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REVIEW ARTICLE

Nonoperative management of blunt splenic injury: what is new?

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Abstract The majority of splenic injuries are currently managed nonoperatively. The primary indication for operative management of blunt splenic injury is hemodynamic instability. Findings which correlate with failure of nonoperative management include grade IV or V splenic injury, high Injury Severity Scores, or active extravasation. The role of angiograph/embolization is becoming better defined, appropriate in the patient with pseudoaneurysm or active extravasation or the stable patient with grade IV or V splenic injury.

Keywords Spleen · Splenic injury · Nonoperative management · Angiography and embolization

Introduction

Currently, most blunt splenic injuries are managed nonoperatively with a high rate of success. This is especially true in the pediatric population, where the vast majority of blunt splenic injuries are observed. Patients who present with hemodynamic instability, peritonitis, or signs/concern for other intra-abdominal injury warrant urgent exploration. For all others, a trial of nonoperative management (NOM) may be appropriate. The remainder of this review will focus on NOM of blunt splenic injury in the adult patient, with particular attention paid to areas of controversy. For purposes of this study, our primary focus was on the literature from the last 10 years, although several classic papers will also be highlighted.

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Evaluation

In the blunt abdominal trauma patient without peritonitis and with normal hemodynamics, contrast-enhanced abdominal computed tomography (CT) should be performed. This allows assessment of the severity of splenic injury with determination of the grade of the splenic injury, quantification of the volume of hemoperitoneum and may reveal vascular abnormalities such as contrast blush or extravasation, pseudoaneurysm, or arteriovenous fistula. Furthermore, abdominal tomography may also detect other intra-abdominal injuries warranting laparotomy. The preferred protocol for proper evaluation of blunt splenic injuries is CT scan with intravenous contrast in both the arterial and venous phases. In a blinded retrospective analysis by experienced radiologists at a level I trauma center, the sensitivity for intraparenchymal splenic artery pseudoaneurysm was 70 % for arterial phase imaging as compared to 17 % for portal venous phase imaging [1]. In a separate retrospective analysis of traumatic splenic injuries, 60 % of contained vascular injuries (pseudoaneurysms and arteriovenous fistulae) were only seen on arterial phase imaging [2]. For evaluation of active hemorrhage or parenchymal injury, portal venous phase was both more sensitive and accurate than arterial phase (93 vs. 76 % and 95 vs. 81 %, respectively) [1].

Characteristics of the splenic injury

Grade

Higher-grade splenic injury (Table 1) according to the American Association for the Surgery of Trauma Organ Injury Scale (OIS) [3] has been associated with higher risk of failure of NOM. In a large, retrospective, multicenter

Table 1 Spleen OIS

Grade[a]	Injury type	Description of injury
Spleen Injury Scale		
I	Hematoma	Subcapsular, <10 % surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10–50 % surface area
		Intraparenchymal, <5 cm in diameter
	Laceration	Capsular tear, 1–3 cm parenchymal depth that does not involve a trabecular vessel
III	Hematoma	Subcapsular, >50 % surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma ≥5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25 % of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury which devascularizes spleen

[a] Advance one grade for multiple injuries up to grade III

study of 1488 patients with blunt splenic injury, overall success with NOM correlated with grade of splenic injury, 75 % in grade I, 70 % in grade II, 49.3 % in grade III, 16.9 % in grade IV, and 1.3 % in grade V [4]. This study also demonstrated increasing frequency of immediate operative intervention and increasing failure rates of NOM in relation to higher grade of injury. Failure of NOM was seen in 5 % of grade I injuries, 10 % of grade II, 20 % of grade III, 33 % of grade IV, and 75 % of grade V injuries. During the time frame of this study (1993–1997), immediate operative intervention decreased from 52 to 39 % and overall NOM failures declined from 13.5 to 10.8 %. It is important to note, however, that splenic artery angiography/embolization was not yet used with significant frequency.

