International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

Non-Operative Management of Splenic Injury

Hatem Mohamed Abdel Moneim Farag, Abdel Wahab Saleh Wahab, Mohamed Hassan Mansour Mubarak, and Amr Ahmed Fouad Mohamed

Department of General Surgery, Faculty of Medicine, Zagazig University, Egypt

***Corresponding author: Mohamed Hassan Mansour Mubarak**

Email: mohamedhsn74@icloud.com

Abstract:

Background: Non-operative care has become the preferred option for the majority of patients with traumatic splenic injury who stay hemodynamically stable, regardless of injury severity. This method attempts to protect splenic immune function and avoid splenectomy complications while maintaining a high splenic salvage rate. Safe management requires appropriate patient selection, continuous clinical and hemodynamic monitoring, serial laboratory assessments, and prompt access to surgical and interventional radiology services. Although success rates are normally high, failure can occur in individuals with persistent hemodynamic instability, high-grade injuries, extensive hemoperitoneum, vascular anomalies, increased transfusion requirements, or related multiple-organ injuries. Splenic angioembolization has become a valuable treatment option for patients with active contrast extravasation, pseudoaneurysms, or other vascular abnormalities, increasing bleeding management and lowering the need for surgery. This mini-review examines the indications, contraindications, monitoring needs, activity limits, failure predictors, and role and potential complications of angioembolization in the non-operative treatment of traumatic splenic injury.

Keywords: Splenic injury; Non-operative management; Blunt abdominal trauma; Splenic angioembolization; Splenic salvage; Hemodynamic stability; Splenectomy.

Introduction:

Nonoperative management of blunt splenic injury is more common than surgical management, with more than 80% of patients trying nonoperative treatment. Nonoperative therapy has a good success rate, ranging from 80% to 95% of patients with grade IV and V injuries. Nonoperative management needs good patient care, careful use of angioembolization, and, most critically, proper patient selection. In the Eastern Association for the Surgery of Trauma (EAST) multi-institutional RCT of individuals with blunt splenic damage, it was discovered that all-cause mortality increased from 4% in patients successfully managed nonoperatively to 16.5% in those who failed nonoperative therapy. Thus, surgeons must recognize the risk variables associated with failure of nonoperative therapy in order to reduce failure and increase splenic salvage on an individual basis**(1)**.

Regardless of the severity of the injury, non-operative treatment (NOM) is currently the recommended course of action for most traumatic splenic injuries, especially in patients who are hemodynamically stable. Hemodynamic stability after first resuscitation—generally defined as a systolic blood pressure greater than 90 mmHg without persistent indications of shock—is the primary indication for NOM. The goal of this approach is to maintain splenic function in order to lower the risk of severe post-splenectomy infection. Patients chosen for NOM must have stable vital signs and show no peritoneal symptoms, such as guarding or rebound discomfort, which could indicate uncontrolled intraperitoneal bleeding or related hollow viscus injury that needs to be explored surgically right away. Even patients with head injuries, intoxication, or advanced age can be managed non-operatively if close observation is possible in a well-resourced setting. Reliable clinical assessment is crucial because it enables ongoing evaluation through serial abdominal examinations and laboratory monitoring (1).

Institutional capabilities, such as the availability of contrast-enhanced computed tomography for precise injury grading, intensive or intermediate care units for close hemodynamic monitoring, quick access to the operating room, and interventional radiology services, are critical to the successful implementation of NOM. The criteria for NOM have been broadened by contemporary trauma management to include patients over 55, those with higher-grade splenic injuries (AAST grades III–V), and those with vascular lesions or contrast extravasation found on CT scans. The success rates of NOM have greatly increased since findings like a contrast blush, pseudoaneurysm, or arteriovenous fistula are now seen as indicators for supplementary splenic angioembolization rather than absolute contraindications. Conservative management is further supported by minimal transfusion requirements, often less than two to four units of packed red blood cells, though transfusion thresholds may differ based on the clinical setting (2).

Although NOM is widely applicable, it should not be used in patients who have serious concomitant injuries that require an emergency laparotomy, generalized peritonitis, or persistent hemodynamic instability after appropriate resuscitation. Ongoing bleeding, hemodynamic decline, an increase in the need for transfusions, or clinical signs of rebleeding are indicators of NOM failure, at which point surgical intervention is required. For the majority of traumatic splenic injuries in stable patients, NOM is the standard of care. The main elements of this spleen-preserving approach are activity limitation, serial hemoglobin testing, close monitoring, and the selective use of splenic angioembolization (3).

