# Nonoperative management of blunt liver and spleen injury in children: Evaluation of the ATOMAC guideline using GRADE

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**BACKGROUND:** Nonoperative management of liver and spleen injury should be achievable for more than 95% of children. Large national studies continue to show that some regions fail to meet these benchmarks. Simultaneously, current guidelines recommend hospitalization for injury grade + 2 (in days). A new treatment algorithm, the ATOMAC guideline, is in clinical use at many centers but has not been prospectively validated.

**METHODS:** A literature review conducted through MEDLINE identified publications after the American Pediatric Surgery Association guidelines using the search terms *blunt liver trauma pediatric*, *blunt spleen trauma pediatric*, and *blunt abdominal trauma pediatric*. Decision points in the new algorithm generated clinical questions, and GRADE [Grading of Recommendations, Assessment, Development, and Evaluations] methodology was used to assess the evidence supporting the guideline.

**RESULTS:** The algorithm generated 27 clinical questions. The algorithm was supported by six 1A recommendations, two 1B recommendations, one 2B recommendation, eight 2C recommendations, and ten 2D recommendations. The 1A recommendations included management based on hemodynamic status rather than grade of injury, support for an abbreviated period of bed rest, transfusion thresholds of 7.0 g/dL, exclusion of peritonitis from a guideline, accounting for local resources and concurrent injuries in the management of children failing to stabilize, as well as the use of a guideline in patients with multiple injuries. The use of more than 40 mL/kg or 4 U of blood to define end points for the guideline, and discharging stable patients before 24 hours received 1B recommendations.

**CONCLUSION:** The original American Pediatric Surgery Association guideline for pediatric blunt solid organ injury was instrumental in improving care, but sufficient evidence now exists for an updated management guideline. (*J Trauma Acute Care Surg*. 2015;79: 683–693. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

**LEVEL OF EVIDENCE:** Expert opinion, guideline, grades I to IV.

**KEY WORDS:** Pediatric trauma; nonoperative management; blunt liver injury; blunt spleen injury; guideline.

Nonoperative management (NOM) of blunt trauma began more than 40 years ago, followed by a period of slow adoption.[1] In the late 1990s, the American Pediatric Surgery Association (APSA) Trauma Committee, under the direction of Steven Stylianos, developed management guidelines to standardize care.[2] Validation of the safety of NOM stimulated the widespread adoption within the pediatric surgical community and among adult trauma providers caring for children.[3]

The APSA Trauma Committee guideline recommended a length of hospitalization based on injury grade, with the days of hospitalization defined as the injury grade + 1 day.[2] The use of the intensive care unit (ICU) was reserved for Grade 4 or higher injuries. Return to normal activities was allowed after injury grade + 2 (in weeks). By the next decade, many leaders in the pediatric trauma community described the original guidelines as too conservative with excessive hospitalization.[4–6] Paradoxically, NOM of pediatric liver and spleen injury never reached the benchmarks set by the APSA Trauma Committee in many clinical settings.[3,7,8] A landmark article in 2008 by McVay et al.,[9] from Arkansas questioned the appropriateness of injury grade for guiding management. Aptly named "Throwing out the 'Grade' Book," the authors suggested that management should be guided by hemodynamic status, not findings on imaging studies. This report triggered an interest in developing a pediatric guideline applicable to both the stable and unstable patient with a blunt liver or spleen injury (BLSI).

In 2012, a pediatric trauma consortium, ATOMAC,[10] developed a practice management guideline (PMG) for BLSI now used at many additional pediatric trauma centers throughout the United States (Fig. 1).[11] The PMG was developed over a 2-year period involving a critical appraisal of the literature, bracketing the ranges of expert opinions, and iteratively refining the algorithm through clinical use. Instructions accompany the algorithm to standardize its use during hospitalization and at discharge (Table 2 and Supplemental Digital Content 1, http://links.lww.com/TA/A655).