The 2012 iteration of the EAST practice management guidelines for the selective NOM of blunt splenic injury suggest that success with NOM has been reported for all grades of injury and the presence of high-grade injury is not necessarily a contraindication to a trial of NOM [5]. However, the rate of failure of NOM in high-grade splenic injury is high. As shown in an EAST study, inappropriate selection of patients for NOM of blunt splenic injury may result in preventable deaths [6]. Many single-institution studies have sought to define factors associated with failure of NOM in higher-grade (grade IV and V) injuries, but conclusions are difficult to draw as they represent such a small fraction of the study population in question. On the other hand, a review of 3085 adults with severe blunt splenic injury (Abbreviated Injury Score ≥4) in the National Trauma Data Bank from 1997 to 2003 revealed that NOM was attempted in 40.5 % of patients but ultimately failed in greater than half (54.6 %) [7]. The ReCONECT study of New England trauma centers examined outcomes of only grade IV and V blunt splenic injuries in 14 trauma centers from 2001 to 2008 [8]. They accumulated 388 patients, with approximately four grade IV patients for every one grade V patient. Of grade IV patients, 38 % underwent immediate operation and a third of those who underwent a trial of NOM eventually required an operation. Of grade V patients, 60 % underwent immediate operation and another 25 % failed NOM. In simplistic terms, two of five grade IV and only one of seven grade V patients ultimately kept their spleens. Thus, the low likelihood of splenic preservation with high-grade splenic injury must be weighed against the high risk of bleeding. Does this make sense? It does not for grade V splenic injury in the adult; grade IV injury is less clear.

Quantity of hemoperitoneum

Quantity of hemoperitoneum can also be assessed and has been reported in several studies to be associated with failure of NOM [4, 9, 10]. Moderate to large volumes have been reported in 59–64 % of patients with splenic injury with failure rates of 10–12 %. Quantity of hemoperitoneum alone, however, was not associated with a statistically significant increased risk of failure.

Vascular abnormalities

Vascular abnormalities detected on CT may include contrast extravasation or blush, pseudoaneurysm, or arteriovenous fistulae. Comparison of studies can be confusing because the terms contrast blush, contrast extravasation, and active extravasation are applied to a variety of findings [11]. Most commonly, contrast blush refers to early enhancement in splenic parenchyma, indicative of an arterial pseudoaneurysm. In some instances, contrast blush refers to extravasation of contrast from intraparenchymal vessels. Contrast can either collect within the parenchyma or flow outside of the spleen. As one may expect, active extravasation of contrast freely flowing outside the confines of the spleen portends to failure without intervention. In a Taiwanese study, patients with contrast extravasation outside the boundaries of the spleen had an odds ratio >80 of requiring splenectomy due to hemodynamic decompensation [12].

Contrast blush has been reported in 6.6–32 % of blunt splenic trauma [9, 13–16] and is associated with higher NOM failure rates. Furthermore, contrast extravasation has been reported to increase the failure rate of NOM by 24 times [9]. Similarly, the presence of pseudoaneurysms or AV fistula has been reported to increase failure rates for NOM by 11 and 40 %, respectively. In the setting of hemodynamically stable patients with these findings, angiography and embolization is being utilized with increasing frequency at many centers though the protocols are varied. Most studies, however, seem to support the concept that splenic artery embolization improves splenic salvage rates.

Splenic artery embolization

Splenic artery angiography and embolization has been utilized with increasing frequency as an adjunct to NOM, although its use varies across centers and the indications are still poorly defined. A 2013 retrospective study examined 150 patients with grades I–III blunt splenic injury with and without contrast blush on CT [17]. The majority of patients ($n = 110$) had no blush and were simply observed. Of patients with contrast blush ($n = 40$), 18 were observed, while 22 patients underwent angiography and embolization. There was no difference in outcomes between those observed who had and did not have contrast blush; furthermore, no benefit was seen in the group with blush who underwent embolization relative to the group with blush who were observed. This suggests that, in grades I–III splenic injury, contrast blush does not predict worse outcomes nor does angioembolization provide any advantage.

