Review
https://doi.org/10.23934/2223-9022-2021-10-2-347-356

Combined Blunt Splenic Injury in Adults: Modern Approach to Diagnosis and Treatment

V.V. Aleksandrov✉, S.S. Maskin, V.V. Matyukhin

Department of Hospital Surgery
Volgograd State Medical University of the Ministry of Health of the Russian Federation
1 Pavshikh Bortsov Sq., Volgograd, 400131, Russian Federation

✉ **Contacts:** Vasiliy V. Aleksandrov, Candidate of Medical Sciences, Associate Professor of the Department of Hospital Surgery of the Volgograd State Medical University.
Email: 79178304989@yandex.ru

BACKGROUND The high frequency of injuries of the spleen, as well as its important immunocompetent role in the body, dictate the need to develop a standardized approach to the diagnosis and treatment of this category of patients.

AIM Standardization of the treatment and diagnostic approach for combined blunt splenic injury to improve treatment results.

MATERIAL AND METHODS The analysis of literary sources of Russian and foreign authors on this issue.

RESULTS The therapeutic and diagnostic algorithm was developed for combined blunt splenic injury based on the severity of the patient, and a detailed description of non-operative and damage control surgical treatment was given.

CONCLUSION The use of endovascular interventions in the treatment of splenic injuries, as well as their gradual treatment in conditions of severe polytrauma, helps to reduce mortality.

Keywords: blunt abdominal trauma, concomitant injury, blunt splenic trauma, damage control surgery, non-operative management, angioembolization, organ-sparing operations

For citation Aleksandrov VV, Maskin SS, Matyukhin VV. Combined Blunt Splenic Injury in Adults: Modern Approach to Diagnosis and Treatment. *Russian Sklifosovsky Journal of Emergency Medical Care*. 2021;10(2):347–356. https://doi.org/10.23934/2223-9022-2021-10-2-347-356 (in Russ.)

Conflict of interest Authors declare lack of the conflicts of interests

Acknowledgments, sponsorship The study had no sponsorship

Affiliations

Vasily V. Aleksandrov	Candidate of Medical Sciences, Associate Professor of the Department of Hospital Surgery, Volgograd State Medical University; https://orcid.org/0000-0001-8364-8934, 79178304989@yandex.ru; 40%, concept and design of the study, collection and processing of material, writing text of the article
Sergei S. Maskin	Doctor of Medical Sciences, Professor, Head of the Department of Hospital Surgery, Volgograd State Medical University; https://orcid.org/0000-0002-5275-4213, maskins@bk.ru; 30%, research concept and design, editing of the article
Viktor V. Matyukhin	Candidate of Medical Sciences, Associate Professor of the Department of Hospital Surgery, Volgograd State Medical University; https://orcid.org/0000-0002-8195-6172, victor.matyukhin@gmail.com; 30%, collection and processing of material

BPsyst - systolic blood pressure
aPTT - activated partial thromboplastin time
AC - abdominal cavity
HSh - hemorrhagic shock
DO - dynamic observation
DPL - diagnostic peritoneal lavage
GIB - gastrointestinal bleeding
GIT - gastrointestinal tract
RPS - retroperitoneal space
BSI - blunt splenic injury
ALV - artificial lung ventilation
ITT - infusion-transfusion therapy
LT – laparotomy
LS – laparoscopy

MSCT - multislice computed tomography
NOM - non-operative management
ARF - acute respiratory failure
ICU - intensive care unit
FG - free gas
FF - free fluid
FFP - fresh frozen plasma
SE – splenectomy
CI - concomitant injury
USDS - ultrasonic duplex scanning
TBI - traumatic brain injury
HR - heart rate
RR - respiratory rate
CMEV - contrast media extravasation
EE - endovascular embolization
AAST — The American Association for the Surgery of Trauma
DC — damage control surgery
EAST — Eastern Association for the Surgery of Trauma
OPSI — overwhelming postsplenectomy infection
WSES — World Society of Emergency Surgery

It is so common for an abdominal surgeon - to sit washed and dressed for surgery in the corner of a quiet operating room under the clock showing midnight ... In a few minutes the patient will be brought in and another emergency laparotomy will begin. This is the culmination of the process that began a few hours ago - with a meeting between the surgeon and the patient, examination, diagnosis and development of an action plan.
Peter F. Jones

INTRODUCTION

A splenic injury occurs in 16–30% of patients with blunt abdominal trauma, and in case of concomitant injury (CI) it reaches 49% [1–5]; in children it ranks first and accounts for 46.9–61% [6]. In 70% of cases, other organs of the abdominal cavity (AC) and the retroperitoneal space (RPS) - pancreas, kidneys, intestines - are simultaneously damaged; in 88.7% of cases it is CI [7]. The mechanism of the injury is as follows: a blow to the region of the VIII – XII ribs on the left (splenic ruptures are associated with fractures of the lower ribs on the left in 40–50% of cases), to the left hypochondrium due to road traffic accidents (35.5–58.1%), compression/work injury (3.2–6.5%), falling from height (25.8–45.1%), household accidents / beating (12.9%) [3, 7–10]. Low mobility, plethora of the organ and capsular weakening predispose to rupture [10].

Based on the analysis and systematization of literary sources, a therapeutic and diagnostic algorithm was developed for suspected concomitant blunt splenic injury (BSI).

1. In case of **hemodynamically unstable** patients (BPsyst less than 90 mm Hg, HR more than 120 beats per minute, RR more than 30 breaths per minute, obvious signs of HSh) emergency ultrasound examination of the AC and RPS organs is performed (level of evidence - A, strength of recommendation - 1; A1) [2, 11, 12, 13]. If a retroperitoneal / splenic hematoma is detected, duplex ultrasound scanning (USDS) to assess the presence of blood flow as a sign of ongoing bleeding (B1) [11]) (*E-FAST* protocol) and to search for free fluid (FF), as well as plain radiography of AC organs (for the purpose of detecting free gas (FG) in the AC/ RPS) and radiography of other segments (if clinically indicated) [13, 14] are performed.