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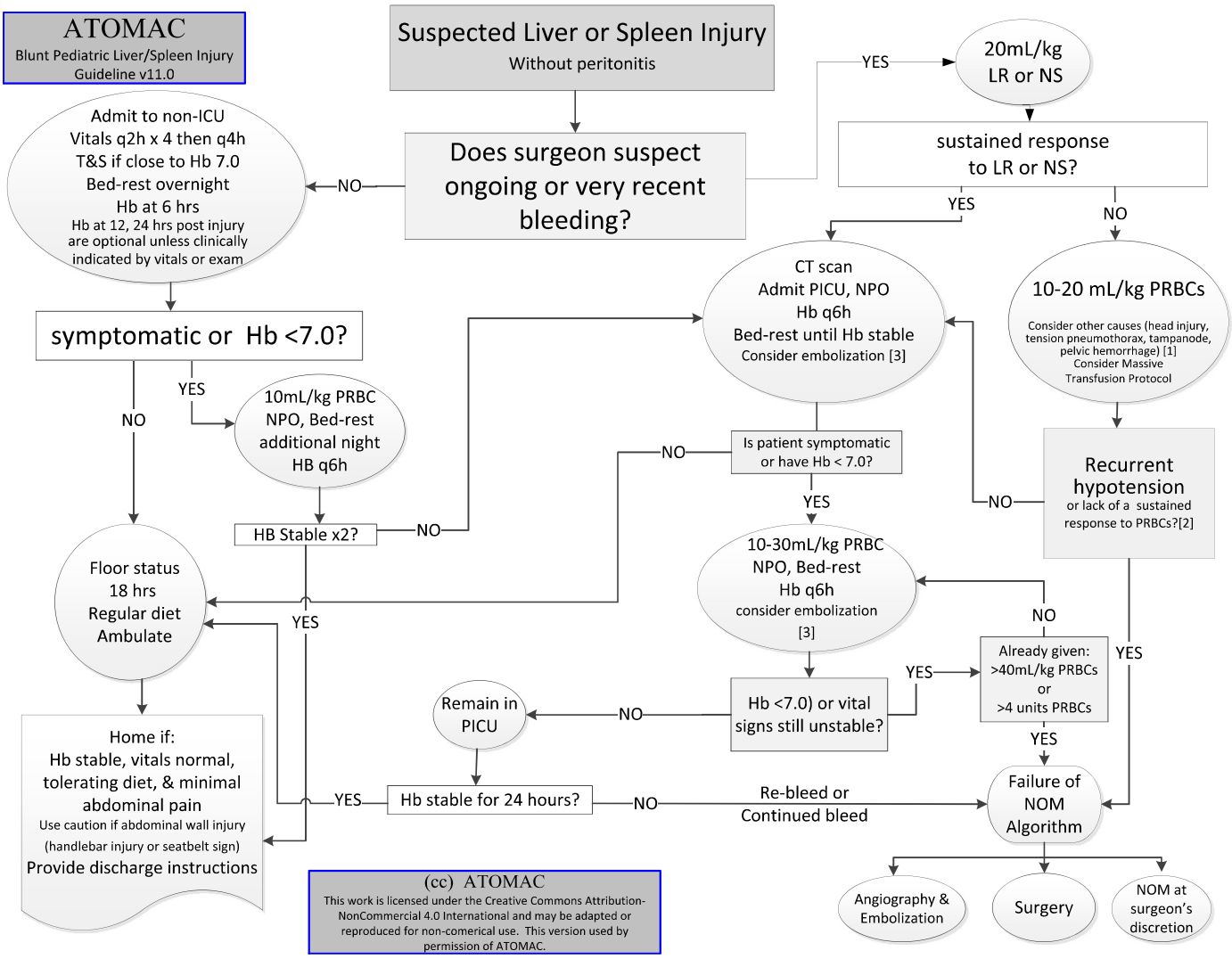


**Figure 1.** ATOMAC guideline for management of pediatric BLSI. [1]More than 50% of injured children with hypotension have no significant intra-abdominal bleeding but do have severe traumatic brain injury. [2]Recurrent hypotension within the first hour because of intra-abdominal bleeding or an SBP of less than 50 mm Hg after transfusion is an ominous sign, and strong consideration should be given to operative or angiographic intervention. [3]Embolizing CT blush may be considered, but more than 80% of children with blush do not require angiography for successful NOM. [4]Interventional modalities such as ERCP, laparoscopy, angiography, or percutaneous drainage may be required to manage complications of bile leak or hemobilia. Hb, hemoglobin; NPO, "non per os" or nothing per mouth; PICU, pediatric ICU; PRBC, packed red blood cell; q6h, every 6 hours; SBP, systolic blood pressure.

The evidence supporting the original guideline development was supplemented by expert opinion. The authors now subject the guideline to analysis based on Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) methodology to rate the level of evidence associated with the PMG.

## PATIENTS AND METHODS

ATOMAC, a research consortium of American College of Surgeons Level 1 pediatric trauma centers, conducted a systematic literature review of pediatric BLSI to critically appraise data on clinical management. The participating centers in ATOMAC include the following: Phoenix Children's Hospital (Phoenix, Arizona); Dallas Children's Medical Center (Dallas, Texas) and Dell Children's Hospital (Austin, Texas); The Children's Hospital at Oklahoma University (Oklahoma City, Oklahoma), Le Bonheur Children's Medical Center (Memphis, Tennessee); and Arkansas Children's Hospital (Little Rock, Arkansas).

The algorithm gave rise to 27 clinical questions on BLSI management (see Table Supplemental Digital Content 1, http://links.lww.com/TA/A655). The literature review, conducted through MEDLINE, identified publications using the search terms *blunt liver trauma pediatric*, *blunt spleen trauma pediatric*, and *blunt abdominal trauma pediatric*. Articles were excluded if they were published before the 2000 APSA guidelines or did not address BLSI management. Additional studies were included as needed for specific questions.

Publications on pediatric BLSI were reviewed and the level of evidence was assessed using the GRADE system.[11] GRADE is a two-part process; first, the overall body of research