In higher-grade blunt splenic injury, the advantage of splenic artery embolization seems to be more clear-cut. A retrospective, single-center review from 2012 reported on the selective use of angioembolization in hemodynamically stable adults selected for NOM [18]. Of the 539 patients reviewed, 435 underwent observation alone (81 %), while 104 (19 %) underwent angioembolization. Failure rates for grades I–III did not differ whether or not angioembolization was utilized. For grade IV and V injuries, failure of NOM was significantly reduced with the addition of angiography and embolization (23 vs. 3 %, and 63 vs. 9 %, respectively). Additionally, contrast blush was a statistically significant risk factor for failure of NOM. These same authors, in a separate retrospective study, reported the implications of contrast blush on grades IV–V splenic injuries [19]. Of 556 patients who were selected for NOM, 95 (17 %) had a contrast blush. Eighty-eight of these patients underwent angioembolization, and three patients ultimately failed NOM (3.4 %). Of the seven patients with contrast blush who were observed, five ultimately required surgery for a failure rate of 71.4 %. Of the patients without contrast blush, 51 (9.5 %) had grades IV–V injuries and angioembolization was employed in 20 (39 %) of these with no reported failures. In the 31 patients with grades IV–V injuries without blush in whom angiography was not performed, eight patients (26 %) failed NOM, leading the authors to conclude that in stable patients with grades IV–V injuries, absence of contrast blush does not reliably exclude bleeding and that angioembolization, regardless of contrast blush presence or absence, may be beneficial in grades IV–V injuries.

In a 2011 meta-analysis comparing observation alone to splenic artery embolization, NOM was attempted in 68.4 % of 10,157 patients [20]. Failure of NOM overall was 8.3 % and increased by grade from 4.7 to 83.1 % in those who were observed alone. In the case of splenic artery embolization, the rate of failure was 15.7 % and did not vary significantly by grade. When examined by grade of injury, there was a significant improvement in splenic salvage rates for grade IV and V injuries when angioembolization was employed. Despite these findings, significant variation still exists among centers. This was reflected in surveys reporting opinions on management of blunt splenic injuries [21]. In this survey, initial angioembolization was felt to be appropriate by only 23.5 and 25.5 % of respondents for grade IV and V injuries, respectively. Similarly, a retrospective analysis of four level I trauma centers throughout the USA revealed a significant variation in the use of splenic artery embolization from 1 to 19 % which was associated with differences in splenic salvage rates [22]. These centers had similar rates of immediate splenectomy at 16 %. High splenic artery embolization centers ($n = 2$, defined as a splenic embolization rate ≥ 10 %) had significantly higher spleen salvage rates and fewer NOM failures, a difference which was most pronounced for grade III and IV injuries. Patients treated at high angioembolization centers were more likely to leave with their spleen by an odds ratio of 3.

Addition of a protocol may serve to improve salvage rates further. The group at Wake Forest had been using angiography at the discretion of the trauma surgeon for the last decade [11]. They developed an algorithm for which all hemodynamically stable patients with grades III–V injury undergo angiography, and all ideally get some form of embolization. They published not only their historic results and the results of their algorithm but also the outcomes of patients who deviated from the algorithm. They documented a high rate of protocol compliance, and their prospectively collected group NOM failure rate was only 5 % as compared to their historic failure rate of 15 % for grades III–V. In those who deviated from the protocol, failure of NOM was also significantly increased at 25 %.

The group at Case Western Reserve showed the progression of success in NOM throughout the years, comparing the era of pre-angioembolization (1991–1998), selective use of angioembolization (1998–2001), and protocoled use (2002–2007) [23]. Utilizing a protocol as to when to embolize patients increased their success. The protocol suggested that patients with contrast blush or pseudoaneurysm on CT, grade III injuries with large hemoperitoneum, or grade IV injuries be sent for angiography. Grade V injuries generally underwent operation. They reported a significant increase in the use of angioembolization over time which correlated with an increased rate of attempted NOM (61 % in group I, 82 % in group II, and 88 % in group III). Successful NOM also improved over time (77 % in group I, 94 % in group II, and 97 % in group III) but was not significantly different between time periods employing selective vs. protocoled use of angioembolization.

The trauma group at the Oslo University Hospital, Ulleval, in Norway showed a similar progression of NOM success in a series of papers [24, 25]. In 2002, angioembolization was introduced into their algorithm for splenic injuries. All grades III–V injuries underwent angioembolization, as well as any grade with active extravasation or pseudoaneurysm. The protocol called for all grades III–V patients to undergo proximal embolization, with additional distal embolization for pseudoaneurysms or extravasation. Comparing the 2 years of patients before and after the implementation of this protocol, the Oslo group showed an increased success at NOM with decreased laparotomy rate [25]. In 2008, their protocol was refined based on analysis of their internal data. They removed grade III splenic injuries seen on CT scan from their mandatory angioembolization arm. With this change, all grade IV and V injuries underwent angioembolization. Regardless of injury severity, angioembolization was mandated for any pseudoaneurysm or active extravasation. When comparing their first 6 years of protocoled patients to the next 2 years of the updated protocol, they had similar characteristics for grade III patients. Mortality and complication rates remained the same despite the decrease in percentage of grade III splenic injuries undergoing angioembolization, from 68 % in the mandatory group to 32 % in the non-mandatory group [24].