Splenic injuries may be missed by ultrasound imaging, especially in the absence of hemoperitoneum. The method detects FF in the volume of up to 200 ml with an accuracy of 94.3%, from 200 to 500 ml - with an accuracy of 98.5%. However, up to 29% of splenic ruptures are not associated with sonographic hemoperitoneum. The sensitivity of ultrasound in detecting splenic ruptures reaches 80–84% for injuries of grade III or higher severity according to the *AAST* classification (Table), and is significantly lower for *AAST* grades I – II, the specificity being 100% [14].

Table

Splenic Injury Classification According to the American Association for the Surgery of Trauma

Splenic Injury Grade	Type of Injury	Morphological Assessment of Splenic Injury
I	Hematoma Laceration (tear)	Subcapsular hematoma <10% of surface area Capsular tear, <1 cm depth
II	Hematoma Laceration (tear)	Subcapsular hematoma, 10-50% of surface area Intraparenchymal hematoma <5 cm Capsular tear, 1-3 cm in depth, without trabecular vessel involvement
III	Hematoma Laceration (tear)	Subcapsular hematoma >50% of surface area Subcapsular, unstable of any diameter Subcapsular or intraparenchymal hematoma with rupture and bleeding Intraparenchymal hematoma ≥5 cm or Parenchymal laceration >3 cm in depth or with trabecular vessel involvement
IV	Laceration (tear)	Parenchymal laceration involving segmental or hilar vessels producing >25% devascularisation
V	Laceration (tear) Splenic vascular injury	Completely shattered spleen Hilar vascular injury which devascularized spleen Complete separation of the spleen from the vascular pedicle

Ultrasound signs of splenic trauma:

a) subcapsular hematoma: accumulation of fluid clearly delimited by a crescent or elliptical capsule. It flattens or compresses the splenic parenchyma, and may be anechoic, with increased echogenicity, or heterogeneous;

b) Splenic lacerations: abnormal heterogeneous areas, may be anechoic in case of rapid bleeding, but are often more echogenic than the normal spleen. There may be contour discontinuity / capsule disruption (72%). Most lacerations occur along the lateral edge of the spleen. FF is almost always present as an anechoic streak;

c) a sentinel clot in the form of an echogenic or heterogeneous zone in the FF adjacent to the site of the injury is an indirect sign of the ruptured spleen;

d) intraparenchymal hematoma: the focal area of increased echogenicity, USDS shows uneven contours and absent vascular pattern (12%);

e) splenic infarction: a zone of decreased or mixed echogenicity, well-defined, triangular in shape, with the base directed towards the splenic capsule.

Hemodynamically unstable patients with the signs of ongoing intra-abdominal (with an amount of FF of at least 500 ml) / retroperitoneal bleeding / increase in size of splenic hematoma, in the presence of FG in the AC/RPS undergo emergency laparotomy (LT) (A1) [2, 6, 10-15] combined with resuscitation [13].

In case of FF presence in the AC of less than 500 ml or uninformative ultrasound with the absence of FG in the AC/ RPS, or in the absence of FF / FG in the AC /RPS, but with a clinically "restless" abdomen, diagnostic peritoneal lavage (DPL) (A1) [10, 11, 13] /mini-laparotomy is urgently performed, and with 10 ml gross blood on initial aspiration, > 500/mm3 white blood cells (WBC), > 100,000/mm3 red blood cells (RBC), or the presence of bile, gastric / intestinal contents / food particles, urine, cloudy exudate due to fibrin strands, alkaline phosphatase level above 10 IU/L / amylase level more than 75 IU /L patients are transferred to LT (A1) [2, 10, 12].

The diagnostic value of plain radiography in patients with concomitant abdominal trauma is 41.2–66.4%. If the spleen is damaged, a homogeneous shadow descending downwards along the left abdominal canal to the iliac fossa can be detected in the left subphrenic space; an elevation and limited mobility of the left hemidiaphragm, sometimes reactive pleural effusion on the left, displacement of the stomach and left bend of the colon downwards and to the right; swollen abdomen and blurred contour of the greater curvature, its "serration", rib fractures on the left are noticed [14].

Patients with absent FF and FG in the AC/RPS, no ultrasound signs of blood flow in the retroperitoneal/splenic hematoma, "calm" abdomen are observed and treated in the intensive care unit (ICU) [2, 11-13].

2. In case of **hemodynamically stable** patients (BPsyst more than 90 mm Hg, HR under 120 beats per minute, RR under 30 breaths per minute, no signs of HSh) MSCT of the abdomen is urgently performed (A1) [2, 5, 7, 9–12, 14] (other segments – if clinically indicated); in case of suspected damage to large blood

vessel/parenchymal organs of the AC/RPS, and/or FF in the AC, and the absence of FG in the AC/RPS, CT angiography is performed to identify the source of possible bleeding [13, 14]. The accuracy of computed tomography (CT) in detecting hemoperitoneum is 100%.

CT is indispensable in the diagnosis of intraparenchymal or subcapsular hematoma. Intraparenchymal hematoma has an irregular rounded shape, with clear uneven contours, and is located in the center of the organ; subcapsular hematoma is located under the capsule of the organ, has a crescent shape with clear contours, a heterogeneous structure with a density of up to 45-50 HU in the 1st – 3rd day after injury and 10–15 HU – starting from the 5th day. In case of lacerations, a zone of irregular shape with uneven blurred contours of an inhomogeneous structure with a density of up to 30–35 HU in the first 3 days after injury and 20-25 HU – starting from the 5th day is revealed. The sensitivity and specificity of the method for splenic injuries is 96–100% [11].

