“CAROL DAVILA” UNIVERSITY OF MEDICINE AND PHARAMCY, BUCHAREST

PHD SCHOOL

MEDICINE

PHD THESIS

Abstract

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NONOPERATOR MANAGEMENT OF SPLENIC TRAUMA: ANGIOGRAPHY’S ROLE IN DIAGNOSYS AND THERAPY

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“ The opinions expressed only engage me. I do not cherish them for the simple fact that I have consecrated this work to them. I did this work precisely because I have this opinions. “

- G. Clemenceau

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II. PERSONAL CONTRIBUTIONS

List of abbreviations

AE= AngioEmbolization

SAE =Splenic AngioEmbolization

DSAE = Distal Splenic Angio Embolization

PSAE = Proximal Splenic Angio Embolization

DSA = Diagnosed Splenic Angiography

ATLS = Advanced **T**rauma **L**ife **S**upport;

VA = Ventricular Alura

CT = **C**omputed **T**omography;

AVF = Arterio Venous Fistula

BF = Breathing Frequency

GCS = Glasgow Coma Scale

ISS = Injury Severity Score

SPA = Splenic PseudoAneurism

RTS = Revised Trauma Score

CA = Contrast Agent

BP/SBP = Blood pressure / Systemic blood pressure

TBI = Traumatic brain injury

NST = Non-surgical treatment

1. 1. INTRODUCTION

Trauma represents the major cause of death in patients aged under 45 , being among the 3 causes of mortality in all groups of age (Wortman cit.O'Neill[1],2,3); it is the main cause of mortality in men aged under 40 (4).

Almost 198 000 people die after the traumatic lesions - 1 patient every 3 minutes (5).

According to Kauvar(6), traumatisms represent 12% of the pathology, being the main cause of the lost years in people aged under 44 and liable for the 30-40% death rate.

The road accidents represents the main cause of death in patients aged between 5 and 29 (7), the World Health Organisation estimating that the roads accidents will represent the third global cause of death in 2020 (cit.Kirkpatrick[8]).

Death that may be prevented in traumatic patients are the most frequently secondary to the bleeding: early by exsanguination and late by organic multiple failure and the interaction of the bleeding with the cerebral lesions, the hemorrhage representing the trauma cause of death in 30-40% of the cases (8).

In patients with significant abdominal lesions, every therapeutic delay by 3 minutes increases the mortality by 1% (8).

The prevalence of the intraabdominal post-traumatic lesions is around 15% (5), the spleen being one of the most frequently interested viscera.

One of five patients suffering from severe traumatisms presents an abdominal lesion and, 46% of them, the interested organ is the spleen (9).

According to Smith (10), the abdominal traumatism is an evolving disease so that the continuous monitoring (clinical and paraclinical) represents a usual requirement in the modern traumatology.

The concept of the CT integration to the Emergency Department determined the increase of this exam's frequency in the secondary examination of the patients with abdominal lesion suspicion.

The splenic angioembolization associated to the non-surgical treatment increased the percentage of the splenic salvation to incredible values. We thus may say that the current major therapy in splenic trauma is the non-surgical treatment allowing the conservation of the organ and of its functions and avoiding the complications of a non-therapeutic laparotomy (the frequency of the non-therapeutic laparotomy was 14%, 58% representing the abdominal penetrating wounds((10) or of splenectomy.

The current frequency of the splenectomy in splenic contusive lesions is 10% and the development of the interventional radiology and its use in TNO allows the salvation of 80-98% of the spleen (Wong cit. Liao[11]).

The following two fundamental concepts were defined in traumatology:

• reconsider the concept that any post-traumatic hemoperitoneum must be immediately operated (12)

and

• the splenic traumatic lesions do not represent anymore an absolute surgical indication (in most cases).

The severe trauma represents a major emergency (that must be understood as a phenomenon) whose evolution depends on the time range of the lesions solving, by avoiding the secondary pathology ('second injury') caused by hypoxia and tissue hypoperfusion 'globally thinking and locally acting'.

Trauma represents the major cause of mortality in patients under 40 years old, and the abdominal traumas hold the third place for morbidity and mortality (13).

2. HISTORY

The first experiential angiographies were performed on animals (in early 20th century) and their number was low because of the systemic toxicity of the contrast agent intraarterially injected. At the end of the '20s, an iodized organic substance soluble in water (initially used in the therapy of the staphylococci infections of the gall bladder) was changed to used in angiography exams (14).

1933- Burke şi Madigan(15) shows the diagnosis of the splenic rupture (lower polar complex rupture with detached fragment) by use of Thorotrast; it suggests that the colloidal Thorium Dioxide intravenous injection shows the SCIV perisplenic extravasation (4 hours after the administration), and a large part of the contemporary medical authorities considered that this finding is not practical!

1951 – Biermann describes the catheterization of the visceral branches of the abdominal aorta (cit. Freeark[16]);

The following important step for the therapeutic angiography was made by Seldinger, by describing the transfemoral angiography in 1953.

1957- Norell(17) publishes the first case of angiographically diagnosed splenic rupture; he injected the contrast agent in the aorta by means of a catheter inserted through the femoral artery (transfemoral percutanous abdominal retrograde aortography); the diagnosis was intraoperatorily confirmed (broken subcapsular hematoma);

1958- Ödman would have used the selective arteriography of the celiac trunk for the first time in the splenic rupture diagnosis (cit. Lundström[18]).

1968 – Freeark(16): the femoral retrograde aortography plays an important part in the diagnosis and the evaluation of the traumatic splenic lesions (especially, in polytraumatic patients).

1973- Awe(19) publishes a study correlating the clinical and the angiographic findings to establish the surgical indication. He declares 6 cases of minor splenic ruptures non-surgically successfully treated, declaring that, in patients with normal abdominal clinical exam, the surgery may be postponed or excluded (the minor spenic lesions heal spontaneously, as well as in the case of the percutaneous splenoportography).

1981 – Sclafani(20) performs the first spenic angioembolization for hemostatic purposes (prior to the execution of the splenectomy) by using the absorbable gelatin and the temporary vascuclar occlusion with balloon.

1995 – Sclafani(21) publishes a reference article in Journal of Trauma that opens the way of the interventional angiography to the therapy of the traumatic lesions of the abdominal parenchymatous organs.

3. NOTIONS OF SPLENIC VASCULAR ANATOMY

The vascularization of the spleen is made by the splenic artery, the largest branch of the celiac trunk. It insures the vascularization of the spleen of the body and of the pancreatic tail, and partially of the stomach. Other variants (collateral circulation) are represented by the short gastric veins (vasa brevia) and the splenic ligament veins. The splenic artery goes suprapancreatically presenting three branches meant for the pancreas (the dorsal pancreatic artery, the large pancreatic artery, the caudal pancreatic artery); on the pancreatic tail, it is anteriourly located in the spleno-renal ligament. At this level, it divides into 2 terminal branches, disappear in the inferior one, sometimes presenting the third branch - the middle branch (22,23,24).

The collateral branches (22, 25) of the splenic artery are:

- the dorsal pancreatic artery (the posterior pancreatic artery)

the largest one;

origin: the proximal part of the splenic artery (40-51%)

the celiac trunk (3-28%);

the common hepatic artery (17-22%);

the superior mezenteric artery (15-46%).

- the large pancreatic artery (the magna pancreatica artery)

the second branch in size;

origin: the middle part of the spenic artery.

- the caudal pancreatic artery

the most distal pancreatic branch;

origin: - the distal part of the splenic artery (70%);

- the lower polar artery (30%).

The ideal place for putting the hemostatic material in the PSAE is between the dorsal pancreatic artery and the magna pancreatica artery (22).

The left gastro-epiploic artery origins from a few cm proximal from the bifurcation of the splenic artery in the terminal branches; other possible origins: the lower terminal branch or one of its branches.