Care Components of Non-operative Management

1) **Monitoring the Patient**
2) In order to keep an eye out for persistent or recurrent bleeding, patients with blunt splenic injuries should have regular physical examinations and vital sign monitoring. When the heart rate becomes more tachycardic or when the diastolic blood pressure rises, indicating a narrow pulse pressure, the vital signs can show bleeding without obvious instability. The best

hemodynamic monitoring for these patients has not been the subject of any specialized research. Similarly, for all injury classes, it is generally agreed upon to trend hemoglobin levels every six hours for a minimum of twenty-four hours (4). These same specialists concurred that tests for grades III through V should be prolonged to at least 48 hours, and that these patients should be admitted to intensive care for preliminary monitoring. Since this has been successfully implemented in the pediatric population, some writers have recently argued for hemodynamic monitoring alone, without serial hemoglobin checks (5). For injuries ranging from grades III to V, it is advised to do serial examinations and continuous hemodynamic monitoring for at least 24 hours in a setting that allows for this kind of monitoring. Serial examinations and intermittent hemodynamic monitoring are advised for lower-grade injuries. For all damage grades, the treating surgeon should decide whether to perform serial hemoglobin monitoring (1).

3) **Venous Thromboembolism Prophylaxis**
4) About 48 hours after a traumatic splenic injury, patients become hypercoagulable. Starting chemical venous thromboembolism (VTE) prevention and perhaps worsening bleeding when attempting splenic salvage must be weighed against this danger. Ten studies involving over 14,000 patients that examined early (≤48 hours) with late (>48 hours) initiation of VTE chemoprophylaxis in adults with blunt splenic, hepatic, and/or kidney injury were included in a recent meta-analysis by Murphy et al. (6). In the splenic subgroup analysis, there was no difference in the likelihood of nonoperative failure between the early and late groups. Additionally, they discovered that patients who got early VTE prophylaxis had considerably lower risks of developing VTE (odds ratio, 0.51; 95% confidence range, 0.33–0.81). A recent AAST prospective multi-institutional research by Schellenberg et al. likewise demonstrated lower incidence of VTE without increased bleeding complications when chemophrophylaxis was started within the first 48 hours in patients with traumatic solid organ injury (7). The World Society of Emergency Surgery suggests beginning VTE prophylaxis between 48 and 72 hours after injury, the AAST Critical Care Consensus statement suggests it within 48 hours, and the WTA suggests it within 24 hours. These findings suggest that it is safe to begin VTE prophylaxis 24 hours following an injury (8).
5) **Activity Restrictions**

- ❖ In the early days of nonoperative treatment for spleen injuries, bed rest was widely utilized. This practice is not supported by any prospective or randomized data. Because it is challenging to accurately assess exposure (walking or moving around the room), the available retrospective data is difficult to interpret. Avoiding direct strikes to the flank and abdomen is more crucial. Bed rest is not advised for spleen injuries alone (1).
- ❖ Most practitioners continue to limit patients' activities in the outpatient setting for a while after they are discharged. According to Savage et al. (9), the mean recovery period for splenic injuries of grades I and II was less than that of more severe grades III to V injuries (12.5 vs. 37.2 days). Remarkably, on outpatient follow-up CT scans, a tiny percentage (9.3%) showed

a worsening of the injury. For at least six to eight weeks, people with grades III to V injuries should refrain from engaging in activities that could cause a blow to the abdomen or flank.

- **Failure of Non-operative Management**

Although the phrase "failure of nonoperative management" is widely used, its definition varies. It was described by Peitzman et al. (10) as a patient who was admitted with a diagnosis of blunt splenic damage and was scheduled for nonoperative treatment but ultimately needed a laparotomy. After an initial period of monitoring, some have expanded the concept to include invasive treatments such splenectomy or angioembolization (11). When comparing studies, this lack of agreement is more significant from an academic standpoint than from a therapeutic one. Hemodynamic instability, image-documented splenic bleeding, declining hemoglobin levels, chronic discomfort, and abscess are some of the manifestations of patients who do not respond to nonoperative treatment. Usually, failure occurs soon after an injury. 97% of splenectomies occurred within five days of blunt splenic damage, according to a National Trauma Data Bank research (12). Furthermore, an AAST multi-institutional prospective analysis discovered that the risk of splenectomy was 3.1% during the index stay and 0.27% during the following 180 days for patients treated nonoperatively for 24 hours **(13)**.