In case of contrast media extravasation (CMEV) into the AC/RPS/splenic parenchyma (unstable hematoma), arterial or arteriovenous pseudoaneurysm detection - regardless of injury grade - endovascular splenic artery embolization (A2) is performed [3, 8, 10, 11, 14], thus decreasing the odds of surgical intervention to 9.9–15.7%, and increasing the incidence of organ-sparing surgeries from 53 to 75% [1, 4, 16]. If EE is impossible, the incidence of inevitable surgeries increases up to 19.6% with *AAST* grade III BSI, up to 33% with *AAST* grade IV, and up to 75% with *AAST* grade V [1]. The optimal EE method for blunt splenic injuries has not yet been developed [16]. Proximal and combined EE are preferred for multiple splenic vascular injuries (C1) [11, 15, 16]. In their systematic review and meta-analysis based on 876 patient cases *Rong JJ et al.,* 2017 [16] showed the advantages of proximal EE in comparison with distal and combined ones for splenic infarct and abscess. *Lee R et al*., 2020 [17] evaluating the outcomes of the distal EE of the splenic artery in 42 patients with *AAST* grade V BSI, concluded that in 88% of cases the technique was effective regardless of the patient's hemodynamic status.

If EE is ineffective, the amount of FF in the AC ⩾500 ml, and a growing retroperitoneal/splenic hematoma, LT, revision of the retroperitoneal hematoma (to stop ongoing intra-abdominal/retroperitoneal bleeding) and splenectomy (SE) are performed (A2) [9, 11, 13, 15].

If EE is ineffective, the amount of FF in the AC under 500 ml, contrast media extravasation (CMEV) into the splenic parenchyma (unstable hematoma), LS is urgently performed to stop bleeding and clean and drain the AC [2, 6, 11, 15]. Laparoscopic surgeries can be performed for *AAST* grade I – III BSI in 40% of cases [18], the method has contraindications: damage or suspicion of damage to the diaphragm (with undrained pleural cavity), severe respiratory distress, hemodynamic instability [1, 19]. In case of stable subcapsular hematoma up to 2 cm in diameter the volume of intervention can be limited to bringing the omentum to the bruised part of the spleen and draining the left subphrenic space for 5–8 days. If a peripheral hematoma occupies the pole of the spleen or its main body, and is unstable, or its diameter is more than 2 cm, puncture aspiration with the closure of the puncture hole with an adhesive composition is performed [18]. If the spleen is ruptured in the area of colicosplenic ligament attachment and parenchymal bleeding is of low-intensity, laser coagulation of the ruptures [1], defect repair with surgical glue, application of hemostatic agents, splenorrhaphy done as omentolienopexy may be performed [4]. A non-contact method of argon plasma coagulation has a high efficiency, allowing formation of a reliable dense eschar [1]. In case of an unsuccessful attempt at hemostasis, the growth of the intraparenchymal hematoma, laparoscopic SE is performed [1, 18, 19]. In case of an unclear source of ongoing bleeding or impossibility / ineffectiveness of hemostasis, LS procedures are converted to LT [6, 12, 13].

In case of effective EE, the absence of hemoperitoneum (“stabilization” of an unstable hematoma), the hemodynamically stable patient is left under dynamic observation (DO) [15, 17].

If EE is effective and the amount of FF in the AC is more than 500 ml (intra-abdominal bleeding stopped with hemodynamic stability), LS is urgently performed to clean and drain the AC [6, 13].

In case of effective EE and the amount of FF in the AC being less than 500 ml (insignificant intra-abdominal bleeding stopped with hemodynamic stability), the absence of FG in the AC / RPS and a "calm" abdomen (no signs of peritonitis, intestinal obstruction, tension of the anterior abdominal wall), DO is organized [15, 17]. In case of a “restless” abdomen DPL is performed, and if clinically indicated (if, in addition to damage to the parenchymal organ, there is a rupture of a hollow organ without FG in the AC / RPS) LT is performed [11, 12, 13].

In the absence of CMEV into AC / RPS or the organ parenchyma, the absence of FG in the AC and RPS, the absence of hemoperitoneum (stable hematoma), DO is performed [15, 17].

In the absence of CMEV into AC / RPS or the splenic parenchyma, the absence of FG in the AC / RPS, with FF <500 ml to clarify its nature DPL is urgently performed. In cases of bowel perforation the sensitivity of CT reaches 90%; in hemodynamically stable patients, CT and DPL are complementary diagnostic methods (A1) [12] and, if appropriate indications are identified (rupture of a hollow organ without FG in the AC / RPS), the switch to LT is performed [11, 12, 13].

In the absence of CMEV into AC / RPS/splenic parenchyma, the absence of FG in AC and RPS, with FF in the AC not less than 500 ml LS is urgently performed to search for a possible hollow organ rupture (without abnormal presence of FG in the AC or RPS), to adequately clean and drain the AC. When the latter is found, the conversion of access is indicated [11–13].

If CT detects signs of damage to a hollow organ, FG in the AC / RPS, distinct symptoms of peritonitis, LT is urgently performed [2]. If CT results are doubtful or negative, the abdomen is "calm", as well as in case of non-operative managementt of splenic injuries, DO (A1) and repeated CT are performed 12–48 hours and on the 7th day after injury (A2) [2, 10, 11]. According to the *WSES* recommendations, dynamic CT is necessary for *AAST* grade III– V BSI, decreased hematocrit levels, pseudoaneurysms of the splenic artery, coagulopathy, splenopathy, impaired consciousness (A2) [11]. In case of a "restless" abdomen, DPL and, if clinically indicated, LT are performed [11–13].