The splenic vein

It forms by the unification of the segmentary veins (3.4 cm from hill) → lobar veins (or it drains directly to the main venous trunk); it presents a retropancreatic route so that it may unify with the upper mezenteric vein on the pancreatic col to form the portal vein. It never presents sinuosities, being placed lower to the splenic artery trunk.

According to Looten (1919-cit.26), the splenic vein trunk is made by the unification of the upper and the lower venous groups made of 4-5 affluents. In 1958, Neder states that the splenic vein trunk is made by the confluence of 3 branches (68.6%) and 2 branches (31.4%). According to Voboril (1982) (cit.26) and Redmond (1989)(27), he considers that the affluents of the splenic vein are similarly organized to those of the spenic artery and that the venous spenic drainage is similar to the arterial one.

The second venous drainage possibility would be by the short gastric veins and the left gastro-epiploic vein.

4. SPENIC INTERVENTIONAL RADIOLOGY

4.1. General Data

The post-traumatic abdominal arterial bleeding non-diagnosed / lately diagnosed represents the main cause of the non-favourable evolution of the patients. The continuous / persisting bleeding remains the main cause of death in traumatic patients in the first 24 hours after the admission (28). The solution is represented by the diagnosis in the early therapy by endovascular techniques, laparotomy or their combination (29). The decision must be quickly taken based on expertise / clinical insignt and the recognition of the lesion pattern. Currently, the use of SAE has determined the decrease of the splenic surgeries (30), the frequency of the interventions made in emergency decreasing from 33.3% to 11.9% after the introduction of this method (31) respectively from 55% to 30% (32). However, 5 to 7% of the patients with spleni contusions need angioembolization (33).

4.2. Embolization-used materials

They may be classified as permanent and temporary (34).

- Permanent: wire binding; occlusion/vascular closure devices (vascular plugs); adhesives; embolism particles;
- Temporary: gelatin sponges: Gelfoam (Gelfoam, Pfizer, New York, NY); re-channeling of the obliterated vein occurs in 2-4 weeks (35).

Most of the emobolization materials need a cascade of functional coagulation.

Currently, we use for splenic embolization the wire binding ('metallic coils'), fragments of hemostatic agents ('Gelfoam pledgets', TachoSil) with the diameter > 1,000 μm that, injected through the catheter, locks the harmed vein by executing the hemostasis (some special spirals allowing the further MRI exam were created-'magnetic-resonance-compatible coils') or micro-spheres (PVA). The advantage of the mentioned temporary hemostatic agents is that, in a few weeks, they are absorbed under the action of the macrophages, performing thus the new permeability of the vein (36). However, due to this evolving possibility, some authors (36,37,38,39) contraindicate these hemostatic agents (high rate of bleeding). Similarly, Smith (37) noted some higher results by using the metallic coils. Haan (39) declares the increased frequency of the splenic arrest after the use of Gelfoam.

4.3. Post-traumatic vascular lesions diagnosed at tomography (MDCTangioCT) with angiography indication

The AAST recent guides (2018)(40,41) classified the splenic vascular lesions (the active extravazation of the CA, SPA, AVF) under the CT imaging criteria for the classification of the post-traumatic lesions:

- 4^{th} degree: vascular lesion or intracapsular active bleeding;

- 5^{th} degree: vascular lesion or extracapsular extended active bleeding.

The vascular lesions shown by this method (29,42,43,44,45) are represented by:

- the extravazation of the extra or intrasplenic contrast agent; (high risk of failure of SAE)(45); the extravazation of the intrasplenic constrast agent is represented by a persisting 'blush' of the Contrast agent appearing prior to the venous phase and not disappearing in the parenchymatous phase.
- PSAIS: an intraparenchymatous sacular collection delimited by a density similar to the adjacent veins, without showing a blood extravazation.

4.4. The indications of the splenic angiography (46,47,48,49):

the 3^{rd}, 4^{th} and 5^{th} degree splenic lesions;

the vascular lesions initially found at CT irrespective of the lesion degree;

the active bleeding at CT or 'contrast blush' in hemodynamically stable patient;

the inexplicable decrease of the Ht in the absence of other lesions;

the large hemoperitoneum.

4.5. **Indications** of SAE (32,50,51)

The hemodynamic stability in patients with:

- extravazation of the Contrast agent/blush/SPA/AVF at CT;

- severe splenic lesion degree (III-V);

- average, large hemoperitoneum (defined as the blood accumulation of both the upper and pelvic quadrants).

4.6. Types of SAE

Depending on the lesion's 'pattern', the splenic angioembolization (SAE) (44,63) may be made:

4.7.1. distally (supraselective);

it executes the isolation of the harmed vessel, it keeps the normal blood flow for an important spleen area but it needs large execution time and special technical skills (87,109). Likewise, it implies the use of a large quantity of contrast agent (the risk of contrast agent nephropathy) and a higher irradiation dose (110), proportional to the difficulty of the procedure's execution (82). It is indicated in localized vascular lesions (vascular truncation, SPA, focal extravazation) (44,111).

4.7.2. proximal

(the trunk of the splenic artery, distal from the dorsal pancreatic artery origin, between the dorsal pancreatic artery and the magna pancreatica artery, at 2 cm distal from the dorsal pancreatic artery); it is made by metallic coils or absorbable hemostatic materials (Gelfoam – Pharmacia, Kalamazoo, MI; Tachocomb) and it determines the demostasis by increasing the arterial blood flow (deviated through the collaterals) (112) and of the distal intrasplenic systolic pressure (in average 40 mmHg-[113]), facilitating, thus, the organization of the clots and the healing of the lesion (favouring the implicit coagulation [114]); it prevents an RIS (82,87).

The viability of the spleen is ensured by the collateral circulation (branches of the left gastric artery, the gastro-epiploic artery, the omental, pancreatic, the short gastric arteries) proven by the experimental studies made on animals (97, Anderson cit. Zmora [115]).

The action mechanism of the PSAE is made by decreasing the intrasplenic systolic arterial pressure helping the hemostasis and allowing the healing of the harmed splenic parenchyma (44).

4.7.3 combined

The decision of performing the PSAE after the DSAE depends on the lesion pattern, the patient's condition, the local practices and the preference of the intervention radiologist(44). In the presence of multifocal lesions and angiographically objective splenic branch lesions, the PSAE will be performed immediately after the DSAE; for a single lesion with angiographic correlation, only the DSAE(82) is indicated, keeping the PSAE for a possible rebleeding.

The explanation of this indication: some vascular lesions cannot be identified at the initial angiography and can cause rebleeding after the disappearance of the vasospasm(118,119).

4.8. The indications of the SAE (68,82,88,90,120) are:

The proximal SAE (121):

- hilar lesions;
- >= 3rd degree;
- > 3 separate/distinct peripheral vascular lesions;
- the lesion affects >50% of the splenic parenchyma;
- AVF, SPA;
- the vascular lesions with amputation angiographic aspect (suggesting the associated spasm lesion);
- average/large hemoperitoneum;
- the technical impossibility of the distal SAE execution;
- the splenic multiple lesions (‘Seurat’ spleen)(44);
- the CT-proven lesion unidentified to angiography (87,110).

Selective SAE: limited splenic vascular lesions (121);

- the extravazation of the Contrast agent;
- SPA;
- AVF.

Benefits: it ensures the hemostasis and the normal blood perfusion of the rest of the organ.

 Combined SAE(121): multiple vascular lesions (severe lesion degrees), intraperitoneal extravasation, SPA.

The SPA embolization must avoid the distal bleeding (‘back-door bleeding’) secondary to collateral blood flow; the occlusion of the vessel proximal and distal to the lesion is indicated (64,122).

Jeremitsky(123) considers the indication of SAE only in cases of active bleeding or the presence of intrasplenic pseudoaneurysm (identified on CT-scan), while the degree of splenic lesion and the degree of hemoperitoneum do not represent 'per se' some absolute indications; Wei(61) considers the SAE useful also in severe lesions (4^{th} or 5^{th} degree) that associate significant hemoperitoneum (indication also established by Thompson[124]).