**TABLE 1.** Recommendations

| Grade | Recommendation |
|---|---|
| 1A | An abbreviated period of bed rest of 1 d or less for stable patients is unequivocally supported for children whose hemoglobin has been documented to be stable. The use of bed rest on the day of admission will be discretionary until data are available. |
| 1A | A transfusion threshold of 7.0 g/dL is safe and reasonable for children undergoing NOM for BLSI. |
| 1A | NOM in the face of peritonitis should be excluded from a PMG for SOI. |
| 1A | Failure to stabilize as noted by persistent or recurrent hypotension cannot have NOM dictated by algorithm alone without taking into account local resources and other injuries. These patients should be considered for surgery, urgent embolization, or continued NOM, depending on other injuries and the center's resources. |
| 1A | Management of pediatric BLSI may be based on hemodynamic status, rather than grade. |
| 1A | Where not contraindicated, a NOM guideline be may be applied to patients with multiple injuries. In patients with other intra-abdominal injuries, such as pancreatic trauma or small bowel injury, the other injuries may take priority over the liver or spleen injury. |
| 1B | Transfusion beyond 40 mL/kg or >4 U in pediatric trauma seems to be highly correlated with failure of NOM, and care beyond these thresholds should be individualized. |
| 1B | In children with isolated BLSI without signs of clinical bleeding at presentation and stable hemoglobin, discharge before 24 h seems to be safe. Patients at risk for missed injury, need for operation, or recurrent bleeding are those with multiple identified abdominal injuries (especially pancreas), those with a contrast blush on CT scan, and those with bicycle handlebar injuries, and may not be candidates for early discharge. Since delayed bleeds have occurred (often outside of the APSA guideline period), standardized education remains an important component of the discharge. |
| 2B | Hemodynamic status at presentation may be used as a determinant for ICU admission regardless of grade, with the exception of Grade 5 injuries, which require ICU. |
| 2C | Patients not admitted to the ICU and without signs of ongoing bleeding may be allowed to drink and eat when comfortable and able. |
| 2C | AE may be used in the NOM of children with BLSI to improve splenic salvage and possibly complement available treatments of hepatic injury, but not all children with contrast extravasation need AE. |
| 2C | Clinical determination of recent or ongoing bleeding in children requires integration of multiple factors to determine the relative importance of SOI bleeding. Important factors to consider are listed on the algorithm instructions to assist in the determination recent bleeding significant enough to suggest shock. |
| 2C | Consider use of 1:1:1 transfusion ratios early in resuscitation. |
| 2C | Consideration for TEG-directed therapy may be given based on adult data. |
| 2C | Limiting crystalloid volume and early use of transfusion in children with significant bleeding should be considered based on the adult literature. |
| 2C | A pediatric PMG may be used for all children < 18 years of age, but a caution about the use of the algorithm for children > 16 years of age may be appropriate. |
| 2C | While routine reimaging in all children with BLSI is not indicated, some cases may benefit from reimaging. Patients who might benefit have not been defined, but patients with high-grade injuries near the hilum seem to be at the greatest risk of developing pseudoaneurysms based on the reported cases of relevant pseudoaneurysms. |
| 2D | Grade 1–2 injuries receive telephone follow-up at 2 wk, and Grade 3–5 injuries receive office visit at 2 wk. All patients have a final telephone follow-up at least 2 mo after injury. |
| 2D | Children are advised to avoid nonsteroidal anti-inflammatory drugs at the time of discharge until follow-up is complete. |
| 2D | Children may return to school when comfortable and able to comply with ongoing sports and contact restrictions. Modifications to allow children to change class early should be used if there is concern about injury occurring between classes or elsewhere, depending on the child's environment. |
| 2D | ERCP can be considered as an adjunct in the management of blunt hepatic injury with biloma or ductal injury. |
| 2D | Management of late-presenting liver or spleen injury beyond 24 h of injury is at the discretion of the treating surgeon. Patient care should be based predominantly on the reason for finally seeking care (pain, ileus, etc.) rather than on the initial injury. |
| 2D | No evidence in the literature suggests routinely performing a type and screen in a hemodynamically stable patient, without evidence of ongoing bleeding, and with a stable hemoglobin, above the transfusion threshold is necessary. There is evidence to suggest that eliminating a type and screen in stable patients could potentially reduce the cost of care. |
| 2D | Parents and patients are instructed to return to the emergency department for increasing pain, pallor, dizziness, difficulty breathing, vomiting, worsening shoulder pain, jaundice, gastrointestinal bleeding, or black tarry stools. |
| 2D | Transfusion of red blood cells in response to shock is recommended, but no studies have evaluated if transfusion before surgery would improve the success rates of NOM. |
| 2D | The use of serial hemoglobin measurement every 6 h is commonly used in all NOM studies, but no evidence supports a meaningful impact on management. |
| 2D | A hemoglobin drop of 0.5 g/dL the day of admission is expected from a 20-mL/kg bolus of crystalloid in a patient receiving maintenance and does not represent ongoing bleeding. |

addressing the question is assigned a "grade," and then, recommendations are derived by considering the evidence grade and other clinically important factors such as desired outcome.[11] The evidence grade, A (very confident) to D (little confidence), is assigned according to three criteria as follows: the quality of the trial designs, the magnitude of the measured effect, and the number of published studies. Outcomes measures are determined as critical, important, or of limited importance. The derived recommendation for the formal clinical question is then graded as 1 (strongly recommended) or 2 (weak or conditional recommendation).

The algorithm, instructions for use, and discharge instructions generated informal questions, which were converted to formal clinical questions using the PICO format, defined as patient population (P), intervention (I), comparators (C), and Outcome (O) as defined by the GRADE methodology. The unabridged PICO questions are available online (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/A655).

Because of print space considerations, summaries of only the most important aspects of the literature review are discussed later. A full review of the assessment of all 27 clinical questions is provided in the Supplemental Digital Material (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/A655).