- **Risk Factors for The Failure of Non-operative Management**
- According to a study by Godley et al. (14), being 55 years of age or older was traditionally seen as a contraindication for nonoperative management. Ten of the eleven patients (91%) who were over 55 did not respond to nonoperative care, according to the investigators. Although patients over 55 had a lower damage grade, a subsequent investigation by Bee et al. (15) similarly found a higher failure rate in this age group compared with younger patients. Age 55 and above was found to be an independent predictor of nonoperative management failure in their multivariate study. In a secondary analysis of an EAST multi-institutional trial, Harbrecht et al. (16) discovered that patients over 55 had a failure rate that was 2.5 times higher than that of those under 55. Studies have shown that elderly individuals can be safely maintained without surgery, despite the fact that age is a significant risk factor. In a retrospective analysis of patients with blunt splenic injuries, Cocanour et al. (17) discovered that the failure rate for patients 55 years of age and older was comparable to that of patients under 55 (17% vs. 14%). Although patients 55 years of age and older had a greater death rate (67% vs. 4%), this study concluded that nonoperative therapy was safe for this age group because none of the deaths were related to splenic injury. The fact that the majority of these studies are retrospective and may reflect practice habits at the time rather than an actual elevated risk must be taken into consideration when interpreting all of these findings. As of right now, preventive spleen ectomy or embolization based only on age is not advised.
- A higher probability of nonoperative management failure is also linked to certain CT findings. Increased failure rates are linked to hemoperitoneum volume, particularly moderate (250–500 mL) to large (>500 mL) volumes (18). There is also an increased risk for vascular damage, such as contrast blushing, pseudoaneurysms, or arteriovenous fistulae.

Failure rates are 11% to 40% greater when these anomalies are visible, therefore their existence, quantity, and size are crucial. There is conflicting information about the relationship between subcapsular hematoma and nonoperative failure. In a retrospective analysis of 312 patients, Lopez Jr. et al. (19) found a nonoperative failure rate of 5.9%, with subcapsular hematomas present in 80% of the failures. However, Dreizin et al. (18) discovered that the subcapsular hematoma's volume was not a predictor of failure when they measured it in a different retrospective research. Patients with spleen injuries who now show one or more of these abnormalities on a CT scan (Fig. 1) are most likely to have a splenectomy within the next few hours to days. It is necessary to closely monitor these patients in a monitored environment. Angioembolization should be carried out for people who have vascular anomalies. (**1**).