Van der Vlies(66), classifies SAE indications in:

• absolute

4^{th} - 5^{th} lesion degree, irrespective of the other findings;

extrasplenic contrast substance extravasation;

• relative

1^{st} - 3^{rd} lesion degree in the presence of the tomographic 'blush contrast';

intrasplenic vascular lesions (pseudoaneurysm, arterio-venous fistula);

large hemoperitoneum;

decrease of hemoglobin values during hospitalization.

4.9 Repeated embolization

(the 'second-look' angiography) is indicated in recurrent bleedings after the initial negative angiography (10%) (70).

4.10 Prophylactic PSAE

It is indicated to high risk patients (83,87,233):

- aged > 50;

- large hemoperitoneum;

- polytraumatic;

- needing extended surgical procedures in other regions (orthopedic, neurosurgical) that increase the bleeding risk and the secondary aggravation of the lesions (specially, cerebral).

4.10 Prophylactic PSAE

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4.12 Complications of SAE

They were classified as major (may cause death/severe invalidity, 20%) and minor (they exclude the vital risk, 23%) (9). .

4.16. SAE Failure

The SAE technical failure is defined as the impossibility of cannulating and embolizing the splenic artery / its branches.

The SAE therapeutic failure is considered when the hemostasis – needed surgery must be performed after the gesture (102).

2. PERSONAL CONTRIBUTIONS

1. SPECIAL PART

1. Introduction

The therapy of the traumatic splenic lesions took several stages – principle splenectomy, splenic conservatory surgery (splenography, partial splenectomy, subtotal splenectomy, application of the local hemostatics), the splenectomy followed by the intraomental splenic implant, the non-surgical treatment, the splenic angioembolization.

The current belief: not any post-traumatic hemoperitoneum must be immediately surged.

The non-surgical treatment (TNO) is currently the 'golden standard' (the 'golden standard' in the splenic traumatology.

The non-surgical treatment may be used as unique method (in most cases) or associated to the diangnosed and therapeutic angiography.

SCUB, the reference medical unit in Romanian traumatology, followed the occidental trend, succeeding in obtaining some results similar to the Level 1 Trauma Centres in the world.

It is an observational study, non-randomized made during 01.01.2006 – 31.12.2019, that includes a 64-patient specimen with splenic trauma, a patient population representative for non-iatrogenic splenic trauma, isolated/polytraumatisms, diagnosed in a traumatology specialized centre.

2. Working hypothesis and general objectives

The study-commencement hypothesis is the existence of data that affirms the effectiveness of diagnostic and therapeutic angiography in splenic contusive traumatology.

The main objective of the study was the investigation of the effectiveness of the two therapeutic methods, and the main endpoints of the study were:

- post-traumatic mortality,

- the surgical intervention need (laparoscopic/classic) to solve the splenic bleeding,

-number of hospitalization days,

- the need to be hospitalized for more than 1 day in STI,

-the number of days after which the thrombocytes increased,

- the evolution of Hb values (hospitalization, pre-angiography, post-angiography, discharge),

-the identification of the most common injury mechanisms involved in splenic trauma (iatrogenic trauma and spontaneous ruptures are excluded),

- evaluation of indications for angiography and splenic angioembolization as part of TNO.

A secondary endpoint of the study was represented by the frequency of complications not requiring a surgical intervention.

Finally, a secondary objective of the study was to compare the accuracy for the diagnosis of active hemorrhage in the spleen, between CT investigation and angiographic investigation.

Also, the demographic parameters of the patients were monitored in the study, variables that measure the intensity of the trauma (GCS, ISS, RTS), the degree of splenic rupture, the severity of the hemorrhage (active intraperitoneal, intrasplenic bleeding, intraparenchymal posttraumatic vascular lesions), the degree of hemoperitoneum and, in descriptive statistics, the relationship between vascular injury and splenic lesion degree.

It should be noted that full data was not available for all patients in the study.

The study analyzes retrospectively the period 2006-2017 and prospectively the period 2018-2019.

2.1 Inclusion criteria:

patients with splenic injuries by contusive mechanism, isolated or polytrauma, who had a CT examination with SCIV at admission and subsequently diagnostic splenic angiography (ASD) or therapeutic (splenic angioembolization, ESA);

2.2 Exclusion criteria:

• abdominal or thoracic-abdominal wounds with splenic involvement;

• patients who underwent an abdominal surgery before ASD or SAE;

• patients with different degree burns;

• patients declared dead upon their arrival to the Emergency Room or who died within the first 24 hours of admission.

The procedure was performed after the informed consent was signed by the patient or family.

2.3 ATLS principles

Based upon the Advanced Trauma Life Support (ATLS) criteria, in the Emergency Department, traumatized patients were classified into 3 categories:

-stable: after the injection of 1500 cc lactated Ringer bolus, the BP is maintained at physiological values (with the preservation of the infusion solutions at a normal rate);
- transitory stability: it includes cases that have been stabilized but cannot be maintained without continuous infusion at a rapid rate;
-unstable: patients with no response to infusion solutions, who require immediate surgical exploration.
The considered parameters were: blood gas analysis, TAS, AV, FR.
The ideal SBP value for abdominal injuries by blunt mechanism was established at:
▪90 mmHG (isolated abdominal contusions);
▪110 mmHg (associated CBT).

2.4 Followed and analyzed variables

They were represented by age, sex, trauma etiology, injury mechanism, shock, injury degree, applied treatment, associated injuries, morbidity, mortality, the hospitalization period.

The decision to perform AE rests with the endovascular/trauma surgeon.

International trauma guidelines (EAST, WTA) and clinical judgement/appreciation were the basis of therapeutic decisions(6,7).

In hemodynamically stable traumatized/polytraumatized patients or stabilized (through the initial resuscitation procedures), abdominal or cranio-thoracic-abdominal-pelvic CT examination with SCIV was performed. The examination was performed following the arterial, venous and late venous times necessary to establish a precise lesional diagnosis and the presence of active splenic bleeding/intrasplenic posttraumatic vascular lesions.

The abdominal CT exam established:

-splenic lesion degree (AAST OIS 1994 classification, supplemented by the one revised in 2018);

- the presence of intrasplenic posttraumatic vascular lesions: active extravasation of SCIV, PSAIS, AVF, vascular truncation;

- estimation of the hemoperitoneum volume;

Angiographic procedures were classified into:

-diagnostics (diagnostic AD angiography) and

-therapeutic (splenic angioembolization SAE),

targeting:

- indication of embolization;

-SAE technique: proximal (PSAE), distal (DSAE), combined, repeated;

- the material used for AE.

The SAE indication was established by the interventional radiologist together with the head surgeon of the trauma team and the choice of modality and material used for the procedure belonged to the interventional radiologist.

After the procedure, the patients were clinically and paraclinically evaluated to diagnose a complication; clinical deterioration required a repeat CT examination (post-procedural complication, continued bleeding).

2.5 Definition of the used terminology

For clarification purposes, we used the following definitions:

- isolated splenic lesion = single abdominal lesion/in the absence of plurisystemic lesions influencing the prognosis;

- low splenic lesion degree = 1^{st}, 2^{nd} degree;

-severe splenic lesion degree = 3^{rd}, 4^{th}, 5^{th} degree;

-immediate laparotomy= performed in the first 24 hours post-trauma;

-delayed laparotomy= performed more than 24 hours after admission;

-TNO= intentional observation of a demonstrated post-traumatic splenic injury;

-TNO failure= patient with delayed laparotomy performed after 3 stable hematocrit determinations/24 hours; the need for surgery in a patient treated non-operatively with/without SAE;

clinical/paraclinical evidence of persistent bleeding requiring laparotomy for hemostasis or delayed diagnosis of a major intra-abdominal injury;

-stable hematocrit = initial and tertiary measurement without differences greater than/equal to 3%;

-massive transfusion: ≥ 5U MER(8,231);

-polytraumatism/severe traumatism: ISS ≥16;

- TNO success= patient discharged with spleen "in situ" and without indication of splenic surgery at the most recent clinical check-up;

-initial SAE= angioembolization performed in the first 12 hours after admission;

- technical failure of angioembolization = impossibility of cannulation and embolization of the splenic artery; the experience of the interventional radiologist decreases this risk.