## RESULTS

The search of MEDLINE yielded 596 articles. After excluding articles published before 2000 (n = 388) and those

**TABLE 2.** Instructions for Using the ATOMAC Guideline.

- Follow Advanced Trauma Life Support protocol first.
- Patients with peritonitis are managed per surgeon discretion. Do not use this algorithm for patients with peritonitis.
- Guideline was based on pediatric studies with predominantly younger patients, so take caution in patients 16 years or older.
- May be used for trauma patients with multiple injuries when not contraindicated.
- Important recent or continued bleeding is defined by the surgeon. Examples include pallor, hypoperfusion, hemodynamic signs of hypovolemia, anemia, inadequate hemoglobin increase to transfusion, and lactic acidosis.
- "Stable hemoglobin" means a hemoglobin value not dropping >0.5 g/dL in 12 h. Repeat hemoglobin at 24 h is optional.
- Any laboratory value suspected to be erroneous may be repeated before medical decision making.
- Times refer to the time of injury.
- Late presentation:
  - Stable patients presenting within 48 h after injury are admitted for observation (18 h), but hemoglobin rechecks are optional.
  - Injuries presenting >48 h after injury are managed at surgeon discretion.

not addressing BLSI management issues (n = 242), 142 articles were available for analysis. None of the articles reported randomized controlled trials. Retrospective reviews constituted the most common (n = 56) study design (Fig. 2). In total, the publications represented 69,182 pediatric patients with a BLSI.

## In Children With BLSI, Is There Adequate Evidence to Support NOM Based on Hemodynamic Status Rather Than Grade of Injury?

Before the APSA guideline, NOM of BLSI was based on hemodynamic status.[1,9,12] Four prospective studies have supported the concept of management based on hemodynamic status rather than grade.[4,9,13,14] Mehall et al.[15] reported the first prospective study directly challenging the APSA guidelines shortly after they were introduced. The authors evaluated 44 patients with liver or spleen injuries and concluded that management based on hemodynamic status was safe.[15] Another study from Arkansas in 2008 looked at 101 patients and again confirmed safety and shortened hospital length of stay.[9] The use of hemodynamic status to guide management has also been prospectively validated by St Peter et al.[14] in Kansas City and has been subsequently validated in long-term studies by the same group.[16] Despite the renewed interest in hemodynamic status, basing the decision for surgery on clinical grounds, rather than grade, is not novel,[15] as hemodynamic status was the primary determinant of management before the APSA guideline.

**Assessment**: Multiple well-conducted retrospective and prospective studies have demonstrated the safety of NOM based on hemodynamic status in short- and long-term follow-up.

**Recommendation**: (1A) Management of pediatric BLSI may be based on hemodynamic status, rather than grade.

**TABLE 3.**

**Classification of Important Outcomes**

| Critical, Important, Limited (1–9) | | |
|---|---|---|
| Importance | Rating | Outcome |
| Critical | 9 | Mortality |
| | 8 | Iatrogenic coagulopathy |
| | 8 | ARDS |
| | 8 | Complications of missed bowel injury |
| Important | 6 | Splenic salvage |
| | 6 | Avoiding adhesions/complications of laparotomy |
| | 6 | Avoiding transfusion blood/components |
| | 6 | Complications of AE |
| | 6 | Complications of ERCP, interventional radiology |
| | 5 | Minimizing ICU use |
| | 4 | Minimizing follow up imaging |
| | 4 | Minimizing LOS |
| | 4 | Minimizing school absence/parent work absence |
| | 4 | Pain control without narcotics |
| Limited importance | 3 | Minimizing follow-up |
| | 3 | Avoiding NPO |
| | 3 | Minimizing laboratory testing |
| | 2 | Return to normal sports activity |
| | 1 | Minimizing vital measurements |

ARDS, adult respiratory distress syndrome; LOS, length of stay; NPO, non per os.

## In Children With Suspected BLSI, Can Hemodynamic Stability Be Algorithmically Defined by a Limited Number of Descriptors, or Is Clinical Determination of Recent or Ongoing Bleeding Necessary to Determine Management?

Several articles use the terms stable and unstable in determining management.[9,15] The Western Trauma Association adult guidelines, however, noted these definitions to be problematic.[17] No single measure defines shock in the pediatric patient.[18] Many patients who are bleeding slowly are stable, while others with concurrent injuries are unstable but not bleeding.[19,20] Blood pressure is a poor marker for hemorrhagic shock in the pediatric patient, and heart rate is neither sensitive nor specific, especially in the setting of concurrent head injury.[19,20] A modified pediatric shock index has been published but not yet validated, and a single study suggesting a lactate of 4.0 may indicate shock in the pediatric patient has also been

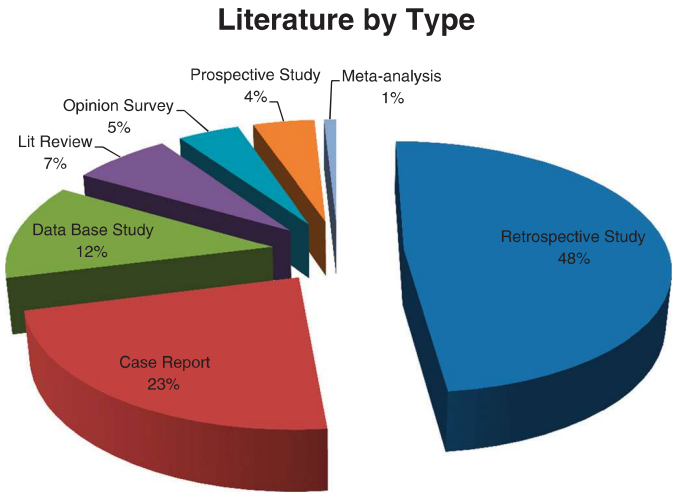


**Figure 2.**

presented (Western Pediatric Trauma Conference 2014).[21] The recently described use of Compensatory Reserve Index, or CRI, which uses continuous feature extraction from oximetry waveforms, may eliminate this dilemma, but data are still pending for pediatric trauma, and CRI devices are not yet available for use in the United States.[20,22–24]

**Assessment**: Evidence suggests hemodynamic stability in pediatric patients is difficult to define in the absence of clinical context. Some studies have included clinical judgment in the pathways of management, but none of them have directly studied clinical sensitivity or specificity. Clinical judgment of recent or ongoing bleeding has been used to determine management since NOM began and is an important part of the adult algorithms.