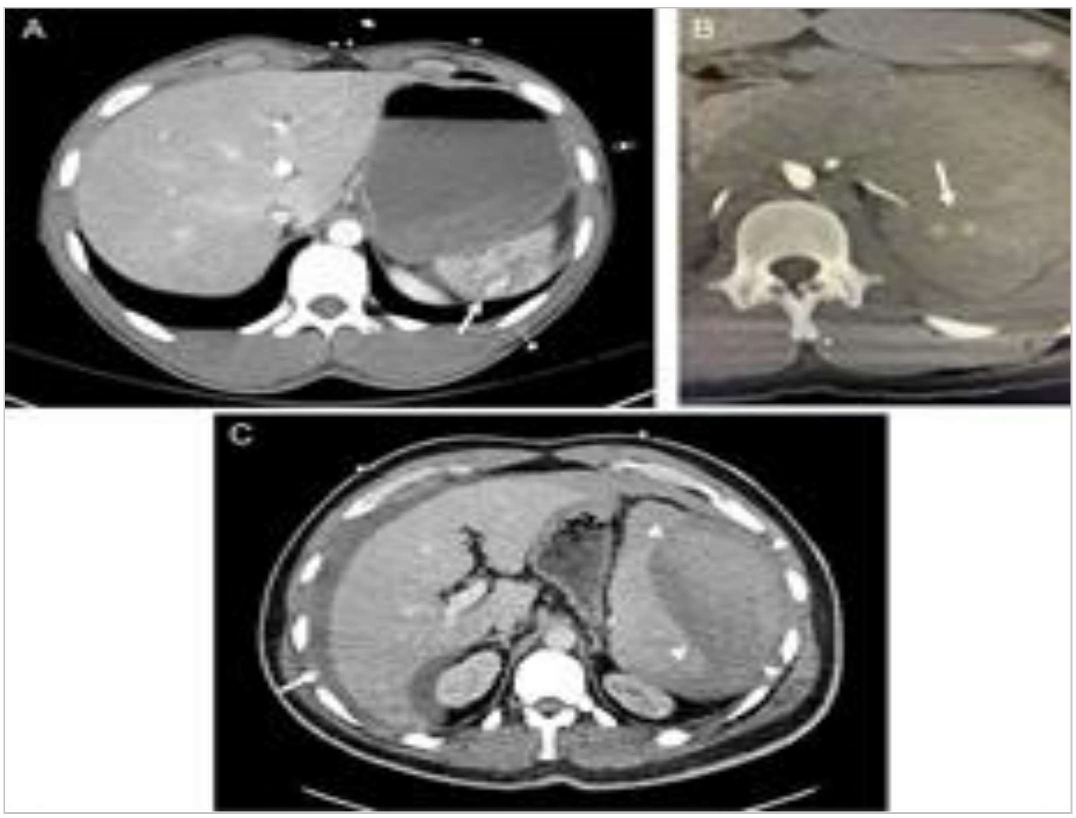

Fig 1. Computed tomography scan findings associated with increased risk of nonoperative management failure. **(*A*)** Active contrast extravasation. **(*B*)** Parenchymal pseudoaneurysm. **(*C*)** Large subcapsular hematoma (arrowheads) with moderate volume hemoperitoneum (arrow) **(1)**.

It should come as no surprise that nonoperative management failure is more common in cases of higher-grade splenic injuries. Failure rates are considerably higher in patients with multiple damage to solid organs. Malhotra et al. (20) compared patients with a single organ damage to 163 patients who had traumatic injuries to both the liver and the spleen. In addition to greater injury severity scores, admission lactate levels, and lower systolic blood pressure, patients with liver and spleen injuries also had higher nonoperative failure rates (11.6% vs. 5.8%). It was once thought that patients with concurrent traumatic brain injury (TBI) and spleen damage had a higher chance of failing. A retrospective multi-institutional study by Radin et al. (21), which discovered that the existence of TBI was an independent predictor of nonoperative management, corroborated this. More recent research has cast doubt on this conclusion, showing that prompt splenectomy in patients with severe traumatic brain injury was not linked to an increased chance of survival regardless of the severity of the injury (22). The retroactive character of the data should be taken into consideration when interpreting these findings. In order to prevent bouts of hypotension that could exacerbate a traumatic brain injury, some institutions have lower limits for splenectomy in the context of a head injury. This link may be the result of common practice patterns. As of right now, there is no advice to proactively remove or angioembolize a spleen just because a TBI is present **(1)**.

- **Role of Angio-embolization in Non-operative Management**

Because it can confirm the existence of a vascular anomaly and specifically embolize the related vessel, angio-embolization is a diagnostic and therapeutic method utilized in the treatment of splenic injuries. It is a crucial technique for increasing the splenic salvage rate because it controls bleeding from splenic injuries (23). Schurr et al.'s (24) retrospective study was among the first to identify splenic vascular abnormalities as a risk factor for unsuccessful nonoperative management. They found that having a splenic vascular abnormality on the admission CT scan increased the likelihood of nonoperative management failure. It's interesting to note that a number of vascular anomalies were discovered during the laparotomy after being overlooked during the initial scan. This was believed to be a result of the then-current CT scanning technology. In order to detect the development or emergence of splenic vascular anomalies that would not have been visible on the first scan, the Memphis group recommended a second CT scan within 24 to 48 hours (25).

Splenic vascular anomalies were also found to be a risk factor for nonoperative failure by the team at Shock Trauma in Baltimore. They adopted an other strategy. They employed angiography for all patients with an AAST grade III or higher spleen injury (1994 criteria) rather than depending on the CT scan to detect all of the splenic vascular anomalies. Embolization was carried out if angiography revealed a splenic vascular anomaly. Embolization of these vascular anomalies may improve splenic salvage, according to the hypothesis for both groups. Vascular abnormalities were linked to increased nonoperative failure rates. Embolization of patients with verified vascular anomalies was linked to better splenic salvage, according to a review of data from these and other hospitals. The Shock Trauma group used angiography, which was the criteria standard at the time, to identify patients with splenic vascular anomalies, while the Memphis group used initial and repeat CT scans (26).