We defined the hemodynamic instability based upon one of the criteria initially found in the UPU: pulse > 120/min or SBP < 90 mmHg with the presence of cutaneous

vasoconstriction (cold, sweaty extremities, decreased capillary refill), altered state of awareness and/or tachypnea; patients with transient hemodynamic stability were considered hemodynamically unstable.

The Used Classifications

The following classifications were used:

▪ 2.7.1 AAST OIS classification (reviewed in 1994)

- it is based on CT/intraoperative/necropsic findings and allows a correct assessment of the degree of a contusive splenic injury (American Association for the Surgery of Trauma – Organ Injury Scale (AAST-OIS) published in 1989(232) and revised in 1994 (233), known as the Moore classification (table 1).

Table no. 1. Moore Classification (reviewed in 1994).

1	Non-expansive subcapsular hematoma <10% of the surface Parenchymal capsular lesion <1 cm depth
2	Non-expansive subcapsular hematoma 10-50% of the surface Non-expansive intraparenchymal hematoma with the diameter of <5 cm Capsular lesion with active bleeding Parenchymal lesion. 1-3cm that does not involve the trabecular vessels
3	Subcapsular hematoma >50% of the surface or expansive Ruptured subcapsular-intraparenchymal hematoma Intraparenchymal hematoma diam. ≥ 5 cm or expansive Parenchymal lesion >3 cm deep or with damage to trabecular vessels
4	Injury involving the segmental or hilar vessels with the production of major devascularization (> 25% of the spleen)
5	Spleen crushing Hilar vascular injury with splenic devascularization

* 1 degree is added for the splenic multiple lesions up to the 3rd degree.

▪2.7.2 AAST-OIS classification changed by Kozar(95,96)(Table 2)

In 2018, Kozar et al. (95,96) carried out an update of the AAST-OIS classification of splenic, hepatic and renal traumatic injuries. This classification includes 3 types of criteria to define the

lesion degree: imaging, intraoperative and anatomical-pathological. The final AAST lesion degree is represented by the highest value of one criterion. However, the most important modification of this classification is represented by the introduction of splenic vascular lesions diagnosed on CT examination (PSAIS, AVF). For a precise description of post-traumatic splenic vascular lesions, CT examination in the arterial and venous times is recommended.

Table 2. AAST-OIS classification changed by Kozar.

AAST degree	**AIS severity**	**Imaging criteria (CT)**	**Operating criteria**	**Anatomo-pathological criteria**
1	2	• Non-expansive subcapsular hematoma <10% of the surface • Parenchymal lesion <1 cm deep • capsular injury	•Non-expansive subcapsular hematoma <10% of the surface • Parenchymal lesion <1 cm deep • capsular injur	Non-expansive subcapsular hematoma <10% of the surface • Parenchymal lesion <1 cm deep • capsular injur
2	2	• subcapsular hematoma 10-50% of the surface; intraparenchymal hematoma < 5cm • 1-3 cm deep parenchymal lesion	• subcapsular hematoma 10-50% of the surface; intraparenchymal hematoma < 5cm • 1-3 cm deep parenchymal lesion	• subcapsular hematoma 10-50% of the surface; intraparenchymal hematoma < 5cm • 1-3 cm deep parenchymal lesion
3	3	• subcapsular hematoma >50% of the surface; ruptured subcapsular hematoma; intraparenchymal hematoma ≥ 5cm • > 3cm deep parenchymal lesion	• subcapsular hematoma >50% of the surface; ruptured subcapsular hematoma; intraparenchymal hematoma ≥ 5cm • > 3cm deep parenchymal lesion	• subcapsular hematoma >50% of the surface; ruptured subcapsular hematoma; intraparenchymal hematoma ≥ 5cm • > 3cm deep parenchymal lesion
4	4	•any injury in the presence of a vascular injury or limited active intrasplenic bleeding •parenchymal lesion with the involvement of segmental or hilar vessels with the production of devascularization > 25%	•parenchymal lesion with the involvement of segmental or hilar vessels with the production of devascularization > 25%	parenchymal lesion with the involvement of segmental or hilar vessels with the production of devascularization > 25%
5	5	• any injury in the presence of a vascular	• hilar vascular injury with devascularization of the	• hilar vascular injury with devascularization

		injury with active extrasplenic, intraperitoneal bleeding • crushing of the spleen	spleen • crushing of the spleeni	of the spleen • crushing of the spleen

*the vascular injury is defined as PSAIS or AVF and appears as a localized (focal) collection of Contrast Agent whose attenuation decrease during the venous time. The active bleeding represents an area of vascular contrast, localized or diffuse, that increases in size or attenuates in the late phase.

*Add 1 degree for multiple splenic lesions up to 3rd degree.

•Classification of the hemoperitoneum degree

the comparison of CT classification of hemoperitoneum degree: classic(234,235) versus Hagiwara(129,236)

1. The Federle classification of hemoperitoneum, considering the 7 intraperitoneal spaces: right subphrenic, left subphrenic, subhepatic, right paracolic, left paracolic, pelvis, intramesenteric.

- 1-2 intraperitoneal spaces = small (250 ml)
-2-4 intraperitoneal spaces = moderate (250-500 ml)
->4 intraperitoneal spaces = large (>500 ml)

2. CT classification of Hagiwara hemoperitoneum:

0 - hemoperitoneum absent
1+ - present in only one anatomical area (hepatorenal, perihepatic, perisplenic)
2+ - ≥ 2 areas (parieto-colic grooves, lateral perivesical)
3+ - the entire pelvis

2.8 The statistic analysis

The patients with splenic trauma in the analyzed group were divided into two groups, depending on the therapeutic approach: group A consisted of 37 cases in which splenic angioembolization was performed; group B (27 cases) in which only diagnostic splenic angiography was performed.

A comparative analysis was performed between the 2 groups of patients. In the descriptive analysis, the following elements were determined: the average, the standard deviation (D.S), the median, the Inter-Quartile-Range (IQR), the skewness (the deviation from the symmetry of the distribution), the minimum value and the maximum value for the continuous variables, in whereas absolute frequency (number) and relative frequency (percentages) were determined for category variables. For comparison purposes, a bootstrap procedure (resampling with re-introduction) of the difference in arithmetic means was used, using 100,000 such resamplings, and the p-value and Confidence Interval (CI) 95% were determined (the CI was evaluated as the difference between the quantile of 2.50% and that of 97.50%). The bootstrap procedure is a test based on random sampling with reintroduction that allows the determination of precision measures of the estimated sample. This technique allows the sampling distribution of any statistic to be estimated using random sampling methods. Bootstrapping is the practice of estimating properties of an estimator such as its variance by measuring those properties when sampling from an approximate distribution. When a set of observations can be assumed to be from an independent and identically distributed population, this can be implemented by

constructing a number of samples with replacement of the observed data set and of equal size to the observed data set. The technique can be used to construct hypothesis tests when this hypothesis requires difficult formulas for calculating standard errors. In the doctoral study, the interpretation of the p value was used as follows: $p \leq 0.05$ indicates statistical significance with strong evidence against the null hypothesis; p with a value close to the cut-off (0.05) indicates an uncertain result that can be either significant or without statistical significance; $p > 0.05$ indicates result without statistical significance; $p < 0.001$ indicates a result with strong statistical significance. Pearson's correlation coefficient (r) or bivariate correlation measures the correlation between two variables in the same category. Its values are between 0 and 1, where 1 represents positive linear correlation, meaning the two values are closely correlated. The results are interpreted as follows: Pearson coefficient between 0.1 and 0.3 or for negative values between -0.1 and -0.3 shows a weak correlation between the two variables; Pearson coefficient between 0.3 and 0.5 or between -0.3 and -0.5 indicates a mediocre correlation; Pearson coefficient between 0.5 and 1 or between -0.5 and -1 indicates a strong correlation. R program version 3.5.3 (2019-03-11) Copyright (C) 2019 The R Foundation for Statistical Computing, R Core Team (2019) was used for statistical analysis. A: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/ 65 The R package asbio was used for the bootstrap analysis, (c): Ken Aho (2019). asbio: A Collection of Statistical Tools for Biologists. R package version 1.5-5. https://CRAN.Rproject.org/package=asbio.