**Recommendation**: (2C) Clinical judgment of recent or ongoing bleeding as well as the relative importance of the BLSI bleeding is required for appropriate management. No single current vital sign, test, or calculated number can currently identify patients with ongoing bleeding caused by BLSI.

## In Children With Clinical Signs of Ongoing Bleeding, Should Crystalloid Volume Be Limited to 20 mL/kg Before Transfusion?

Advanced Trauma Life Support recommends three boluses of normal saline before blood transfusion.[25] Currently, evidence from human as well as animal models suggests that large amounts of crystalloid are detrimental to bleeding trauma patients.[26–31] Pediatric patients may be resistant to some of the adult complication of excess crystalloid but still showed adverse consequences.[31]

**Assessment**: No properly controlled studies are available in children. Retrospective adult studies seem to suggest that limited crystalloid may be associated with lower morbidity and mortality.

**Recommendation**: (2C) Limiting crystalloid volume and early use of transfusion in children with significant bleeding should be considered based on the adult literature.

## In Children With Recent or Ongoing Bleeding Requiring Transfusion, Should a Goal of 1:1:1 Component Ratio or Thromboeslastogram-Directed Therapy Be Used Before Clinical Coagulopathy, or Should Components Be Reserved for Clinical Signs of Coagulopathy?

Pediatric trauma patients requiring transfusion have been shown to demonstrate coagulopathy at presentation.[32] Hemostatic resuscitation may improve survival in adults and may limit the patients needing massive transfusion.[33,34] In pediatric patients, limited literature exists to predict which patients need massive transfusion.[35] Several authors of adult studies advocate for early activation of the massive transfusion protocol with either empiric 1:1:1 or directed therapy. Although evidence exists regarding usefulness of thromboeslastogram (TEG)-directed therapy in adult trauma patients, none exists in pediatrics.[33] For outcome data, neither a retrospective study looking at 105 massively transfused pediatric trauma patients was able to show a relationship between component ratios and survival,[36] nor was a prospective study performed before and after initiation of a massive transfusion protocol with fixed ratios.[37] Using a 22-center database, Brasel et al.[38] were able to demonstrate improved survival for both high plasma- and high platelet–to–red blood cell ratios (independently) in children.

**Assessment**: While there is strong evidence that low ratio component transfusion is associated with worse outcomes in the massively transfused adult population, the converse is less clear. The evidence demonstrating clinical improvement with component therapy in children is mixed and may be impaired by survival as well as publication bias. Some pediatric data weakly suggest benefit. No adequate studies of TEG-guided resuscitation in pediatric trauma currently exist.

**Recommendation**: (2C) Consider use of 1:1:1 transfusion ratios early in resuscitation for children suspected of needing massive transfusion. TEG-directed therapy may be useful based on adult data.[39]

## In Children With BLSI and Clinical Signs of Significant or Ongoing Bleeding, Should Transfusion Be Given Preoperatively to Improve the Success of NOM?

Older publications suggested that resuscitation should be limited or withheld preceding surgical exploration in penetrating torso trauma.[30] With the use of data from published literature, it seems that many pediatric patients are taken to the operating room before receiving a blood transfusion.[40] In successful NOM of pediatric patients, 18% are transfused, and it seems that transfusion is often performed early in their treatment.[11,12] While surgery before transfusion may contribute to the failure of NOM, no direct data could be found to support this. Although permissive hypotension shows promise in the animal laboratory and adult trauma literature, no similar data are present in pediatrics.[26,41–44]

**Assessment**: No studies have evaluated whether transfusion preoperatively improves the success of NOM.

**Recommendation**: (2D) Consideration of transfusion of red blood cells in response to shock before surgery should be considered, but no evidence supports an improvement in NOM.

## Can Children With BLSI Who Fail to Stabilize Without Intervention Have Management Determined Through a Single Arm of a PMG Algorithm, or Does Treatment Need to Be Individualized Based on Concomitant Injuries and Local Resources?

The current adult NOM literature and algorithms direct patients with bleeding from liver or splenic injury who fail to stabilize after blood transfusion to operation;[14,43,45–47] however, in pediatric trauma, hypotension is often not caused by bleeding.[19] When instability is caused by bleeding, it is sometimes difficult to quantify the relative contribution of head injuries and other injuries to initial hemodynamic instability.[19,48] Despite these observations, operation for failure to stabilize remains a basic tenant of management in the majority of the literature.[19,48] Hypotension caused by solid organ injury (BLSI) is often an ominous sign. Pediatric patients with hypotension caused by BLSI (noted as systolic blood pressure < 50 mm Hg in one study) are at significant risk of failing NOM.[19,40] In an adolescent

trauma study, angioembolization (AE) was shown to be an acceptable alternative to splenectomy in many patients.[48]

**Assessment**: Multiple large retrospective studies, well-done prospective studies, and guidelines direct patients who fail to stabilize to intervention based on local resources, but note that instability may not be solely caused by hemorrhage in the pediatric patient.