The prevalence of transverse ruptures without great vessel injuries established by CT with intravenous contrast (A2) [11] creates the prerequisites for successful non-operative management (NOM) of BSI [6] in ICU under the following conditions:

1) stable hemodynamic parameters (BPsyst more than 90 mm Hg; HR less than 120 beats per minute) against ongoing infusion combined with endoscopic hemostasis, the absence of HSh (A2) [2, 7, 11, 20, 21]. According to the *WSES* and *EAST* recommendations, NOM of BSI is the method of choice for hemodynamically stable patients (A2) [11, 21]. Until recently, hemodynamic instability was an absolute contraindication to NOM (A1) [3, 6, 11, 15], but *Guinto R. et al*., 2020 [22] have analyzed the possibility of angioembolization as the first stage of NOM in hypotensive patients with *AIS* grade IV–V BSI and came to the conclusion that the technique did not lead to increased mortality, despite a higher percentage of intra-abdominal infections. The authors emphasize that with such injuries of the spleen, surgeons in most cases (95%) tend to perform SE, but in some cases, after a positive response to the initial anti-shock measures, EE can be used. In 29% of patients, EE was ineffective and required SE [22]. Taiwanese researchers *Liao CA et al.,* 2020 [23] also did not find a significant difference in mortality rate of hypotensive patients who underwent EE or SE; the time to achieve hemostasis, blood transfusion volume and hospital length of stay did not significantly differ;

2) stable parameters of red blood cell (RBC) concentration, levels of hemoglobin and hematocrit (B1) [12]; baseline hemoglobin level can mask bleeding [20, 24];

3) absence of hollow organ injuries, peritonitis, requiring emergency surgery (A1) [2, 6, 7, 11]. The incidence of missed AC organ injuries requiring LT under conditions of NOM of BSI is 0.8–2.3% [15];

4) the volume of blood in the abdomen is less than 500 ml, without a tendency to increase [21]; this indicator is relative, since there have been published reports on the successful conservative treatment of splenic ruptures in children with large hemoperitoneum, in particular in a child with hemoperitoneum of 1700 ml, whose hemodynamic parameters were stabilized by massive transfusion of blood plasma, prothromplex and tranexamic acid, and subsequent LS (after 14 hours after admission and 18 hours after injury) did not reveal ongoing bleeding and indications for SE, and the patient was discharged without complications [6]. *Salottolo K. et al*., 2020 [25] on hemodynamically stable patients with BSI have proven that moderate (in addition to Koller's and Morrison's pouches blood is found in the flanks of the abdomen) and large (additional accumulation of blood in the pelvis) volume of hemoperitoneum is an independent predictor of endovascular/open intervention, along with higher *AAST* grades of BSI, patient age and splenic vascular injuries;

5) absence of CMEV in free AC / splenic parenchyma on CT angiogram [7, 12, 21] or successful EE; the effectiveness of NOM has been proven for peripheral ruptures of *AAST* grade I – II [26], intraparenchymal hematomas less than 5 cm in diameter (*AAST* grade II); in the absence of CMEV under the capsule of the organ and an enlarged spleen [15, 26]; and small subcapsular (less than 10% of the surface - up to 2 cm in diameter –

AAST grade I) unstressed hematomas which do not tend to grow [21]. *Carvalho F.H. et al.*, 2009 (cited from [15]) considered the overall trauma severity and the *AAST* grade of BSI to be the main predictors of NOM failure. In 2000, *Velmahos G.C. et al.* (cited from [2, 8, 15]) noted that conservative treatment of patients with not less than *AAST* grade III BSI and in need of transfusion of 1 L of blood is less successful, and in 2010, they named *AAST* grade V of BSI and traumatic brain injury (TBI) to be such factors; out of 224 patients with *AAST* grade IV – V of BSI, NOM was effective in 64% [8, 10]. The presence of traumatic pseudoaneurysms or active extravasation (17%) on CT increases the likelihood of NOM failure in 60% of patients with any degree of splenic injury [11, 27]. *Rodeghiero F. et al.,* 2012 (cited from [2]), *Coignard-Biehler H. et al.*, 2011 (cited from [2]) described the possibility of NOM for patients with *AAST* grade III-V of BSI under the condition of EE of the splenic artery. According to the meta-analysis of *Requarth J. et al.*, 2011 (cited from [10]), which included 10,157 patients, conservative treatment was successful in 91.7% of cases. *Fernandes T.M. et al.*, 2013 (cited from [8]) successfully used NOM in 24 out of 26 patients (92%) with *AAST* grade IV of BSI. *Cirocchi R. et al.*, 2013 (cited from [2, 15]) analyzed 21 studies with 16940 patients and determined that NOM of BSI is the "gold standard" for *AAST* grade I and II. Up to 80–85% of all the patients with BSI are treated conservatively [3, 7, 8, 11, 21];

6) absence of severe concomitant injuries and massive blood loss, signs of coagulopathy [12, 15, 21] /splenopathy [27]. According to *Fang J.F. et al.,* 2003 (cited from [15]) NOM of patients with BSI suffering from hepatic cirrhosis with coagulopathy and portal hypertension was ineffective in 92% of cases and was accompanied by 55% of postoperative mortality. The absence of spontaneous hemostasis was explained by increased hydrostatic pressure in the splenic parenchyma and a deficiency of blood coagulation factors. The authors noted a direct correlation between the mortality rate and the prolongation of the prothrombin time, the severity of trauma and hypoproteinemia;

7) age under 55: a number of studies confirm age-related changes in the structure of the organ and its capsule which reduce the likelihood of spontaneous hemostasis (age over 55 is a relative contraindication (B2) [11, 15]);

8) clear consciousness, since in case of its impairment the risk of missed injuries requiring emergency LT increases. This condition is also debatable, since *Rozycki G.S. et al.*, 2005 (cited from [15]), having conducted a study among 126 patients with score of 8 and less on the Glasgow scale, concluded that NOM of patients with blunt trauma of the parenchymal organs of AC and severe TBI is safe. According to *Pal JD and Victorino GP*, 2002 (cited from [15]), based on their study of 1388 patients, the diagnostic value of CT in hemodynamically stable patients with impaired consciousness is comparable to LT and demonstrates sensitivity, specificity and accuracy of 97.7% –99 ,4%. At the moment, it is believed that NOM of patients with TBI is possible only under condition of immediate availability of CT angiogram and EE; in other cases, surgeons are inclined towards SE (C1) [11].

9) availability of appropriate medical equipment and personnel for round-the-clock DO in ICU, CT scan with contrast, angiography and EE, the possibility of quick access to blood products (A2) [2, 6, 7, 11, 21, 27].

The complex of conservative measures (in addition to EE) includes:

1. Rest creation (strict bed rest for 8-10 days) [6].

2. Prevention of hypoxemia (A1) [12, 24], prescription of analgesics [6] and therapy aimed at prevention and treatment of the organ failure.