2.9 Results

2.9.1 General features of the study group

The patients with splenic trauma in the analyzed group were divided into two groups, depending on the therapeutic approach: group A consisted of 37 cases in which splenic angioembolization was performed; group B (27 cases) in which only diagnostic splenic angiography was performed (without embolization) with a watchful waiting attitude

We may observe that starting from 2009 (the year in which the first ESA was performed in SCUB), with the exception of 2010, the number of splenic angioembolizations was higher than cases with diagnostic splenic angiography, a finding that suggests the establishment of clear indications (clinical and imaging) for this procedure.

The first part of the study consisted of a descriptive analysis, for the interval variables being determined: the mean, the standard deviation (SD), the median, the minimum and the maximum of the distribution, and for the graphic representation, histograms and normal probability plots were used; for the categorical variables, the absolute frequencies (in the form of the number for each category compared to the total number) and the relative frequencies (the percentage for each category) were determined, for the graphic representation, barplots were used.

Age analysis

there were patients from all age categories, the averages in the two groups revealing that the typical patient is the young-middle-aged adult

17 cases (26.56%) were ≥ 55 years old (55-81 years), with the predominance of the male sex (63%), situations confirmed in the most recent studies.

Distribution of the patients specimen by gender:

A homogeneity of gender distribution is observed between the two groups, with the predominance of the male sex, a characteristic of traumatic pathologies.

ISS and RTS values at admission

ISS values ≥ 16 and the increased percentage of patients with severe abdominal trauma/polytrauma suggest that these cases were admitted/sent/transferred to SCUB.

Splenic rupture degree (AAST-OIS)

small rupture degrees (1-2) were characteristic to batch B, while large rupture degrees (3-5) were characteristic of batch A.

Hemoperitoneum degree:

In batch A, there was a higher frequency of major intraperitoneal hemorrhages, while medium intraperitoneal hemorrhages predominated in batch B.

For increased accuracy, we used the Hagiwara classification to evaluate the hemoperitoneum; large hemoperitoneum (degree 3+) predominated in batch A.

Patients proportion comparison to the hemodynamic shock

The proportion of cases with hypovolemic shock was higher in batch B patients, but the difference is without statistical significance, as revealed by the Fisher's exact test (p value = 0.0611)

Day of thrombocytes increase

We analyzed the day when the increase in thrombocytes started, considering this increase as an indicator of the stop of bleeding (mainly) and a consequence of SAE (secondary).

Post-procedural complications

The proportion of complications was higher in group A of patients, the two-way $\chi 2$ (chi-square) test for two independent proportions shows, however, that the difference is without statistical significance ($\chi 2 = 1.10$, degrees of freedom = 1, p value = 0.2926)

Procedural failure

Treatment failure (with the need for surgical intervention for splenic hemostasis).

The proportion of failures was higher in group A of patients, the two-way Fisher's exact test for two independent proportions shows, however, that the difference is without statistical significance (p value = 0.5684).

Interference analyses

In this part of the work, inferential analyzes were made to evaluate the effectiveness of therapeutic methods for the treatment of splenic trauma.

2.9.20.1 Comparison of the hemoglobin values at admission and prior to the procedure

A first analysis investigated the clinical-hemodynamic evolution of patients with splenic trauma, separately for each group, using a comparison between Hb values at admission and Hb values before performing angiography. Since we are talking about measurements performed on the same patient at different moments in time, the test used was Paired T (T test for correlated samples).

• **Analysis of lot A**

Table 40. Analysis of lot A

Admission Hb average	**Pre-angiography average Hb**	**Statistics T, freedom degree, p wave**	**Differences average [IC95%]**
11.76	10.50	T = 4.31, gl = 36, val p = 0.0001	1.26 [0.67 la 1.85]

The test reveals that Hb values before angiography were statistically significantly lower compared to the time of admission, indicating an evolution of bleeding in these patients.

Analysis of lot B

Admission Hb average	**Pre-angiography average Hb**	**Statistics T, freedom degree, p wave**	**Differences average [IC95%]**
11.02	9.79	T = 3.18, gl = 24 val p = 0.0039	1.23 [0.43 la 2.03]

The test reveals that the Hb values preliminary to the angiography were statistically significantly lower than at the time of hospitalization, suggesting the evolution of bleeding but, most likely, not from the splenic level.

Comparison between Pre-Angiography Hb values and Post-Angiography Hb values, for each group (the inferential test was Paired T):

• **Comparison for lot A**

Table 42. Comparison for lot A

Pre-Angiography average Hb	**Post-angiography average Hb**	**Statistics T, freedom degree, wave p**	**Differences average [IC95%]**
10.46	10.20	T = 1.07, gl = 35, val p = 0.2902	0.26 [-0.23 la 0.74]

The test shows that there were no differences with statistical significance, the evolution of bleeding seems to be stopped. Therefore, SAE was effective, the goal of this method being achieved.

Comparison for lot B

Table 43. Comparison for lot B

Pre-Angiography Hb average	**Post-angiography Hb average**	**Statistics T, freedom degree, wave p**	**Differences average [IC95%]**
10.10	9.52	T = 1.39, gl = 16, val p = 0.1813	0.58 [-0.30 la 1.46]

The test reveals that there were no differences with statistical significance, the evolution of bleeding seems to be stopped. The result underlines the correctness of the decision not to perform SAE.

Comparison between Post-Angiography Hb values with Hb values at discharge, for each group (the inferential test was Paired T)

• Comparison for lot A

Table 44. Comparison for lot A

Post-angiography Hb average	**Discharge Hb average**	**Statistics T, freedom degree, wave p**	**Differences average [IC95%]**
10.23	10.48	T = -1.03 gl = 34, val p = 0.3097	-0.25 [-0.74 la 0.24]

The test reveals that there were no statistically significant differences in patients with no hemorrhagic complications during hospitalization, emphasizing the efficiency and safety of the method.

• Comparison for lot B

Table 45. Comparison for lot B

Post-angiography Hb average	Discharge Hb average	Statistics T, freedom degree, wave p	Differences average [IC95%]
9.40	10.02	T = -1.16 gl = 12, val p = 0.2684	-0.62 [-1.77 la 0.53]

The test reveals that there were no statistically significant differences in patients with no hemorrhagic complications during hospitalization; the decision to perform splenic angiography, without the need for angioembolization, was safe and rational.

The analysis highlighted that, for both diagnostic and therapeutic methods, active bleeding was stopped, the methods being therefore effective for splenic trauma.

Comparaion of the splenic trauma severity (AAST-OIS) between the 2 groups

For the comparison of the severity of splenic injuries (AAST-OIS), considering the characteristics of the two distributions, a resampling procedure with replacement (bootstrap) was used for the difference of the two means of the distributions (SE is the mean error, CI95% was calculated as the difference between the 97.5% and 2.5% quantiles of the bootstrap distribution):

Table 48. Comparison of the splenic trauma severity of the two lots

Lot A Average	**Lot B Average**	**AverageSE, p bootstrap value**	**Averages Differences [IC95%]**
3.73	2.89	SE = 0.263, p = 0.0008	0.84 [0.36 la 1.38]

The differences were statistically significant ($p < 0.01$), in patients from group A the trauma was more severe.

The comparison between the performance of angiography and CT examination for the diagnosis of posttraumatic splenic hemorrhage

In this part of the paper, a comparison was made between the performance of different diagnostic methods for highlighting post-traumatic bleeding at the splenic level. Th angiography (considered as the gold standard) and CT examination with SCIV were compared. The comparison included a crude analysis and one using the Cohen kappa statistic method.