**Recommendation**: (1A) Strong. Failure to stabilize as noted by persistent or recurrent hypotension cannot have NOM dictated by algorithm alone without taking into account local resources and other injuries. These patients should be considered for surgery, urgent embolization, or continued NOM, depending on other injuries and the center 's resources.[48,49]

## Is AE Safe (Performed With Minimal Complications) and Effective (Reduces Bleeding and Need for Transfusion and/or Allows for Splenic Preservation) When Used in NOM of Children With BLSI or Not?

AE has been recommended as an alternative to splenectomy in children by some experts.[46] There have been multiple case reports describing AE as successful and safe in children with BLSI of both liver and splenic injury.[50–58] However, in the pediatric patient, retrospective observational data show that few patients with contrast extravasation require AE to achieve successful NOM. Among those who do, AE seems to be safe in this population, and some studies point to a decrease in the need for operative intervention.[59–61] In a select group of high-grade injuries or injuries that continue to bleed, it may have a role.[62,63] AE also seems to have a role in severe blunt hepatic injury, both acutely and in selected cases of pseudoaneurysm.[55,64,65]

**Assessment**: Multiple studies show safety of AE in children, and a few suggest benefit. Most children with contrast extravasation undergo successful NOM without the need for AE.

**Recommendation**: (2C) AE may be used in the NOM of children with BLSI to improve splenic salvage and possibly complement available treatments of hepatic injury, but most children do not require AE for contrast extravasation.

## In Children With BLSI With Biloma or Suspected Ductal Injury, Should Endoscopic Retrograde Cholangiopancreatography Be Performed or Not to Avoid Major Exploratory Laparotomy?

In rare cases of complications, endoscopic retrograde cholangiopancreatography (ERCP) may be indicated in NOM of BLSI. ERCP has been reported in limited adult and pediatric case reports and one retrospective cohort as an adjunct in major liver injuries and seems to have a role in selective cases of bile duct injury or treatment of bilomas.[46,66–71]

**Assessment**: Major ductal injury is rare in blunt liver injury. Several uncontrolled case series show safety of ERCP in trauma, but no studies prove efficacy.

**Recommendation**: (2D) ERCP may be considered as an adjunct in the management of blunt hepatic injury, although limited data point to efficacy.

## In Children With BLSI, Should Admission to the ICU Be Determined by Grade Alone, Hemodynamic Status, or Both?

Before the ATOMAC guideline, ICU admission was used for patients with Grade 4 or higher injuries.[2] A retrospective cohort study of 171 pediatric patients, however, showed that admission to ICU based on grade of injury resulted in excessive admission of stable patients requiring no intervention.[72] In addition, a retrospective study reviewing 59 patients found that hemodynamic stability could safely be used to guide management location, resulting in decreased use of resources.[9] Grade 5 injuries seem to be more strongly associated with NOM failure than other grades, however, and require ICU admission.[40]

**Assessment**: Some data on ICU use based on hemodynamic status rather than grade exist. Commonly, the hemodynamic status and grade will both suggest similar courses of treatment. Grade 5 injuries are independently associated with a high risk of failing NOM and require ICU admission.

**Recommendation**: (2C) Using hemodynamic status as an indicator for ICU admission should be considered in the BLSI pediatric patient; however, Grade 5 injuries may benefit from ICU monitoring.

## In Children With BLSI, Is Bed Rest Required to Reduce the Risk of Rebleeding, and If So, What Duration Is Required?

There is no evidence to support bed rest as treatment of BLSI.[73] Moreover, despite a common misconception, bed rest was never a recommendation of the initial APSA guideline.[2] Ultimately, bed rest has been accepted as the current standard even in the absence of any clinical evidence and a small amount of evidence to the contrary.[65] The prospective study of St Peter et al. confirmed the safety of an abbreviated period of bed rest, as have other studies.[4,5,14,16] An estimated 36,964 days of hospitalization could be eliminated with an abbreviated bed rest protocol.[5]

**Assessment**: No evidence suggests that bed rest prevents rebleeding in children. Several well-done prospective studies show that an abbreviated period of bed rest is safe but use of bed rest at admission is commonplace despite a lack of evidence.

**Recommendation**: (1A) An abbreviated period of bed rest of 1 day or less for stable patients is supported for children whose hemoglobin has been documented to be stable.

## In Children Who Are Bleeding From BLSI, Is There a Quantity of Packed Red Blood Cell Transfusion That Indicates Failure, and If So, What Volume?

No previous algorithm has defined an end point for failure of NOM in pediatric liver or spleen trauma based on transfusion volume.[46,65] In a survey of pediatric surgeons, more than 50% of the responders would consider NOM a failure at 40 mL/kg.[74] In two studies, 40 mL/kg showed evidence of a breakpoint at which surgery was probable.[75,76] This has recently been supported by Neff et al.[35] who noted transfusion of 40 mL/kg of all blood products within 24 hours identifies children at risk of death.