Later, regardless of whether a splenic vascular abnormality was present or not, authors started sharing their experiences with preventive embolization of grades III through V spleen injuries. This was an expansion of the initial concept that might have confused the precise function of embolization and angiography in the context of adult blunt splenic injuries. According to two studies that closely examined the use of angiography using data from the Trauma Quality Improvement Program, this has resulted in a proliferation of angiography, with rates rising annually. Despite the increased use of angiography, the previous study by Dolejs et al. (27) found no change in overall splenectomy rates over time. In a more recent study, Aoki et al. (28) found that a decrease in total splenectomy rates coincided with an increase in angiography utilization for hemodynamically stable patients with isolated blunt splenic injury. The correlation did not apply to patients who were hemodynamically unstable. The authors came to the conclusion that increased splenic salvage might result from a more liberal use of angiography in stable patients. It is noteworthy, however, that there was no difference in the outcomes of patients who were randomly assigned to prophylactic embolization versus observation in the sole randomized controlled trial that examined the use of prophylactic embolization for grades III to V traumatic splenic injury (29).

Therefore, the presence of an actively bleeding vessel (contrast "blush" outside the splenic parenchyma) or vascular abnormalities observed on the initial CT scan for a patient who does not otherwise meet surgical criteria continues to be the primary justification for angioembolization (13). Due to problems with the timing of arterial contrast bolus on CT, splenic vascular anomalies may still be missed despite advances in CT technology. For higher-grade spleen injuries (grades IV and V), some people continue to support the routine use of angiography. Angiography has a limited yield when used routinely for lower-grade splenic injuries (30). Instead of using invasive angiography as a screening method or preventive embolization, it is probably preferable to repeat a CT scan in 24 to 48 hours or optimize the timing of the contrast bolus to improve initial imaging in order to detect vascular damage. In fact, only 25% of respondents to an AAST member survey believed that angiography should be required for splenic injuries of grades IV and V (31).

Splenic hemostasis can be attained by either proximal or distal splenic artery embolization (Fig. 2). By blocking the primary splenic artery and reducing flow, proximal embolization aims to lower perfusion pressure and facilitate clot formation. It prevents splenic infarction by leaving intact a number of collateral arteries that enter the upper and lower poles and the splenic hilum. In order to control the bleeding without compromising the circulation to the rest of the spleen, a microcatheter is inserted as far distally as feasible in the splenic artery branches prior to embolization. The failure rates of proximal and distal embolization procedures were found to be comparable in a meta-analysis involving eleven distinct investigations. Additionally, they were comparable in terms of the frequency of infections and infarctions (32).