Timeliness of intervention is also of paramount importance. In a 2002–2005 prospective study from Baltimore [26], hemodynamically stable patients with blunt splenic injuries underwent contrasted CT. Per protocol, all patients with active bleeding (contrast extravasation) or vascular lesions (contrast blush) and all patients with grades III–V injuries underwent splenic arteriography. Proximal splenic artery embolization was performed for any vascular abnormality, large hemoperitoneum, abrupt truncation of vessel on angiogram, or at the discretion of the trauma surgeon or interventional radiologist. Distal or selective splenic artery embolization was performed if intraperitoneal extravasation was visualized. Collectively, vascular injuries were seen on CT with increasing frequency in higher-grade injuries. Active bleeding was found in 2 % of each grade I and II, 9 % of grade III, 33 % of grade IV, and 62 % of grade V. The mean time to embolization was 4.4 h. In that time frame, 58 % of active bleeds and 9 % of pseudoaneurysms developed hemodynamic instability and required operative intervention, underscoring the importance of timely angiographic intervention. Of the remaining patients who underwent splenic artery embolization, 95 % of patients with active bleeds and 94 % of patients with vascular lesions were successfully managed without operative intervention.

More recently, Olthof et al. [27] reported on time to intervention (angiography or surgery) in 96 adults admitted with blunt splenic injury. Most patients ($n = 80$) were hemodynamically stable and underwent successful observation with or without the addition of angioembolization. Interestingly, in the 16 hemodynamically unstable patients, seven went immediately to surgery and nine were taken to angiography. Median time to intervention in these patients was not significantly different (46 min for angiography, 64 min for surgery) nor was the rate of complications or need for re-intervention, although the numbers are small.

Other factors associated with failure of NOM

The EAST study brought to light the significance of failure by revealing the mortality of the group as a whole [4]. While patients who underwent immediate operative intervention had an all-cause mortality of 26 %, those patients who had successful NOM had a mortality of 4 % and those who failed NOM had a mortality of 16.5 %. The failure group did have higher Injury Severity Scores (ISS) score and were older than those successfully managed, likely accounting for the mortality differences. This finding has been echoed by other authors as well [28].

In addition to characteristics of the splenic injury, other factors have been purported to be associated with a higher risk of NOM failure. These include advanced age, GCS score, ISS, and ongoing transfusion requirement. However, for each of these factors, the literature remains somewhat contradictory. Olthof et al. [29] reported a systematic review of ten cohort studies (from 1995 to 2011), which investigated a total of 25 prognostic factors. These studies were selected from a total of 31 after being examined for risk of bias and being categorized as high quality. Four studies found age to be a significant prognostic factor for failure with one study reporting age >40 years and two reporting age >55 years. ISS of 25 or higher were also associated with failure. Two of four studies found a significant relationship between transfusion of red blood cells and failure. One study of over 200 nonoperatively managed patients found receiving more than one unit to be an independent risk factor in logistic regression analysis, with a hazard ratio of 2.66. Limited evidence was found in this study linking the presence of traumatic brain injury (TBI) to NOM failure, and some have suggested that splenectomy in patients with moderate to severe TBI is independently associated with increased mortality [30].

Even among experts, the exact trigger for operative management may vary widely. In the Delphi study, no consensus was reached among experts with respect to age, ISS, or GCS [31]. In all three cases, only 25–35 % of respondents agreed that these factors influence their management strategy. An 81 % consensus was reached that operative management was indicated for patients requiring five or more units of packed red blood cells. However, transfusions at this quantity are far beyond the 2+ units predictive of NOM failure [29].