**Assessment**: A moderate amount of retrospective and expert opinion data suggest that 40 mL/kg of all blood products is associated with failure, but no prospective studies include

this as a cutoff point for failure. A threshold for algorithm failure can be defined by expert opinion, even if an operative threshold cannot.

**Recommendation**: (1B) Transfusion of pediatric BLSI beyond 40 mL/kg or more than 4 U seems to be highly correlated with failure of NOM or death, and NOM algorithms should not be used beyond this point. Since prospective data are not available, care beyond these thresholds must be individualized.

## In Children With BLSI Who Never Show Hemodynamic Signs of Significant Bleeding, Is Hospitalization for Grade +1 Day Required to Reduce the Risk of Missed Injury or Recurrent Bleeding, or Can Children Be Discharge After Less Than 24 Hours of Hospitalization?

In the pediatric trauma patient, recurrent bleeding after an initial period of cessation seems to be very uncommon.[77] Several prospective studies have demonstrated the safety of early discharge in stable patients,[4,5,9,14,16] but rare cases of late bleeding have been reported.[77,78] The vast majority of pediatric spleen injuries requiring operative intervention are treated less than 12 hours after injury.[9,14,40,77,79–81] This would include splenic injuries with a contrast blush on computed tomography (CT) scan.[79] The same would seem to hold true with pediatric liver injuries.[9,14,40,82,83] A large multi-institutional retrospective review of more than 1,800 pediatric solid organ injuries (liver, spleen, kidney, and pancreas) found that very few liver/spleen patients fail NOM. Among more than 1,000 BLSIs in the series, only 19 patients failed for shock or bleeding. The median time to operation for all patients was 3 hours, with 87% failing by 24 hours; thus, only 0.6% of the total number of patients failed after 24 hours for all causes.[40] Another series demonstrated only one delayed splenic bleed among 300 patients, and the bleed occurred outside of the period of hospitalization suggested by APSA guidelines.[77]

Factors associated with risk of failure of NOM include a contrast blush on CT scan,[62,79] bicycle mechanism with a handlebar injury,[40,84,85] and more than one abdominal solid organ injury, especially the pancreas.[40,85]

**Assessment**: Multiple prospective observational studies demonstrated the safety of an abbreviated period of hospitalization shorter than the that of the APSA guideline, and national database studies suggest that earlier discharge is already occurring. Failure studies suggest that very few patients benefit from grade + 1 day of hospitalization, and risk factors for failure can be characterized.

**Recommendation**: (1A) In children with isolated BLSI, without recent signs of clinical bleeding, discharge before 24 seems to be safe. Exceptions include patients with pancreatic injuries, multiple identified abdominal injuries, those with a contrast blush on CT scan, and those with bicycle handlebar injuries. Since delayed bleeds have occurred (often outside of the APSA guideline period), standardized education remains an important component of discharge. Patients and families should be instructed specifically on the signs and symptoms of delayed bleeding as well as other complications, and these standard instructions are included in the algorithm instructions (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/A655).

## In Children With BLSI Undergoing NOM Who Have Bled, Can a Transfusion Threshold Be Set in an Effort to Minimize Blood Transfused and Still Allow Safe NOM or Not?

Numerous pediatric studies including randomized trials have demonstrated that a transfusion threshold of hemoglobin equal to 7.0 g/dL in critically ill pediatric patients is as safe as 9.5 g/dL.[86–94] Most of these studies included medically ill, nonhemorrhaging patients and did not focus on the patient with traumatic injury, although one randomized trial on postsurgical patients showed that choosing a threshold of 7 g/dL did not adversely affect patient outcomes in terms of organ dysfunction or mortality.[91] Several trauma studies demonstrate the utility of a hemoglobin of 7.0 (or a hematocrit of 21%) in clinical practice.[9,15,16]

**Assessment**: Pediatric randomized controlled trials in critically ill and postoperative surgical patients combined with the demonstration of safety in prospective pediatric trauma studies suggest that a transfusion threshold can be defined.

**Recommendation**: (1A) A transfusion threshold of 7.0 g/dL is reasonable for children undergoing NOM for BLSI.

## Following NOM of Children With BLSI, When Is It Safe for Patients to Return to School?

Activity restriction was part of the initial APSA guideline.[2] Typical classroom activities, however, would not violate these rules. In several prospective studies, children were given an excuse from gym class and allowed children to return to school when comfortable enough to do so; there were no school-related complications.[14–16] There are no comparative data, however, to evaluate the safety of early versus delayed return to school.

**Assessment**: Well-done prospective treatment studies have allowed early return to school (with modifications to exclude restricted activities) without incident.

**Recommendation**: (2C) With appropriate activity and contact restrictions, children may return to school when comfortable and able. Modifications to allow children to change class early should be used if there is concern about injury occurring. Despite the high quality of the studies, the assigned evidence grade was not higher because of the expected low event rate for rebleeding.

## In NOM of Children With BLSI, What Symptoms Should Prompt Reevaluation?

Readmission after blunt abdominal trauma is uncommon.[95] Because of the paucity of cases, there are no established or accepted guidelines for parental counseling at the time of discharge. In addition to abdominal complaints, several authors reported symptomatic pleural effusions after solid organ injury requiring treatment, especially with high-grade injuries.[96] A list of complications was compiled from the limited experience with trauma readmissions.[78,96]

**Assessment**: Readmission and complications after discharge are rare, and no series of readmissions have been published. Reported complications were culled from the literature, and the recommendation essentially constitutes expert opinion based on reported cases.