We considered the performance of the diagnostic angiography to be perfect/ideal (100%, no false positive cases and no false negative cases), and the CT performance was related to this.

Confusion matrix (the variable we were interested in was the presence/absence of active bleeding):

Table 49. Comparison between the angiography SA diagnosis and CT – performance

	Angiography Active Bleeding	
	Yes	No

CT active bleeding	Yes	14	9
	No	9	35

The trace of the matrix (the sum of the elements of the main diagonal of the matrix) indicates the number of angiographically confirmed CT-diagnosed cases, while the sum of the elements of the secondary diagonal are the CT diagnoses of active bleeding, not angiographically confirmed.

CT performance is 49 / (49 + 18) = 0.7313, i.e. 73.13%.

The proportion of false negative cases (active bleeding at angiography, not detected at CT) is 9 / (9 + 14) = 0.3913, i.e. 39.13%.

The proportion of false positive cases (without active bleeding diagnosed by angiography, but with a diagnosis of active bleeding by CT) is 9 / (9 + 35) = 0.2045, i.e. 20.45 %.

The Cohen kappa index was 0.48, with 95% CI = [0.25 to 0.70].

The analysis shows that the CT examination has a lower performance than angiography for the diagnosis of active bleeding at the splenic level, but it is useful for diagnostic guidance.

Clinical and statistic analysis

The demographic and clinical characteristics of the patients are presented in table no. 50 again, table no. 51 shows the values of the laboratory examinations at admission, pre-procedural, post-procedural and at discharge as well as the day of platelet increase (considered as a marker of stopping the bleeding).

Table 50. The demographic and clinical characteristics of the patients

A. Demographic	**Group A (n=37)**	**Group B (n=27)**	**Global (n=64)**	**p**
Aged, median (IQR), years average ± SD, years	37.0 [12.0, 78.0] 39.9 (± 18.9)	42.0 [13.0, 81.0] 43.6 (± 17.1)	38.0 [12.0, 81.0] 41.5 (±18.1)	NS
Men, n (%)	23 (62.2%)	17 (63.0%)	40 (62.5%)	NS
Lesion mechanism, n (%) AR, Pedestrian Other	 5 (13.5%) 32 (86.5%)	 2 (7.4%) 25 (92.6%)	 7 (10.9%) 57 (89,1%)	 NS NS
Lesion characteristics ISS, median (IQR) average ± SD	 19.0 [4.00, 50.00] 20.8 (± 10.8)	 21.0 [5.00, 41.0] 23.0 (± 9.92)	 19.0 [4.00, 50.00] 21.7 (± 10.4)	NS NS

Vital signs				
TAS UPU, median (IQR)	116 [55.0, 160]	110 [80.0, 165]	112 [55.0, 165]	
average± SD	115 (± 19.7)	115 (± 24.5)	115 (± 21.7)	NS
AV UPU, median (IQR)	95.0 [65.0, 110]	98.0 [78.0, 160]	96.0 [65.0, 160]	
average± SD				NS
Index UPU shock				
median(IQR)	0.800 [0.500, 1.80]	0.900 [0.500, 1.50]	0.800 [0.500, 1.80]	NS
average ± SD	0.839 (± 0.226)	0.915 (± 0.246)	0.871 (± 0.236)	
GCS UPU median (IQR)	15.0 [3.00, 15.0]	15.0 [6.00, 15.0]	15.0 [3.00, 15.0]	
average± SD	14.0 (± 2.75)	14.0 (± 2.30)	14.0 (± 2.55)	
				NS
				NS
				NS
				NS
AAST,n (%) splenic lesion degree				p = 0.0008
1	0 (0%)	4 (14,8%)	4 (6.3%)	
2	4 (10.8%)	6 (22.2%)	10 (15.6%)	
3	24 (64.9%)	12 (44.4%)	36 (56.3%)	
4	8 (21.6%)	5 (18.5%)	13 (20.3%)	
5	1 (2.7%)	0 (0%)	1 (1.6%)	
Hemoperitoneum degree, n (%)				
low	13 (35.1%)	9 (33.3%)	22 (34.4%)	
average	15 (40.5%)	13 (48.1%)	28 (43.8%)	
high	9 (24.3%)	5 (18.5%)	14 (21.9%)	
Hagiwara				
0	5 (13.5%)	2 (7.4%)	7 (10.9%)	
1+	8 (21.6%)	7 (25.9%)	15 (23.4%)	
2+	10 (27.0%)	11 (40.7%)	21 (32.8%)	
3+	14 (37.8%)	7 (25.9%)	21 (32.8%)	
Blood transfusions, n (%)				
yes	19 (51.4%)	14 (51.9%)	33 (51.6%)	
no	18 (48.6%)	13 (48.1%)	31 (48.4%)	
Complications, n (%)				
yes	20 (54.1%)	11 (40.7%)	31 (48.4%)	
no	17 (45.9%)	16 (59.3%)	33 (51.6%)	NS
				NS
Therapeutic failure, n (%)				
yes	1 (2.7%)	2 (7.4%)	3 (4.7%)	
no	36 (97.3%)	25 (92.6%)	61 (95.3%)	NS
				NS
Extra-abdominal surgery, n (%)				
yes	9 (24.3%)	11 (40.7%)	20 (31.3%)	
no	28 (75.7%)	16 (59.3%)	44 (68.8%)	NS
				NS

Hemodynamic shock n (%) yes no	 2 (5.4%) 35 (94.6%)	 6 (22.2%) 21 (77.8%)	 8 (12.5%) 56 (87.5%)	 NS NS
STI days median (IQR) average ± SD	 0 [0, 18.0] 2.22± 4.24	 0 [0, 18.0] 3.81± 5.26	 0 [0, 18.0] 2.89± 4.72	
Days in the Surgical Department median (IQR) average ± SD	 9.00 [1.00, 37.0] 10.2± 6.33	 9.00 [2.00, 30.00] 10.4± 6.25	 9.00 [1.00, 37.0] 10.3± 6.25	
AAST OIS 2018 median [IQR] average± SD	 4.00 [2.00, 5.00] 3.73± 0.838	 3.00 [1.00, 5.00] 2.89± 1.15	 3.00 [1.00, 5.00] 3.38± 1.06	

Table. Values of lab tests

	Group A	Group B	Group A + Group B
A. Emergency Department			
hemoglobin			
average ± SD, g/dl	11.8 ± 2.18	11.0 ± 2.40	11.4 ±2.28
median, [IQR], g/dl	11.9 [6.30, 15.7]	11.3 [4.50, 14.3]	11.8 [4.50, 15.7]
hematocryt			
average ± SD, %	35.6 ± 7.55	33.6 ± 6.85	34.7 ± 7.28
median, [IQR], %	36.7 [14.9, 54.0]	34.9 [14.7, 42.7]	36.1 [14.7, 54.0]
leukocytes			
average ± SD, /mm³	12.8 ± 5.05	14.9 ± 6.07	13.7 ± 5.55
median, [IQR], /mm³	12.5 [4.20, 29.9]	14.5 [4.80, 28.4]	13.1 [4.20, 29.9]
thrombocytes			
average ± SD, /mm³	219 ± 66.3	262 ± 112	236 ± 89.8
median, [IQR], /mm³	211 [74.0, 372]	229 [41.0, 543]	222 [41.0, 543]
B. Prior to the procedure			
hemoglobin			
average ± SD, g/dl	10.5 ± 2.23	9.79 ± 2.38	10.2 ± 2.30
median, [IQR], g/dl	10.7 [6.10, 14.0]	9.50 [4.60, 13.7]	10.3 [4.60, 14.0]
hematocryt			
average ± SD, %	31.9 ± 6.56	29.4 ± 6.62	30.9 ± 6.65
median, [IQR], %	32.7 [19.3, 41.9]	29.0 [15.3, 41.2]	31.4 [15.3, 41.9]
leukocytes			
average ± SD, /mm³	10.8 ± 4.17		11.3 ± 5.16
median, [IQR], /mm³	10.5 [4.20, 20.2]	12.1 ± 6.36	10.2 [4.20, 28.4]
thrombocytes		9.50 [6.30, 28.4]	
average ± SD, /mm³	200 ± 70.1		209 ±92.1
median, [IQR], /mm³	186 [78.0, 363]	222 ± 118	188 [32.0, 568]
		196 [32.0, 568]	