Timing of NOM failure

Most patients who fail NOM do so within the first 4 days following injury. In the EAST study, most failures occurred within the first 24 h (60 %) with decreasing frequency on subsequent days (14 % on second day, 7 % on third day) [4]. Ninety percent of failures occurred within the first 4 days. However, 8 % of failures happened on post-trauma day nine or later, and the majority of those were in patients with low-grade injuries. The concern for delayed failure of NOM was reiterated in a Tennessee statewide database review from 2000 to 2005 [32]. Of 1,932 patients discharged home after nonoperatively managed splenic injuries, 27 patients were readmitted within 6 months and underwent splenectomy. In other words, the rate of splenectomy after discharge home was 1.4 %. The average time to readmission from initial injury was 8 days, ranging from 3 to 146 days. Similarly, in a 6-year review of admissions to a level I trauma hospital in Seattle, the rate of nonoperative failure after discharge was 1.1 % [33].

A recent Canadian study also highlights the timing of NOM failure [34]. Five hundred and thirty-eight patients with blunt splenic injury and ISS >12 from 1996 to 2007 were reviewed. Early operative intervention was employed in 150 (26 %). Among patients selected for NOM, the overall success rate was 87 %. Of those who failed NOM, 65 % did so and required surgery within 24 h. Seven additional cases of delayed splenic rupture occurred from 5 days to 2 months following initial injury, and three of these cases occurred in the post-discharge period with all patients requiring emergent intervention.

Operation for splenic injury

Approximately 20–35 % of blunt splenic injury, generally high grade, requires urgent laparotomy. Current failure rates for NOM of adult blunt splenic injury, assuming appropriate patient selection, are 5–12 %. Although splenic salvage by operative repair of the spleen (splenorrhaphy) should always be considered when operating either early or late (nonoperative failure) for splenic injury, this is feasible in <10 % of patients. The spleens that we could easily repair in past years are generally those managed nonoperatively today.

Acute and post-discharge care

Follow-up imaging

With an understanding of the factors associated with an increased likelihood of failure of NOM, adjuncts to improve splenic salvage, and the time frame within which failures may be expected, the question of how best to manage these patients in the acute setting and after discharge must be answered. Data are lacking on management of adult patients once NOM with or without angioembolization is undertaken, and the necessity for routine post-injury CT scanning is debatable. The studies mentioned previously suggest, however, the incidence of delayed complications is not insignificant. An Ontario group recently reported their 12-year experience with management of hemodynamically stable blunt splenic injuries utilizing splenic artery embolization and follow-up CT scans for all patients at 48 h [35]. When compared to their own historical controls, the proportion of patients managed nonoperatively (77 vs. 53 %), overall splenic salvage rate (77 vs. 46 %), and failure of NOM (0.6 vs. 12 %) all improved. Importantly, the delayed development of pseudoaneurysm or arterial extravasation was found in 6 % of patients on follow-up CT scan 48 h later. The frequency of delayed findings increased with increasing grade, and all patients went on to angioembolization. The recent iteration of the EAST practice management guidelines as well as the Delphi study, however, does not support routine surveillance CT [5, 31].

Intensity of monitoring, resumption of activity, and DVT prophylaxis

The intensity and duration of monitoring in patients with blunt splenic injury, as well as the safe timing of