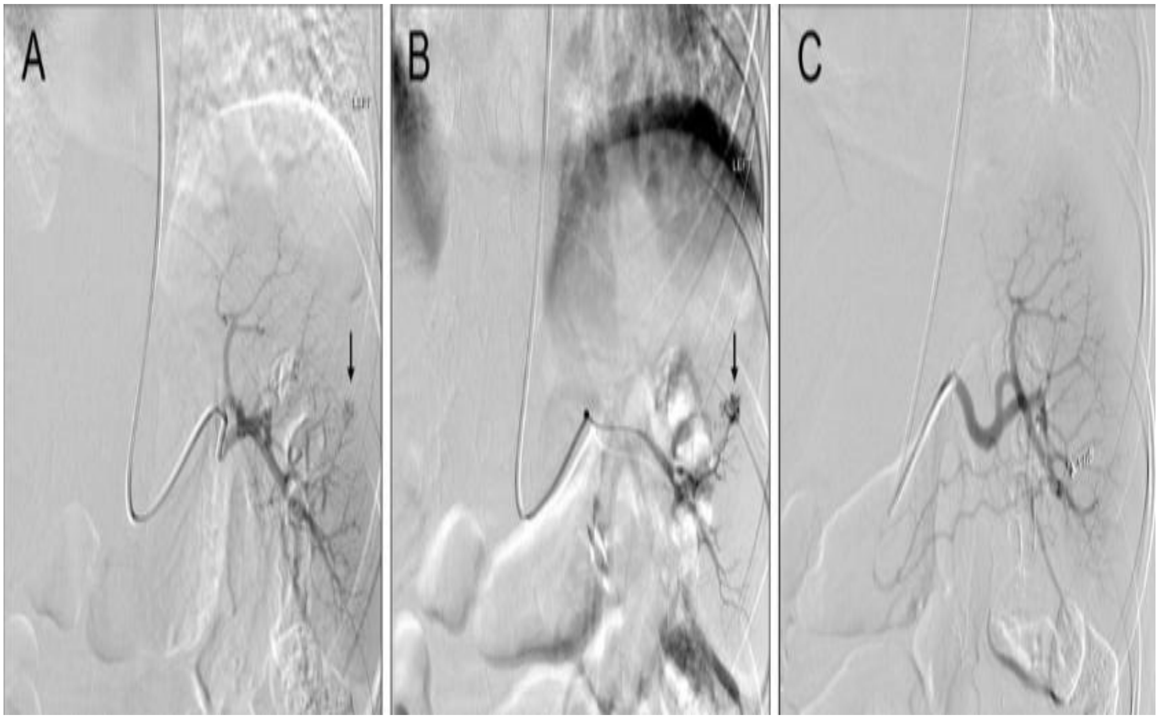

Fig 2. Patient with blunt splenic injury who underwent angioembolization for contrast blush on CT scan. (A) The diagnostic angiogram confirms the active bleed. (B) Selective angiogram of the splenic segment with bleeding. (c) Completion angiogram after distal coil deployment **(1)**.

In 5% to 15% of cases of blunt splenic injury, angioembolization fails to halt bleeding (33). It's unclear why angioembolization doesn't work. It might be the result of bleeding from trauma-induced coagulopathy or vascular injuries that were in spasm during the initial angiography and later became symptomatic. Celiac artery stenosis may play a role in certain situations, according to Requarth & Miller (34). Aortic and splenic artery pressures were measured after proximal splenic artery blockage. Splenic artery stump pressures were higher than anticipated in patients with celiac stenosis. The authors postulated that the increased pressures could result in delayed bleeding and were attributable to collaterals to the spleen that emerged as a result of the stenosis. It is debatable if repeat angioembolization is beneficial when bleeding persists following the first procedure. Repeat angiography is not advised by the Western Trauma Association (WTA) or EAST (4), however some research indicates that it has been successful in a small number of patients (35).

Angioembolization-related major problems are rare but not nonexistent. These include infarction (4.6%) and splenic abscess (4%), which can be treated with a splenectomy. There have also been reports of pseudoaneurysms and arterial damage at the access site. Fever (18.4%), coil migration (3.9%), and contrast-induced nephropathy (1.7%) are examples of minor problems (33).

References:

1. Werner, N. L., & Zarzaur, B. L. (2023). Contemporary management of adult splenic injuries: What you need to know. Journal of Trauma and Acute Care Surgery, 10–1097.
2. Shatz, D. V, De Moya, M., Brasel, K. J., Brown, C. V. R., Hartwell, J. L., Inaba, K., Ley, E. J., Moore, E. E., Peck, K. A., & Rizzo, A. G. (2023). Blunt splenic injury, emergency department to discharge: a Western Trauma Association critical decisions algorithm. *Journal of Trauma and Acute Care Surgery*, *94*(3), 448–454.
3. Denning, N.-L., Abd El-Shafy, I., Munoz, A., Vannix, I., Hazboun, R., Luo-Owen, X., Cordova, J. F., Baerg, J., Cullinane, D. C., & Prince, J. M. (2019). Safe phlebotomy reduction in stable pediatric liver and spleen injuries. *Journal of Pediatric Surgery*, *54*(11), 2363–2368.
4. Murphy, P. B., de Moya, M., Karam, B., Menard, L., Holder, E., Inaba, K., & Schellenberg, M. (2022). Optimal timing of venous thromboembolic chemoprophylaxis initiation following blunt solid organ injury: meta-analysis and systematic review. *European Journal of Trauma and Emergency Surgery*, *48*(3), 2039–2046.
5. Schellenberg, M., Owattanapanich, N., Emigh, B., Van Gent, J.-M., Egodage, T., Murphy, P. B., Ball, C. G., Spencer, A. L., Vogt, K. N., & Keeley, J. A. (2024). When is it safe to start venous thromboembolism prophylaxis after blunt solid organ injury? A prospective American Association for the Surgery of Trauma multi-institutional trial. *Journal of Trauma and Acute Care Surgery*, *96*(2), 209–215.
6. Podda, M., De Simone, B., Ceresoli, M., Virdis, F., Favi, F., Wiik Larsen, J., Coccolini, F., Sartelli, M., Pararas, N., & Beka, S. G. (2022). Follow-up strategies for patients with splenic trauma managed non-operatively: the 2022 World Society of Emergency Surgery consensus document. *World Journal of Emergency Surgery*, *17*(1), 52.
7. Savage, S. A., Zarzaur, B. L., Magnotti, L. J., Weinberg, J. A., Maish, G. O., Bee, T. K., Minard, G., Schroeppel, T., Croce, M. A., & Fabian, T. C. (2008). The evolution of blunt splenic injury: resolution and progression. *Journal of Trauma and Acute Care Surgery*, *64*(4), 1085–1092.
8. Peitzman, A. B., Heil, B., Rivera, L., Federle, M. B., Harbrecht, B. G., Clancy, K. D., Croce, M., Enderson, B. L., Morris, J. A., & Shatz, D. (2000). Blunt splenic injury in adults: multi-institutional study of the Eastern Association for the Surgery of Trauma. *Journal of Trauma and Acute Care Surgery*, *49*(2), 177–189.
9. Requarth, J. A., D'Agostino Jr, R. B., & Miller, P. R. (2011). Nonoperative management of adult blunt splenic injury with and without splenic artery embolotherapy: a meta-analysis. *Journal of Trauma and Acute Care Surgery*, *71*(4), 898–903.
10. Smith, J., Armen, S., Cook, C. H., & Martin, L. C. (2008). Blunt splenic injuries: have we watched long enough? *Journal of Trauma and Acute Care Surgery*, *64*(3), 656–665.
11. Zarzaur, B. L., Kozar, R., Myers, J. G., Claridge, J. A., Scalea, T. M., Neideen, T. A., Maung, A. A., Alarcon, L., Corcos, A., & Kerwin, A. (2015). The splenic injury outcomes

trial: an American Association for the Surgery of Trauma multi-institutional study. *Journal of Trauma and Acute Care Surgery*, *79*(3), 335–342.

12. Godley, C. D., Warren, R. L., Sheridan, R. L., & McCabe, C. J. (1996). Nonoperative management of blunt splenic injury in adults: age over 55 years as a powerful indicator for failure. *Journal of the American College of Surgeons*, *183*(2), 133–139.
13. Bee, T. K., Croce, M. A., Miller, P. R., Pritchard, F. E., & Fabian, T. C. (2001). Failures of splenic nonoperative management: is the glass half empty or half full? *Journal of Trauma and Acute Care Surgery*, *50*(2), 230–236.
14. Harbrecht, B. G., Peitzman, A. B., Rivera, L., Heil, B., Croce, M., Morris Jr, J. A., Enderson, B. L., Kurek, S., Pasquale, M., & Frykberg, E. R. (2001). Contribution of age and gender to outcome of blunt splenic injury in adults: multicenter study of the eastern association for the surgery of trauma. *Journal of Trauma and Acute Care Surgery*, *51*(5), 887–895.
15. Cocanour, C. S., Moore, F. A., Ware, D. N., Marvin, R. G., & Duke, J. H. (2000). Age should not be a consideration for nonoperative management of blunt splenic injury. *Journal of Trauma and Acute Care Surgery*, *48*(4), 606–612.
16. Dreizin, D., Champ, K., Dattwyler, M., Bodanapally, U., Smith, E. B., Li, G., Singh, R., Wang, Z., & Liang, Y. (2023). Blunt splenic injury in adults: association between volumetric quantitative CT parameters and intervention. *Journal of Trauma and Acute Care Surgery*, *94*(1), 125–132.
17. Lopez Jr, J. M., McGonagill, P. W., Gross, J. L., Hoth, J. J., Chang, M. C., Parker, K., Requarth, J. A., & Miller, P. R. (2015). Subcapsular hematoma in blunt splenic injury: a significant predictor of failure of nonoperative management. *Journal of Trauma and Acute Care Surgery*, *79*(6), 957–960.
18. Malhotra, A. K., Latifi, R., Fabian, T. C., Ivatury, R. R., Dhage, S., Bee, T. K., Miller, P. R., Croce, M. A., & Yelon, J. A. (2003). Multiplicity of solid organ injury: influence on management and outcomes after blunt abdominal trauma. *Journal of Trauma and Acute Care Surgery*, *54*(5), 925–929.
19. Radin, R., Chan, L., & Demetriades, D. (2003). Nonoperative treatment of blunt injury to solid abdominal organs: a prospective study. *Archives of Surgery*, *138*(8), 844–851.
20. Alabbasi, T., Nathens, A. B., & Tien, C. H. (2015). Blunt splenic injury and severe brain injury: a decision analysis and implications for care. *Canadian Journal of Surgery*, *58*(3 Suppl 3), S108.
21. Zarzaur, B. L., Savage, S. A., Croce, M. A., & Fabian, T. C. (2014). Trauma center angiography use in high-grade blunt splenic injuries: timing is everything. *Journal of Trauma and Acute Care Surgery*, *77*(5), 666–673.
22. Schurr, M. J., Fabian, T. C., Gavant, M., Croce, M. A., Kudsk, K. A., Minard, G., Woodman, G., & Pritchard, F. E. (1995). Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. *Journal of*