C. Post-procedure			
hemoglobin			
average ± SD, g/dl	10.2 ± 1.87	9.52 ± 1.53	9.98 ± 1.78
median, [IQR], g/dl	10.4 [6.00, 14.7]	9.20 [7.80, 12.9]	9.70 [6.00, 14.7]
hematocryr			
average ± SD, %	31.0 ± 5.35	29.2 ± 4.51	30.4 ±5.13
median, [IQR], %	32.3 [17.8, 42.7]	28.4 [23.5, 39.7]	29.6 [17.8, 42.7]
leukocytes			
average ± SD, /mm³	13.2 ± 5.41		12.7 ± 5.21
median, [IQR], /mm³	12.8 [4.70, 30.6]	11.6 ± 4.74 9.10 [6.20, 19.8]	12.2 [4.70, 30.6]
thrombocytes			
average ± SD, /mm³	196 ± 63.4		196 ± 80.3
median, [IQR], /mm³	186 [86.0, 356]	197 ± 110 177 [58.0, 416]	185 [58.0, 416]
D. Thrombocytes increase day			
Average ± SD, zi	2.26 ± 1.24	3.10 ± 0.968	2.56 ± 1.21
median, [IQR], zi	2.00 [1.00, 6.00]	3.00 [2.00, 5.00]	2.00 [1.00, 6.00]
E. Discharge			
hemoglobin			
average ± SD, g/dl	10.5 ± 1.49	10.1 ± 1.46	10.3 ± 1.48
median, [IQR], g/dl	10.6 [8.00, 14.7]	10.1 [8.00, 13.0]	10.5 [8.00, 14.7]
hematocryt			
average ± SD, %	32.0 ± 4.24	30.7 ± 4.08	31.5 ± 4.20
median, [IQR], %	32.4 [24.2, 42.7]	30.6 [24.3, 39.0]	31.2 [24.2, 42.7]
leukocytes			
average ± SD, /mm³	11.5 ± 4.13	8.74 ± 2.21	10.4 ± 3.75
median, [IQR], /mm³	11.1 [4.70, 18.1]	9.50 [4.80, 12.3]	10.0 [4.70, 18.1]
thrombocytes			
average ± SD, /mm³	427 ± 220	318 ± 127	386 ± 196
median, [IQR], /mm³	346 [106, 894]	300 [114, 572]	332 [106, 894]

The average value of the ISS was 21.7, which highlights the severity of the cases 71.87% of the cases presented ISS ≥ 16. The average and the median ISS had values ≥ 16 (which include cases in the severe category), practically 71.87% had ISS ≥ 16 (highlighting the severity of trauma).

The value of the shock index (average 0.871±0.236; median 0.800[0.500, 1.80]) places these cases in the 2nd class, medium shock.

The splenic lesion degree AAST-OIS evaluated at the admission of the patients showed an average value of 2.95. There were 14 cases of minor injuries (1st degree-4 cases, 2nd degree-10 cases) and 50 cases of severe injuries (3rd degree-36 cases; 4th degree -13 cases; 5th degree-1 case) (Table 52).

Table 52. AAST-OIS splenic lesion degree

	Lot A (N=37)	**Lot B (N=27)**	**Global (N=64)**

	Lot A (N=37)	Lot B (N=27)	Global (N=64)
Spleen Rupture Degree			
1	0 (0%)	4 (14.8%)	4 (6.3%)
2	4 (10.8%)	6 (22.2%)	10 (15.6%)
3	24 (64.9%)	12 (44.4%)	36 (56.3%)
4	8 (21.6%)	5 (18.5%)	13 (20.3%)
5	1 (2.7%)	0 (0%)	1 (1.6%)

We may notice a predominance of the 3rd (56.3%) and the 4th (20.3%) degrees, the SAE being performed in 32 cases (50%). Moreover, in both studied groups, the 3rd degree ruptures were majoritarian (64.9% and 44.4%, respectively). It can be seen from the table that minor-medium rupture degrees were characteristic of group B, while severe rupture degrees were characteristic of lot A.

By applying the revised AAST-OIS classification (2018) (95), the increased lesion degree, the number of each degree cases are (Table 53):

Table 53. Changes of the splenic lesion degree after the introduction of the AAST-OIS classification (revised 2018).

Grad	AAST 1994 (N)*	AAST 2018 (N)*
1	4	4
2	10	7
3	36	23
4	13	**21**
5	1	**9**

*(N) – number of cases.

Generally, the splenic lesion degree increased by 1: degree 3→4: 10 cases; degree 4→5: 3 cases; degree 2→3: 1 case of by 2-3 units: degree 3→5: 4 cases; degree 2→4: 1 case; degree 2→5:1 case.

Thus, the splenic lesion degree advanced (really) to the following values (table 54):

Table 54. Changes of the splenic lesion degree after the application of Kozar classification

Average (SD)	2.95 (0.825)
Median [Min, Max]	3.00 [1.00, 5.00] la
Medie (SD)	3.38 (1.06)

Average (SD)	3.38 (1.06)
Median [Min, Max]	3.00 [1.00, 5.00]

Globally, by applying retroactively the new AAST-OIS classification, 20 cases progressed lesionally, emphasizing the importance of the presence of active bleeding and intrasplenic vascular lesions.

▪ **Treatment**

The SAE was performed in 37 cases (lot A) and the diagnostic splenic angiography in 27 cases (lot B). The decision to perform SAE was exclusively made by the intervention radiologist.

For the patients of lot A, PSAE was performed in 19 cases and DSAE in 18 cases using:

▪ temporary embolic materials: Gelfoam® (Gelfoam, Pfizer, New York, NY) in 25 cases or TachoSil® in 11 cases.

A relatively frequent finding after embolization with Gelaspon® is represented by the appearance of intrasplenic gas bubbles which, depending on the situation, must be evaluated (evolution towards splenic abscess?).

Multiple angiography

In 17 cases, multiple angiography was performed (in the same session), finding:

Cases with multiple angiography (in the same session as splenic angiography)

Number	**Organ/Area**	**Procedure**
3	Pelvis	2 embolizations 1 diagnosed angiography
6	Liver	6 embolizations
2	Liver + Kidneys	2 hepatic embolizations
2	Kidneys	1 left renal angiography 1 bilateral renal angiography
1	Neck	1 left internal carotid artery angiography
1	Axilla	1 left axilla artery angiography
1	Pelvis	1 right common illiac artery angiography
1	Abdomen	1 aortography
Total		
10 embolizations		
7 dg angiographies		

▪ **Repeated splenic angiography**

The splenic angiography was repeated in 3 cases for suspicion of new intrasplenic pseudoaneurysms (highlighted on the initial post-procedural MRI examination).

▪ **Complications**

They were classified as follows:

- minor

Fever, low fevers -13 cases;

- major

Pleurisy – 9 cases;

Respiratory infections 6 cases;

UTI – 1 case;

Sepsis with positive blood cultures – 1 case;

Post-procedural splenic pseudocyst 1 case.