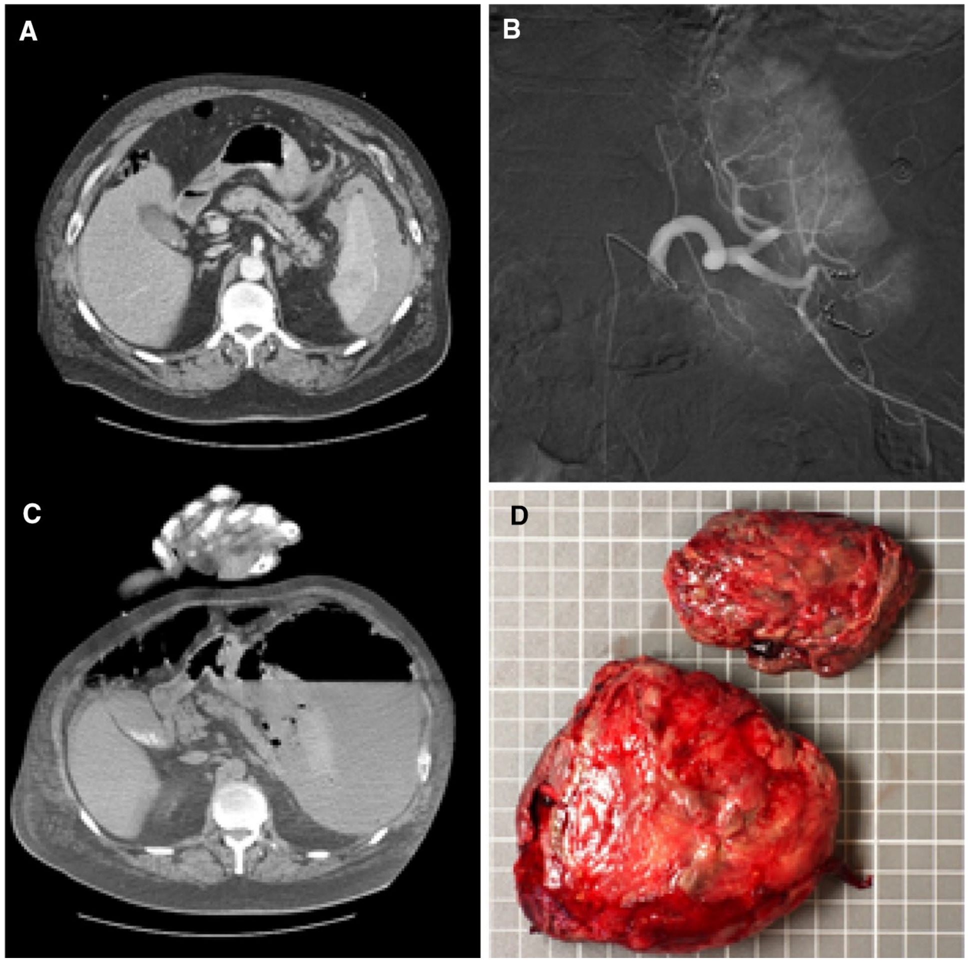

Fig. 1 **a** CT scan of a hemodynamically stable patient with a high-grade blunt splenic injury with contrast extravasation. **b** He underwent successful distal embolization of two areas of bleeding in the lower pole. **c** He returned 1 month later with altered mental status, acute kidney injury, and an abdominal mass which was found to be a large splenic abscess and **d** underwent uneventful splenectomy

institution of DVT prophylaxis and resumption of normal activities are lacking in guidelines. Indeed, the recent iteration of the EAST practice management guidelines includes these as "topics for future investigation" [5]. In the Delphi study, there was consensus on admission to a monitored setting with serial hemoglobin levels at a minimum of every 6 h for the first day and daily after that [31]. Participants differed in their opinions on duration of hospital stay as well as factors impacting that decision though in general most supported a 1- to 3-day period of monitored observation followed by a 1- to 3-day period of observation on the ward. This seems reasonable since most failures occur within the first 4 days [4]. As for activity level following injury, solid data are lacking here as well. UC Davis retrospectively reviewed their time to mobility in various solid organ injuries [36]. They reviewed 182 patients in whom other injuries did not prevent early mobility and showed that early mobilization did not correlate with a higher rate of failure of NOM. However, they did not follow a protocol, and therefore, those who started ambulating later in their hospitalization may have, in fact, had higher-grade injuries. Consensus on this topic was not achieved in the Delphi study either, although most participants frequently recommended a 3-month period of rest before return to contact sports [31].

In the pediatric population, the Trauma Committee of the American Pediatric Surgical Association recommends a period of bed rest to equal the grade of injury plus 1 day [37]. A 2006–2012 prospective study in Kansas City utilizing an abbreviated protocol with a 6-week follow-up revealed no delayed splenic bleeds [38]. In their protocol, hemoglobin levels were drawn every 4 h until deemed stable, usually less than half a point drop. The Kansas City protocol called for bed rest overnight for grades I–II and over two nights for grades III–V. If the patient received a transfusion, the time frame was reset and the clock for bed rest restarted. Their patients were allowed normal daily activities with the exception of no contact sports for 6 weeks. This study demonstrated that bed rest was the limiting factor keeping nearly two-thirds of their splenic injury patients in the hospital. If they would have followed the