3. Replenishment of blood loss (infusion-transfusion therapy - ITT [6], balanced crystalloids (A1) [24] / colloids (for initial resuscitation) (C1) [24]). The optimal concentrations of *Ht* or *Hb* for maintaining hemostasis in those patients have not been established [12, 24]. In the study by *Sartorelli K.H. et al.*, 2000 (cited from [15]) indications for blood transfusion were considered to be as follows: a hemoglobin level of less than 90 g / l (C1) [24] and a heart rate of more than 100 beats / min.

4. Correction / prevention of coagulopathy - by transfusion:

a) fresh frozen plasma - FFP (if fibrinogen level is lower than 1 g / L; prothrombin time and activated partial thromboplastin time (APTT) are 1.5 or more times longer than the normal range; platelet counts lower than 80 × 109 / L) (C1) [24]. Plasma transfusion should be performed prior to normalization of the international normalized ratio and APTT;

b) fibrinogen (initial dose 3-4 g) (C1) [24];

c) cryoprecipitate if the concentration of fibrinogen in the blood is less than 1.5 g / L; initial dose of 50 mg / kg (C1) [12, 24];

d) platelet mass to maintain platelet counts higher than 50 × 109/L (C1) [12]; in patients with ongoing bleeding, severe polytrauma, impaired platelet function (end-stage renal failure) and/or TBI, it is recommended to maintain a platelet counts higher than 100 × 109 / L (C1) [12, 24].

5. Administration of hemostatic agents for 5-12 days [6] - it is recommended to use tranexamic acid in a dose of 1 g within 10 minutes in the first hour after injury (reducing the risk of death from bleeding by 2.5%), followed by intravenous infusion of 1 g within 8 hours (A1) [12, 24]. If the above drugs are ineffective, it is possible to use recombinant activated factor VII (rFVIIa) (C1) [12, 24].

6. Administration of antibacterial agents for the prevention of purulent and bronchopulmonary complications, intestinal insufficiency syndrome for 5-12 days [6] - carbapenems (Tienam-Imipenem + Cilastatin 0.5-1 g IV every 6-8 hours, Meronem 0.5 m 1 g intravenously every 8 hours), 4-th generation cephalosporins (Cefepime 2 g intravenously 2-3 times/ day) or "protected" cephalosporins (Ceftazidime intravenously 2 g 3 times / day; Sulperazon IV 1 + 1 g 3 times / day), 3-d-4th- generation fluoroquinolones (Moxifloxacin 250 ml IV 1 time / day; Levofloxacin 0.5 g 1–2 times / day or 1 g 1 time / day) as a starting therapy.

7. Administration of inotropic agents (adrenaline, dobutamine) for myocardial dysfunction (C1) [24].

8. Prevention of stress bleeding from the upper gastrointestinal tract (GIT) - administration of proton pump inhibitors (A1) [12]. Absolute indications - artificial lung ventilation (ALV), hypoxia (acute respiratory failure - ARF - increases the risk of gastrointestinal (GI) bleeding by 15.6 times), hypotension (increases the risk of GI bleeding by 3.7 times), coagulopathy (increases the risk of GI bleeding by 4.3 times), sepsis (increases the risk of GI bleeding by 2 times).

9. Continuous use of intermittent bladder catheterization for hourly monitoring of urine output; its decrease to less than 0.5 ml / kg / h serves as a reliable indicator of inadequate fluid therapy.

10. Warming the patient (C1) [12, 24]. More than 50% of patients with abdominal trauma and intra-abdominal bleeding suffer from hypothermia, which together with coagulopathy and acidosis constitutes a fatal triad. A decrease in the patient's body temperature (with the esophageal probe) to 34 ° C is accompanied by 4 times higher mortality compared to 35 ° C [12]. The impact of hypothermia includes changes in platelet function, weakening of the function of coagulation factors by 10% with a decrease in body temperature by 1 ° C, inhibition of enzymes and fibrinolysis. It is necessary to remove cold damp clothing, increase the ambient temperature (29 ° C), provide air heating, use warming blankets and mattresses, warm oxygen, 39 ° C crystalloid solutions, as well as devices for artificial warming of patients.

11. Treatment for metabolic acidosis: there is currently no clear data to inform clinical guidance on the use of medicines [12, 24]. The use of sodium bicarbonate is contraindicated in ARF. Tris(hydroxymethyl)aminomethane is not well studied, and not administered in oliguria. Hypoventilation and large infusion volumes of 0.9% NaCl solution should be avoided.

12. Measures for preventing gastroparesis: nasojejunal intubation, prokinetics (metoclopramide, erythromycin (A1)), intravenous administration of solutions containing potassium, hypertensive enemas. Enteral nutrition begins 3 days after the start of conservative treatment.

13. Prevention of venous thromboembolic complications: intermittent pneumatic compression of the lower extremities (A2) [11, 12, 24] and the use of low-molecular-weight heparin (A1) - no later than 24 hours after achieving the final hemostasis (B2) [11, 12, 24, 28].

Urgent surgical interventions for polytrauma, HSh, signs of ongoing bleeding with metabolic acidosis, hypothermia and coagulopathy (B1) [11, 12, 24] should be aimed only at saving lives, be minimally traumatic and comply with the principles of “*damage control surgery*” (*DC*) which involve multistage surgical approach [28].

Stage 1 of *DC* approach for abdominal trauma is a primary emergency surgical procedure of reduced operative time (up to 90 minutes). If hypotension is critical due to profuse intra-abdominal / retroperitoneal bleeding, endovascular balloon occlusion of the aorta (B2) may be used before / during LT [12, 28].