Splenic infarctions – 3 cases;

By using the CIRSE classification (table 57), the following results were obtained:

▪Table. 57. CIRSE classification (**C**ardiovascular and **I**nterventional **R**adiological **S**ociety of **E**urope) of complications (238)

Complications	**Description**
1st degree	Complications appeared during the procedure that are resolved in the same session; does not require additional therapy; without sequelae or post-procedural therapeutic changes
2nd degree	Extended observation (< 48h); without additional procedures; without sequelae
3rd degree	Post-procedural therapy; extended admission (> 48h); without sequelae
4th degree	Minor / average sequelae
5th degree	Permanent severe sequelae (needing daily permanent nursing)
6th degree	Death

1st degree: 0

2nd degree: 10

3rd degree: 16

4th degree: 5

5th degree: 0

6th degree: 0

Severe splenic lesions

By analyzing the period 2009-2019 (an analysis motivated by the possibility of both procedures - ASD and SAE) we found that 44 cases were represented by severe splenic lesions versus 14 cases of minor splenic lesions - 1st degree and 2nd degree (4 and 10 cases, respectively)(fig. 247). Of these, 32 cases were represented by 3rd degree splenic lesions.

The frequency of interventional splenic angiography in the period 2014-2019 was 22.03% compared to the period 2009-2013 when it was 25.39%.

The conclusion can only be that 3rd degree injuries represent the ‘Achilles' heel’ in splenic traumatology. If in 4th – 5th degree injuries the therapeutic orientation is clear, for the 3rd degree injuries we are in a "grey area". Considering these aspects, I tried to develop a clinical-therapeutic algorithm for these injuries, applicable in Level I Trauma Centers.

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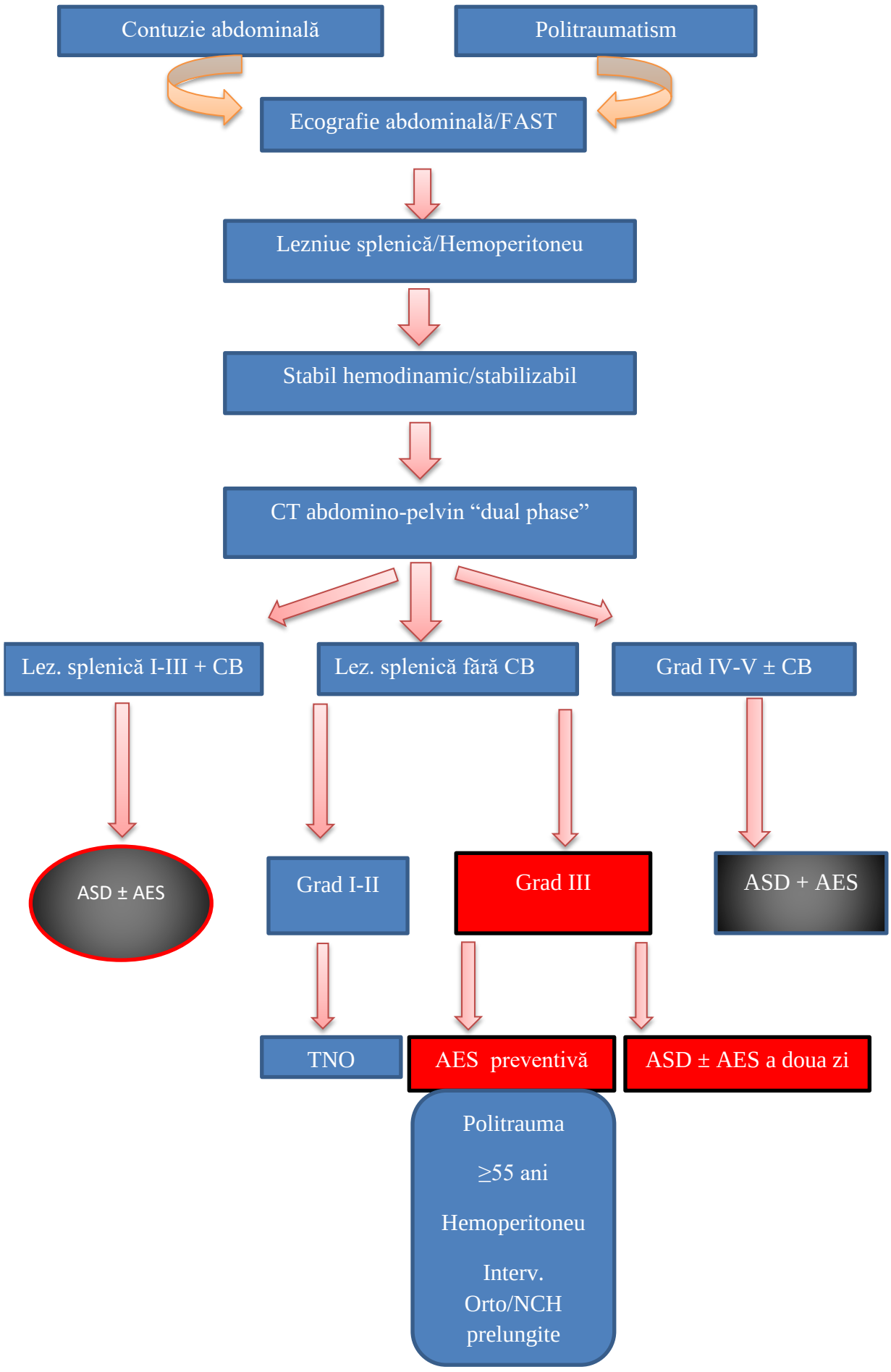
Clinical-therapeutic algorithm for splenic contusive lesions


Contuzie abdominală
Politraumatism
Ecografie abdominală/FAST
Lezniue splenică/Hemoperitoneu
Stabil hemodinamic/stabilizabil
CT abdomino-pelvin "dual phase"
Lez. splenică I-III + CB
Lez. splenică fără CB
Grad IV-V ± CB
ASD ± AES
Grad I-II
Grad III
ASD + AES
TNO
AES preventivă
ASD ± AES a doua zi
Politrauma
≥55 ani
Hemoperitoneu
Interv. Orto/NCH prelungite

Legend: Abdominal contusion, polytraumatism, abdominal ultrasound/FAST, splenic lesion/hemoperitoneum, hemodynamically stable/stabilising, 'dual-phase' abdominal-pelvic CT, 1st - 3rd splenic lesion + CB, no CB splenic lesion, 4th - 5th degree +/- CB

ASD+/- SAE 1st - 2nd degree 3rd degree ASD+SAE

TNO Preventive SAE, ASD +/- SAE the 2nd day

Polytrauma >= 55 years

Hemoperitoneum Orto/NCH extended interv.

2.CONCLUSIONS

In this paper, we approached an important chapter of traumatology aiming the execution of a new updating of the diagnostic and therapeutic methods.

The study carried out over a period of 14 years in the largest Traumatology Hospital in the country, where accessibility to modern investigation and treatment technology is a reality, as well as the analysis of works from the specialized literature, led me to the following conclusions:

-contusive abdominal traumas involving the spleen are frequent, they presenting a high morbidity and mortality;

- SAE, as a part of TNO in splenic contusive injuries, causes the increase of TNO efficiency with an acceptable frequency of post-procedural complications being an important element introduced in modern trauma protocols;

- the comparison of the two analyzed groups shows the safety of diagnostic angiography (relating to active/continuous bleeding/rebleeding) at the splenic level and directs the investigation to other sources responsible for it (depending on the spectrum of lesions present abdominal/extra-abdominal).

- according to this study, the thrombocytes increase day represents the splenic/extrasplenic hemorrhage stopping time in polytraumatized patients;

- the 3rd degree RS represents the "grey area" in which TNO failure is difficult to accept, but possible;

- for severe splenic lesions (3rd - 5th degree) treated non-operatively, AE decreases the risk of splenectomy having, consequently, a firm indication, which leaves no room for unnecessary discussions;

- the integration of interventional radiology in trauma protocols requires available personnel and equipment, rapid multidisciplinary assessment of the case and effective direct communication;

-the admission – SAE is vital.

- the hybrid operating room (equipped for resuscitation, imaging studies, angiography, various surgical interventions) avoids the therapeutic risks/delays associated with patient transport;

- a Level I Trauma Center requires perfect collaboration between intensive care physicians, surgeons and interventional radiologists;

- with clear diagnostic and therapeutic protocols, TNO in contusive splenic lesions becomes ‘efficient, safe and rational’.

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