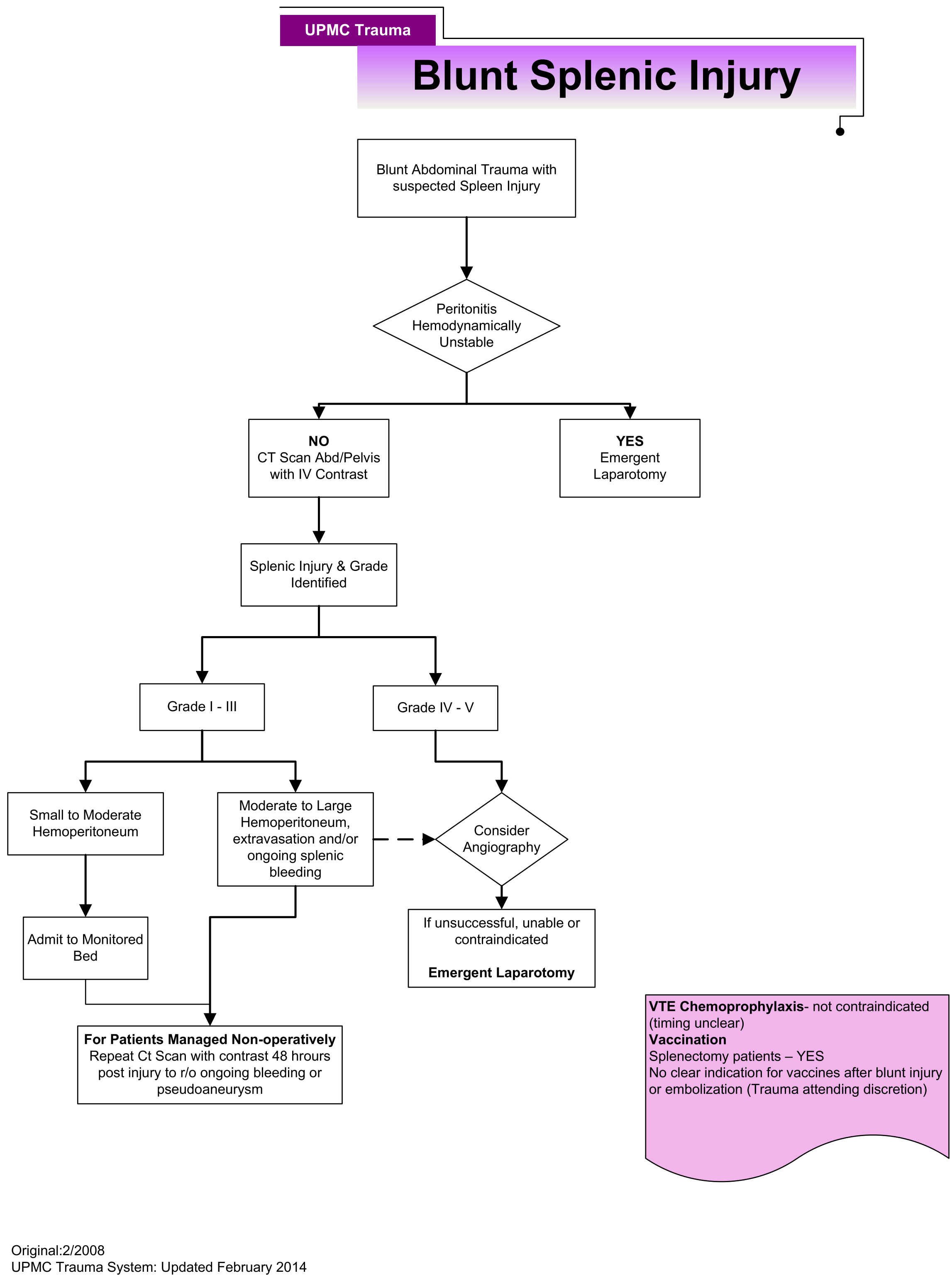

Fig. 2 Suggested protocol for management of blunt splenic injury

current guidelines, these patients would have averaged an extra day of hospitalization. Of note, they had a 1.5 % splenectomy rate (grade V injuries).

