the HCT remains below 21 or the patient demonstrate any evidence of hemodynamic instability the patient will undergo further care based on surgeon discretion consisting of further observation in the ICU, angioembolization, or operative intervention.
 - c. If the HCT remains above 21 for 24 hours on the acute care floor and no evidence of peritonitis or hemodynamic instability occurs the patient is started on a regular diet, ambulated, and discharge home. A follow up phone call in the next week will be performed with appropriate re-enforcement of activity restrictions for the next 6 weeks. Additionally, the patient will follow up in 4 weeks with either his/her primary care physician or surgeon (Please refer to discharge sheet).

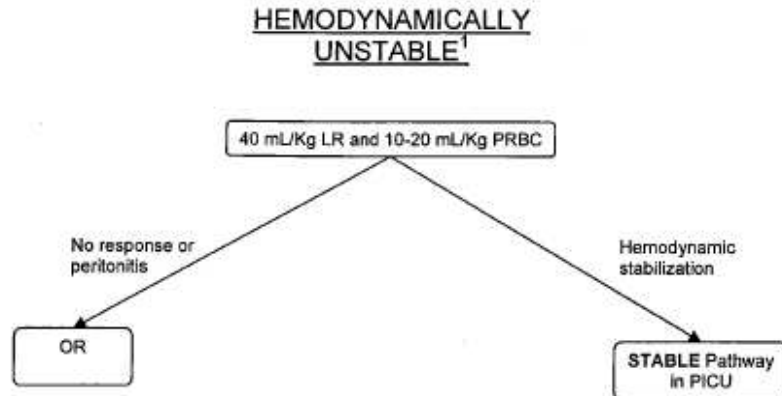
¹ Mehall JR, Ennis JS, Saltzman DA, et al. Prospective results of a standardized algorithm based on hemodynamic status for managing pediatric solid organ injury. *JACS* 194(3):3945, 2001.

² McVay M, Kokoska ER, Jackson RJ, Smith SD. Throwing out the "grade" book: management of isolated spleen and liver injury based on hemodynamic status. *J Ped Surg*. In press.

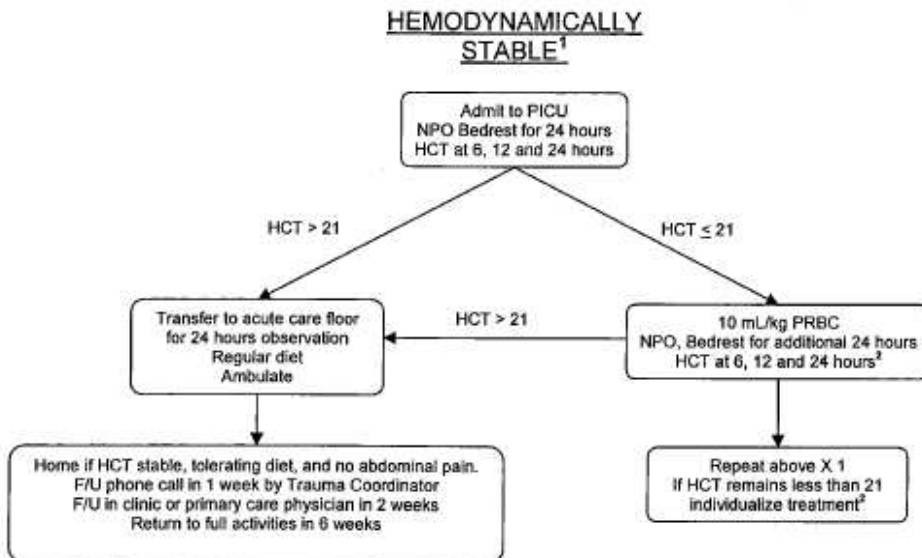
Table 1: Triggers for hemodynamic instability.

Age	Maximum Pulse * (bpm)	Minimum SBP (mmHg)	Respirations (/min)
0 – 12 months	< 160	60	30 - 60
1- 5 years	< 130	70	24 - 40
6 – 11 years	< 110	80	18 - 34
12 – 17 years	< 100	90	12 - 30

* with pain and anxiety treated.



¹Hemodynamically unstable is defined as age inappropriate HR and BP.



¹Hemodynamic instability requires pathway change to **UNSTABLE**. Stable is defined as age appropriate HR and BP.

²Consider further observation, angioembolization, or operative therapy.

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