Access: upper midline incision [5, 10, 25]. During LT bleeding increases due to a decrease in intra-abdominal pressure. The anesthesiologist tries to maintain hemodynamic stability, the surgeon controls temporary hemostasis (B2), and the assistant evacuates the blood using a reinfusion device [5, 10, 12]. If the BPsyst is less than 70 mm Hg, and revision of the AC organs is difficult to implement due to a large hemoperitoneum, it is advisable to press the aorta with a fist / vascular plug to the spine below the diaphragm for 20-30 minutes. This method allows you to stabilize the patient's condition, stop bleeding and gain time for intensive care (C1) [10]. In case of severe bleeding from the parenchyma / vessels of the spleen, a clamp (clip) / tourniquet is applied to its vascular pedicle in order to temporarily stop bleeding and identify the lesions.

In case of *AAST* grade IV–V BSI, detachment of the vascular pedicle, severe crush injuries and ruptures involving the splenic hilum, the impossibility of suturing them, eruption of sutures in combination with hemodynamic instability (A2) [3, 4, 11, 28], agonal state, multiple damage to others organs of AC and / RPS, signs of diffuse peritonitis, age over 65 years, splenomegaly, pronounced adhesion formation, flabby parenchyma, coagulopathy, SE is indicated already at the first stage [11, 15, 19, 25]. The incidence of SE in the management of BSI currently does not exceed 5% in pediatric surgery, and in adults it ranges from 5% with *AAST* grade I to 75–80% with *AAST* grade V [4], on average 24–35% [11]. *Amirkazem V.S. et al*., 2017 [29] in their randomized study proved the advantages of splenic vessel ligation using Ligasure™ energy device (Medtronic, USA) compared to conventional ligation during SE for BSI in terms of less blood loss and reduced duration of surgery.

In other cases, after suturing over a local hemostatic agent the spleen is wrapped up with a VICRYL* (polyglactin 910) /catgut mesh and tamponade (B1) is performed [1, 3, 11, 24, 30]. A solitary rupture (up to 4 cm long and up to 3 cm deep) on the diaphragmatic surface or in the area of the spleen pole (*AAST* grade I – II), may be sutured with a 3/0 absorbable thread on an atraumatic needle transversely to the course of intraorgan vessels [4]. Splenorrhaphy is used in 1–6%, and the inefficiency of suturing reaches 35–50% [1, 11]. In the case of suture eruption omental pedicle flap or a local hemostatic agent can be used [1, 4, 10]. *Maistrenko AN et al*., 2018 [30], performed experimental assessment of the hemostatic properties of a number of local hemostatic agents (absorbable gelatin sponges, "Biatravm", "Resorb-2", "Ferroresorb", "Ferrobiatravm", "Surgicel”, “Surgicel Nu-knit”) for liver and spleen injuries, and the latter two were proven to have the best hemostatic effect.

Wrapping up of the organ with a mesh is quickly performed, moreover, the function of the organ is restored within 1-3 days after surgery. This technique is effective and safe, causes minimal inflammatory response and minor cicatricial changes [1]. SE in young children (up to 4 years) leads to significant autoimmune disorders and the risk of post-splenectomy infection (OPSI) syndrome with mortality rate of 40–70% [1–4, 10]; in adults, the incidence of OPSI after trauma is 0.5%, after planned SE - 20% with mortality rate of 8–10% [16]. Therefore, it is of great importance to preserve the maximum amount of the ruptured spleen [6]. On the other hand, the performance of spleen preserving surgeries is associated with difficulties in hemostasis, therefore, organ-sparing surgeries should not be an end in itself. It is necessary to take into account the severity of the patients’ condition and not expose their lives to additional risk. Once the bleeding stops, further patient treatment is determined at the third stage of *DC*; if bleeding continues, SE is performed [28, 31].

Stage 2 - *Damage Control Resuscitation*: intensive care to stabilize vital body functions, detailed identification of injuries with potential endovascular hemostasis, consultations with related specialists [28, 31].

Stage 3: repeated planned surgery with a thorough revision of all injuries to exclude overlooked injuries [28, 31

In case of renewed bleeding after removal of tampons and the clamp from the vascular pedicle, as well for splenic necrosis, SE is indicated [11, 15].

If the injury is located along the diaphragmatic surface in the area of the poles, resection of the spleen is indicated [4, 6] by ligating the main splenic trunk proximal to its inosculation with the left gastroepiploic artery and short gastric arteries, removing the damaged part and treating the wound surface with cold atmospheric plasma or laser coagulation; then the splenic stump is closed with the vascularized omental pedicle flap which is sutured around the circumference applying continuous or 8-shaped absorbable suture, or the wound is tamponed with hemostatic material [30, 32].

In case of damage to the splenic hilum without injury of the main splenic vessels, it is possible to tamponade the greater curvature of the stomach using sutures drawn through the serous-muscular layers of the gastric fundus and the splenic parenchyma and tying knots over the greater omentum [28, 32].

After SE, pneumococcal (re-vaccination after 5 years) and meningococcal vaccines are administered, and high risk patients are vaccinated against Haemophilus influenzae (A1) [11]. The optimal vaccination period is no earlier than 14 days after SE (C2) [11]. Also, after SE, travelers are recommended to be vaccinated against malaria (C2), patients older 6 months - immunization against influenza (C1), in case of unexplained sudden onset of malaise, fever, chills, antibiotic therapy is required (A2) [11]. The options are:

а) amoxicillin, the initial dose of 3 g, then 1 g every 8 hours;

б) levofloxacin 500 mg every 24 hours or Moxifloxacin 400 mg every 24 hours (for patients with beta-lactam allergy) [11].

The mortality rate reported for operative treatment of splenic injuries is 12–34%, in patients treated with NOM - 4%, in case of the initial treatment with NOM and subsequent conversion - 16.5%, and various intra-abdominal complications (abscesses of the left subphrenic space (5%), pancreatitis, secondary bleeding) are observed in 11.2–35% of patients [2, 5, 8, 19], mostly in operated patients [11, 32].

Mortality rate for solitary splenic injuries is 1–4.3%, for two-stage ruptures - 5–15%; for concomitant and multiple injuries - 13.3–40.9% [4, 9]. By applying the principles of *DC*, it can be reduced to 7.1%, and the complication rate - down to 5.3% [28, 31, 32].