Safe institution of DVT prophylaxis is also a debated topic. In a 2011 review of 312 adult patients with various solid organ injuries (154 included splenic injuries), there was no difference in failure of NOM or blood transfusion requirements in those receiving early (within 72 h) vs. late low molecular weight heparins (LMWH) [39]. The groups were similar with respect to published risk factors for failure of NOM, though the early group was overall less severely injured. Seventeen failures of NOM were reported (5.4 %), but interestingly, all but one occurred prior to receiving LMWH. Similar findings have been reported recently from the University of Arizona [40]. In a retrospective review of propensity-matched patients with various solid organ injuries (including splenic), there was no difference in the failure rate of NOM or blood transfusions between early (≤48 h), intermediate (48–72 h), and late (>72 h) institution of DVT prophylaxis.

Complications

As described above, failure rates for NOM currently range from 4 to 19 % and have dramatically improved over the last 20 years. Although in large part this may be due to increased utilization of splenic artery angiography and embolization, angioembolization is not without complications. At a minimum, there should be a rate of complications that is similar to that of cardiac catheterization, ~1 % for femoral access [41]. In an 11-year review of blunt splenic injuries to a single trauma center in Ohio, the rate of splenic artery embolization for nonoperatively managed patients was 8 % [42]. Minor complications occurred in a third of patients, but this included left-sided pleural effusions and fevers. Fifteen percent of patients had major complications, which included contrast-induced acute kidney injury and splenic infarction, abscess, or cyst (Fig. 1). Of the patients with major complications, three quarters underwent distal embolization. A separate retrospective study reviewed 50 patients with blunt splenic injury managed with splenic artery embolization, comparing outcomes between proximal, distal, and combined embolizations [43]. Overall technical success rate was 98 %, and clinical success for hemostasis was 92 %. Four patients re-bled (two each in the proximal and distal groups), and four patients required splenectomy (one proximal and three in the distal group). Overall, 4 % of the patients developed major complications and 56 % developed minor complications, but there was no difference attributable to either technique used.

A large meta-analysis published in 2011 also sought to address potential differences in complications related to the technique of splenic artery embolization [44]. Fifteen retrospective studies were evaluated, including 479 patients. Overall failure of angioembolization was 10.2 %, with re-bleeding being the most common reason although this did not differ significantly based upon the technique used. Similarly, both techniques had an equivalent rate of infarction (0.5–2.7 %) and infection (0–1.9 %) requiring splenectomy. Minor complications (not requiring splenectomy), however, occurred more often after distal embolization.

Concerns exist regarding remaining splenic function after embolization. In a small study comparing 15 previously embolized patients with grades III–IV injuries, 14 splenectomy patients, and 30 control subjects, both embolized and splenectomy patients had higher leukocyte and platelet counts as compared to controls [45]. Embolized patients had no difference in immunoglobulin titers compared to controls. Utilizing ultrasound evaluation, both embolized patients and controls had similar splenic sizes and vessel flow. To the contrary, a Japanese study reported on immunologic alterations after splenic preservation (embolization or splenorrhaphy) as compared to those who underwent splenectomy and showed no discernible advantage to preservation over splenectomy [46]. Although no patients had documented evidence of severe infection requiring hospitalization, there were no differences in serum levels of IgM or specific IgG antibodies against 14 types of Streptococcus pneumoniae capsular antigen, suggesting that prophylactic measures/vaccination may be necessary after splenic preservation therapy. The immunologic effects of splenic embolization remain to be defined.

Summary

NOM of blunt splenic injury is currently the most common form of management in patients without immediate indications for laparotomy, and success rates have been increasing over the last two decades. In large part, this may be due to increasing use of splenic artery angiography and embolization in patients at increased risk of failure (grade III injuries with large hemoperitoneum, grades IV–V injuries, and those with vascular abnormalities on CT imaging). Other factors associated with failure of NOM continue to be debated and remain poorly defined. Although failure rates have declined, failures still occur and may present in a delayed fashion. The routine use of post-injury CT may be beneficial, but studies are lacking. Opinions vary over duration of hospitalization, resumption of activity, timing of institution of DVT prophylaxis, and need for vaccination after angioembolization, and further study is warranted (Fig. 2).

Conflict of interest Gregory A. Watson, Marcus K. Hoffman, and Andrew B. Peitzman declare that they have no conflict of interest.

Compliance with ethical requirements This work is in compliance with ethical requirements. Gregory A. Watson, Marcus K. Hoffman, and Andrew B. Peitzman declare that this is a review article that includes no studies on humans or animals.

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