Trauma and Acute Care Surgery, *39*(3), 507–513.

23. Weinberg, J. A., Magnotti, L. J., Croce, M. A., Edwards, N. M., & Fabian, T. C. (2007). The utility of serial computed tomography imaging of blunt splenic injury: still worth a second look? *Journal of Trauma and Acute Care Surgery*, *62*(5), 1143–1148.
24. Requarth, J. A., D'Agostino, R. B., & Miller, P. R. (2012). Nonoperative management of adult blunt splenic injury with and without splenic artery embolotherapy: a meta-analysis. *Journal of Vascular Surgery*, *55*(3), 886.
25. Dolejs, S. C., Savage, S. A., Hartwell, J. L., & Zarzaur, B. L. (2018). Overall splenectomy rates stable despite increasing usage of angiography in the management of high-grade blunt splenic injury. *Annals of Surgery*, *268*(1), 179–185.
26. Aoki, M., Onogawa, A., Matsumoto, S., & Matsushima, K. (2023). Recent trends in the management of isolated high-grade splenic injuries: a nationwide analysis. *Journal of Trauma and Acute Care Surgery*, *94*(2), 220–225.
27. Arvieux, C., Frandon, J., Tidadini, F., Monnin-Bares, V., Foote, A., Dubuisson, V., Lermite, E., David, J.-S., Douane, F., & Tresallet, C. (2020). Effect of prophylactic embolization on patients with blunt trauma at high risk of splenectomy: a randomized clinical trial. *JAMA Surgery*, *155*(12), 1102–1111.
28. Crichton, J. C. I., Naidoo, K., Yet, B., Brundage, S. I., & Perkins, Z. (2017). The role of splenic angioembolization as an adjunct to nonoperative management of blunt splenic injuries: a systematic review and meta-analysis. *Journal of Trauma and Acute Care Surgery*, *83*(5), 934–943.
29. Zarzaur, B. L., Kozar, R. A., Fabian, T. C., & Coimbra, R. (2011). A survey of American Association for the Surgery of Trauma member practices in the management of blunt splenic injury. *Journal of Trauma and Acute Care Surgery*, *70*(5), 1026–1031.
30. Schnüriger, B., Inaba, K., Konstantinidis, A., Lustenberger, T., Chan, L. S., & Demetriades, D. (2011). Outcomes of proximal versus distal splenic artery embolization after trauma: a systematic review and meta-analysis. *Journal of Trauma and Acute Care Surgery*, *70*(1), 252–260.
31. Alomar, Z., Alomar, Y., Mahmood, I., Alomar, A., El-Menyar, A., Asim, M., Rizoli, S., & Al-Thani, H. (2024). Complications and failure rate of splenic artery angioembolization following blunt splenic trauma: A systematic review. *Injury*, 111753.
32. Requarth, J. A., & Miller, P. R. (2012). The splenic artery stump pressure is affected by arterial anatomy after proximal embolotherapy in blunt splenic injury. *Journal of Trauma and Acute Care Surgery*, *73*(5), 1221–1224.
33. Zarzaur, B. L., Dunn, J. A., Leininger, B., Lauerman, M., Shanmuganathan, K., Kaups, K., Zamary, K., Hartwell, J. L., Bhakta, A., & Myers, J. (2017). Natural history of splenic vascular abnormalities after blunt injury: A Western Trauma Association multicenter trial. *Journal of Trauma and Acute Care Surgery*, *83*(6), 999–1005.