CONCLUSION

Standardization of the therapeutic and diagnostic approach to concomitant blunt splenic injuries based on the severity of the patient's condition, hemodynamic stability and the degree of organ failure gives a clear idea of the sequence of diagnostic and therapeutic actions in regard to this category of patients, determines the choice of one or another strategy of their management. Rapid progress in endovascular techniques contributes to the expansion of opportunities for non-surgical management of blunt splenic injuries. Hemodynamic instability, previously considered an absolute contraindication to conservative treatment, in recent studies is viewed as a relative contraindication, endovascular embolization of the splenic artery has proven highly efficient. If a possible cause of hemodynamic instability in case of concomitant injury is not abdominal trauma, then in the absence of other indications for LT and the availability of appropriate equipment for dynamic monitoring and vascular hemostasis, an attempt at non-surgical management of patients with splenic injuries should be undertaken. This is particularly justified in case of severe polytrauma, when the slightest prolongation of the initial intervention at the first stage of *Damage Control* surgery leads to increase in mortality. If vascular hemostasis is ineffective or impossible at the first stage of *Damage Control* surgery, as well as in case of severe injury of the spleen (*AAST* grade IV-V), its detachment from the vascular pedicle, extensive crush injuries and ruptures involving the splenic hilum, the impossibility of their suturing, eruption of sutures in combination with hemodynamic instability, agonal state, multiple injuries of other organs of the abdominal cavity and retroperitoneal space, signs of diffuse peritonitis, age over 65 years, splenomegaly, pronounced adhesion formation, flabby parenchyma, coagulopathy, splenectomy should be performed optimally with transection of splenic vessels using Ligasure™ energy device (Medtronic, USA). In other cases, to minimize the time interval, it is advisable to achieve hemostasis by the combined use of absorbable meshes, physical and chemical methods for the hemostatic applications, tamponade with the imposition of a soft clamp / tourniquet on the vascular pedicle and make the final decision on the preservation or removal of the spleen at the third stage.

REFERENCES

1. Khakimov MSh, Sadykov RA, Ashurov ShE, Zhumanazarov AU, Imamov AA. Tactics of treatment for closed traumatic injuries of the spleen. *New Day in Medicine*. 2020;1(29):93–97. (in Russ.).
2. Petrov VG, Mukhacheva SYu, Trapeznikov KM, Magomedjanov KM. The question of non-operative treatment of trauma of the spleen. *Meditsinskaya nauka i obrazovanie Urala*. 2020;1(101):131–136. (in Russ.).
3. Nijdam TMP, Spijkerman R, Hesselink L, Leenen LPH, Hietbrink F. Predictors of surgical management of high grade blunt splenic injuries in adult trauma patients: a 5-year retrospective cohort study from an academic level I trauma center. *Patient Saf Surg*. 2020;14:32. PMID: 32774457 https://doi.org/10.1186/s13037-020-00257-3 eCollection 2020.
4. Pikin IYu, Nuzova OB, Kagan II. Organ-preserving operations for injuries of the spleen (literature review). *J Scientific Articles Health Education Millennium.* 2019;21(1):86–90. (in Russ.). https://doi.org/10.26787/nydha-2226-7425-2019-21-1-86-92
5. Smolkina AV, Makarov SV, Evseev RM, Khalitova NI. Management of patients with concomitant traumas and splenic rupture. *Bulletin of the Medical Institute "REAVIZ" (Rehabilitation, Doctor and Health)*. 2019;3(39):137–140. (in Russ.).
6. Shapkina AN, Kozlova MV, Shmyreva ES, Shumatov VB. How to avoid splenectomy in a child with splenic trauma. *Pacific Medical Journal*. 2018;1(71):72–74. (in Russ.). https://doi.org/10.17238/PmJ1609-1175.2018.1.72–74
7. Suhchkova VA, Konovalenko MV. Not operative treatment of spleen damage at the closed trauma of abdomen in trauma center 1-st level. *Russian Military Medical Academy Reports*. 2019;2(S1):202–205. (in Russ.).