**Recommendation**: (2D) Parents and patients are instructed to return to the emergency department for increasing pain, pallor, dizziness, difficulty breathing, vomiting, worsening shoulder pain, jaundice, gastrointestinal bleeding, or black tarry stools.

## In NOM of Children With BLSI, Should Follow-up Imaging Be Performed or Not?

The initial APSA guideline recommended no follow-up imaging.[2] The two main anticipated findings of follow-up imaging are pseudocysts and pseudoaneurysms. Most pseudocysts previously attributed to trauma seem to be congenital and not related to injury based on rigorous pathologic study.[97] The event rate is unknown but seems very low. Therefore, this discussion will focus on pseudoaneurysms. Pseudoaneurysms have been found in approximately 5% of patents in studies performing routine follow-up imaging.[64,98] The natural history of most splenic pseudoaneurysms is spontaneous thrombosis.[98] However, a retrospective study found that 3 of 11 patients with Grade 4 liver injury developed pseudoaneurysms, 2 of which ruptured, leading to the suggestion that some patients might benefit from reimaging on an individual basis.[55,64] In that study, no pseudoaneurysms were found in Grade 1 or 2 injuries. In a prospective study of 249 children treated for BLSI over a 6-year period, no delayed complications were reported despite the lack follow-up imaging,[24] while another using routine follow-up ultrasound found only a single splenic cyst, which required no intervention.[7,11] A systematic review of the adult and pediatric literature found complications of pseudoaneurysms to be rare with no mortality, leading to the conclusion that there was not adequate evidence to support or dispute the routine use of follow-up imaging.

**Assessment**: APSA guidelines do not recommend routine follow-up imaging. In studies performing routine imaging, a possible role for selected reimaging was suggested by some adverse outcomes in these small series, but the imaging also lead to interventions that may or may not have benefited the patients, particularly in splenic injury.

**Recommendation**: (2C) Routine reimaging in all children with BLSI is not indicated. Patients with high-grade (Grade 4/5) liver injuries near the hilum seem to be at the greatest risk of developing pseudoaneurysms based on the reported cases of relevant pseudoaneurysms and might benefit from reimaging.

## In Children With Suspected or Proven BLSI, Should Peritonitis Be an Exclusion Criterion From a PMG?

Peritonitis is a clinical diagnosis and may suggest underlying bowel injury or pancreatic injury. The only Level 1 recommendations in the Eastern Association for the Surgery of Trauma guidelines state that patients with peritonitis should be taken directly to the operating room.[46,65] In pediatric patients, the evidence is less clear. A single large, multi-institutional observational pediatric study reported moderate delays did not result in clinically important negative outcomes.[99] Studies of NOM in patients with peritonitis from pancreatic injury and concurrent BLSI seem to have been managed nonoperatively.[100–102] In general, however, most BLSI studies excluded peritonitis.[9,14,15,46]

**Assessment**: Peritonitis is excluded from every major protocol and study, but the confounding data of NOM in pancreatitis and bile peritonitis suggest that not every patient needs operation.

**Recommendation**: (1A) A preponderance of studies exclude patients with peritonitis, but some indirect evidence suggests that NOM takes place in children with peritonitis. NOM in the face of peritonitis should be excluded from a PMG, even if NOM is pursued.

# DISCUSSION

Research on the NOM of liver and spleen injury in the pediatric patient has greatly increased the knowledge base, and sufficient evidence exists for the adoption of a new pediatric treatment algorithm based on this information. The use of available literature and expert opinion was instrumental in developing a comprehensive algorithm for the bleeding and nonbleeding patients.

Theoretical retrospective application of the guideline validated the usefulness at multiple centers and also allowed further refinement. During this period, the general safety of the algorithm was confirmed for the full spectrum of injury severity. Prospective, theoretical application of the guideline then raised further questions, which were addressed by adding further detail to the algorithm. The algorithm has now been adopted by 10 Level 1 pediatric trauma centers and has been used successfully for more than 2 years.

While no algorithm can replace clinical judgment, the algorithm does assist in management. The strength of the guideline is in providing evidence-based guidance during initial patient management and defining failure end-points at which patients have been given an ample opportunity to avoid operation. The algorithm simultaneously shortens the length of stay for patients with no signs of bleeding.

# LIMITATIONS

The body of literature in BLSI is enormous in both breadth and scope. Some adult data are potentially applicable to children, while some pediatric data may not be applicable to young adults. Every recommendation from the PMG algorithm received a grade of D or higher because the PMG itself was based on expert opinion. Evidence grading of the algorithm by the authors of the PMG may potentially introduce bias, despite attempts to review all the relevant literature objectively. Prospective validation of this as well as the other PMGs in use is needed.

# CONCLUSION

The original APSA guideline was instrumental in improving care, but sufficient evidence now exists to support the ATOMAC PMG, which provides detailed guidance and allows for improved resource use. While the algorithm needs to be validated prospectively, the recommendations and associated algorithm seem to be supported by a large body of pediatric blunt trauma literature. With the use of GRADE methodology, there is strong support for the ATOMAC guideline.

## AUTHORSHIP

All 11 authors wrote sections of the manuscript, reviewed the entire article, agreed to the final grading, and contributed to the development of the ATOMAC algorithm. D.M.N. compiled and edited the final manuscript.

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## DISCLOSURE

The authors declare conflicts of interest.

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