8. Bazukheir DH, Myasnikov NI. Possibilities of use of nonoperative treatment in service menber with blunt splenic injury. *Russian Military Medical Academy Reports*. 2018;37(1S1):48–51. (in Russ.).
9. Romeo L, Andreotti D, Lacavalla D, Ferro S, Tondo M, Salviato E, et al. Delayed Rupture of a Normal Appearing Spleen After Trauma: Is Our Knowledge Enough? Two Case Reports. *Am J Case Rep*. 2020;21:e919617. PMID: 31900381 https://doi.org/10.12659/AJCR.919617
10. Smolyar AN. Blunt abdominal trauma. Spleen injuries. Part 2. *Russian Journal of Surgery*. 2016;(2):4–10. (in Russ.). https://doi.org/10.17116/hirurgia201624-10
11. Coccolini F, Montori G, Catena F, Kluger Y, Biffl W, Moore EE, et al. Splenic trauma: WSES classification and guidelines for adult and pediatric patients. *World J Emerg Surg*. 2017;12:40. PMID: 28828034 https://doi.org/10.1186/s13017-017-0151-4 eCollection 2017.
12. Spahn D, Bouillon B, Cerny V, Duranteau J, Filipescu D, Hunt B, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition. *Crit Care*. 2019;23(1):98. PMID: 30917843 https://doi.org/10.1186/s13054-019-2347-3
13. Maskin SS, Aleksandrov VV, Matyukhin VV, Ermolayeva NK, Tadzhiyeva AR. Treatment and diagnostic algorithm for associated closed abdominal and retroperitoneal organs injury from the standpoint of evidence-based medicine. *Journal of Volgograd State Medical University*. 2020;(3);3–12. (In Russ.). https://doi.org/10.19163/1994-9480-2020-3(75)-3-12
14. Gavrishuk YaV, Kazhanov IV, Tulupov AN, Demko AE, Kandyba DV, Mikityuk SI, et al. Minimally invasive treatment in the victim with spleen injury. *Grekov's Bulletin of Surgery*. 2019;178(4):58–60. (in Russ.). https://doi.org/10. 24884/0042-4625-2019-178-4-58-60
15. Pankratov AA, Khat'kov IE, Izrailov RE, Kapustin VI, Zhdanov AV. Non-operative management of splenic trauma considering angioembolization potential. *Annals of Surgery*. 2016;21(3):174–179. (in Russ.). https://doi.org/10.18821/1560-9502-2016-21-3-174-179
16. Rong JJ, Liu D, Liang M, Wang QH, Sun JY, Zhang QY, et al. The impacts of different embolization techniques on splenic artery embolization for blunt splenic injury: a systematic review and meta-analysis. *Mil Med Res.* 2017;4:17. PMID: 28573044 https://doi.org/10.1186/s40779-017-0125-6 eCollection 2017.
17. Lee R, Jeon CH, Kim CW, Kwon H, Kim JH, Kim H, et al. Clinical Results of Distal Embolization in Grade V Splenic Injury: Four-Year Experience from a Single Regional Trauma Center. *J Vasc Interv Radiol*. 2020;31(10):1570–1577.e2. PMID: 32340865 https://doi.org/10.1016/j.jvir.2020.01.029
18. Fransvea P, Costa G, Serao A, Cortese F, Balducci G, Sganga G, et al. Laparoscopic splenectomy after trauma: Who, when and how. A systematic review [published online ahead of print, 2019 Oct 31]. *J Minim Access Surg*. 2021;17(2):141–146. PMID: 31670290 https://doi.org/10.4103/jmas.JMAS_149_19
19. Stjazhkina SN, Pelina NA, Salikhova RR. Tactics of the surgeon in closed bio injury with damage to the spleen. *Sinergiya Nauk*. 2019;(31):1493–1499. (in Russ.).
20. Liagkos G, Spyropoulos C, Tsourouflis G, Papadopoulos A, Ioannides P, Vagianos C. Successful non-operative management of blunt abdominal trauma in highly selective cases: A safe and effective choice. *Ulus Travma Acil Cerrahi Derg*. 2018;24(2):104–109. PMID: 29569680 https://doi.org/10.5505/tjtes.2017.83404
21. Ruscelli P, Gemini A, Rimini M, Santella S, Candelari R, Rosati M, et al. The role of grade of injury in non-operative management of blunt hepatic and splenic trauma: Case series from a multicenter experience. *Medicine (Baltimore)*. 2019;98(35):e16746. PMID: 31464904 https://doi.org/10.1097/MD.0000000000016746
22. Guinto R., Greenberg P., Ahmed N. Emergency Management of Blunt Splenic Injury in Hypotensive Patients: Total Splenectomy Versus Splenic Angioembolization. *Am Surg*. 2020;86(6):690–694. PMID: 32683975 https://doi.org/10.1177/0003134820923325
23. Liao CA, Kuo LW, Wu YT, Liao CH, Cheng CT, Wang SY, et al. Unstable Hemodynamics is not Always Predictive of Failed Nonoperative Management in Blunt Splenic Injury. *World J Surg*. 2020;44(9):2985–2992. PMID: 32383055 https://doi.org/10.1007/s00268-020-05562-7
24. Bobovnik SV, Bulanov AYu, Grigor´yev EV, Zabolotskikh IB, Lebedinskiy KM, Sin´kov SV, et al. Protocol of resuscitation and intensive care for acute massive blood loss. *Clinical recommendations FAR*. Moscow; 2018. (in Russ.).
25. Salottolo K, Madayag RM, O'Brien M, Yon J, Tanner A, Topham A, et al. Quantity of hemoperitoneum is associated with need for intervention in patients with stable blunt splenic injury. *Trauma Surg Acute Care Open*. 2020;5(1):e000406. PMID: 32154378 https://doi.org/10.1136/tsaco-2019-000406eCollection 2020.
26. Leppäniemi A. Nonoperative management of solid abdominal organ injuries: From past to present. *Scand J Surg*. 2019;108(2):95–100. PMID: 30832550 https://doi.org/10.1177/1457496919833220
27. Cinquantini F, Simonini E, Di Saverio S, Cecchelli C, Kwan S, Ponti F, et al. Non-surgical Management of Blunt Splenic Trauma: A Comparative Analysis of Non-operative Management and Splenic Artery Embolization-Experience from a European Trauma Center. *Cardiovasc Intervent Radiol*. 2018;41(9):1324–1332. PMID: 29671059 https://doi.org/10.1007/s00270-018-1953-9
28. Pape HC, Peitzman AB, Rotondo MF, Giannoudis PV. *Damage Control Management in the Polytrauma Patient. 2nd ed*. Switzerland: Springer International Publishing; 2017. https://doi.org/10.1007/978-3-319-52429-0
29. Amirkazem VS, Malihe K. Randomized clinical trial of ligasure™ versus conventional splenectomy for injured spleen in blunt abdominal trauma. *Int J Surg*. 2017;38:48-51. PMID: 28034773 https://doi.org/10.1016/j.ijsu.2016.12.036
30. Maystrenko AN, Bezhin AI, Lipatov VA, Chizhikov GM. Determination of blood loss volume in modeling injuries of parenchymatous organs with application of new hemostatic agents in an experiment. *Scientific electronic journal Innova*. 2018;1(10):12–14. (in Russ.). https://doi.org/10.21626/innova/2018.2/03
31. Spinella PC. *Damage Control Resuscitation. Identification and Treatment of Life-Threatening Hemorrhage*. Switzerland: Springer Int Publ; 2020. https://doi.org/10.1007/978-3-030-20820-2
32. El-Matbouly M, Jabbour G, El-Menyar A, Peralta R, Abdelrahman H, Zarour A, et al. Blunt splenic trauma: Assessment, management and outcomes. *Surgeon*. 2016;14(1):52–58. PMID: 26330367 https://doi.org/10.1016/j.surge. 2015.08.001

Received on 02.10.2020

Review completed on 15.01.2021

Accepted on 30.03.2021