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Review

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Blunt Liver Trauma: a Systematic Review

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INTRODUCTION The high incidence of closed liver injuries, general and postoperative mortality dictate the need to find optimal treatment options for those patients.

AIM OF STUDY To conduct a systematic review of the literature on the comparative evaluation of various treatment options for patients with blunt liver injury.

MATERIAL AND METHODS A systematic search for non–randomized studies was conducted from 01 October 2015, and randomized studies - without time limits, until December 31, 2023.

RESULTS There is a clear trend towards non-operative management of hemodynamically stable or stabilized patients, and in case of hemodynamic instability, the use of liver tamponade with angioembolization at the second stage.

CONCLUSION A larger number of well-planned randomized clinical trials are required to concretize the surgical approach to patients with liver injury.

Keywords: blunt liver trauma; atriocaval shunting; perihepatic packing; temporary prosthesis; endovascular surgery; stent graft; surgical treatment for liver injury; angioembolization; non-operative management

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ACS — abdominal compartment syndrome
AE — angioembolization
BAT — blunt abdominal trauma
CT — computed tomography
ERCP — endoscopic retrograde cholangiopancreatography
ISS — Injury Severity Score
IVC — inferior vena cava
MOF — multiple organ failure
MSCT — multislice computed tomography
NOM — Non-Operative Management — tactics of conservative treatment for blunt injuries of parenchymal abdominal organs
OIS — Organ Injury Scaling — organ injury severity scale of the American Association for the Surgery of Trauma
RCT — randomized controlled trial
SIRS — systemic inflammatory response syndrome
TBI — traumatic brain injury

INTRODUCTION

In blunt abdominal trauma (BAT), the incidence of liver injury is 11–54% without a downward trend [1–16]. In case of damage to the hepatic veins and retrohepatic section of the inferior vena cava (IVC), mortality at the prehospital stage exceeds 50%, and among those admitted to hospital - 25-50% [12, 17-19]; in case of damage to the portal vein - 54-71% [12], in case of blunt combined trauma - 28-72% [1, 2, 7, 10-13, 20-25]. Postoperative mortality in case of isolated liver injury is 9-36% [6, 26, 27], in case of combined liver injury - 39-67% [18, 20, 21, 27].

The aim of the study is to conduct a systematic review of the literature on the comparative evaluation of various treatment options for patients with blunt liver injury.

MATERIAL AND METHODS

A systematic literature search was conducted in accordance with the recommendations of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Considering the need to study the issue at the present stage, an analysis of non-randomized studies was carried out from October 1, 2015, and randomized studies - without time restrictions, until October 30, 2023 from

eLibrary (https://elibrary.ru/), PubMed (https://pubmed.ncbi.nlm.nih.gov/) electronic databases, the Cochrane Library (The Cochrane Library; https://www.cochranelibrary.com/) in accordance with the recommendations of the Federal State Budgetary Institution "Center for Expertise and Quality Control of Medical Care" of the Ministry of Health of the Russian Federation (https://rosmedex.ru/pub).

Inclusion and exclusion criteria for original studies in the systematic review. Primary search strategy (without language restrictions): blunt liver trauma; atriocaval shunting; perihepatic packing; temporary prosthesis; endovascular surgery; stent-graft; surgical treatment of liver injury; angioembolization; non-operative management. The systematic review included only full-text studies without language restrictions that involved patients aged 18 years and older, with subsequent exclusion from the query of incomplete text articles, publications devoted to elective surgical interventions, spontaneous ruptures of internal organs, iatrogenic injuries, burn, radiation, chemical trauma, penetrating wounds. The data extraction method was performed by three researchers independently of each other. Any disagreements regarding study selection were resolved by consensus.

Study selection. The stages of the evidence search are presented in the PRISMA flow diagram (Fig. 1).

Figure. Stages of selection of the evidence base
Note: РКИ — randomized clinical trials

RESULTS

As a result, 68 studies were included in the systematic review (including 2 RCTs, 7 systematic reviews, 1 prospective, 1 combined (pro- and retrospective), 6 prospective cohort, 3 combined cohort, 31 retrospective, 7 retrospective cohort studies, 10 descriptions of clinical cases).

COMPARISON OF THE OUTCOMES OF NON-OPERATIVE MANAGEMENT OF PATIENTS WITH BLUNT LIVER INJURY WITH THE OUTCOMES OF SURGICAL TREATMENT

Non-operative management (NOM) of patients with blunt abdominal trauma (BAT) as a complex multidisciplinary strategy is used, as a rule, in large specialized centers with a wide range of diagnostic and therapeutic capabilities [3, 6, 9, 20, 23, 28–42]. The main conditions for successful NOM are as follows:

1) stable hemodynamic parameters, absence of clinical signs of shock [3, 20, 23, 25, 28–30, 38, 41, 42];

2) stable red blood cell, hemoglobin, and hematocrit levels, no symptoms of increasing hemoperitoneum [3, 20, 25, 28, 38];

3) absence of damage to hollow organs, peritonitis requiring emergency surgery [3, 20, 23, 28–30, 38, 42];

4) absence of contrast agent extravasation into the free abdominal cavity, retroperitoneal space or organ parenchyma on CT angiography or successful angioembolization (AE) [20, 23, 25, 28, 29, 38, 41]. A.A. Shchegolev et al. (2016) [25] analyzed the experience of treating 331 patients with BAT, and liver and spleen injuries, and defined the criteria for NOM: presence of consciousness, stable hemodynamics, APACHE II score less than 10, absence of peritonitis, the severity of liver and spleen damage according to the Organ Injury Scaling (OIS) scale is less than III, hemoperitoneum less than 500 ml, absence of coagulopathy. In the group, according to the above criteria, 31 patients were selected, the mortality rate was 3.2% - 1 patient (cause - severe craniocerebral and skeletal trauma), complications were noted in 3 patients (9.6%). The authors believe that the proposed tactics allow avoiding unnecessary laparotomy in 15% of these patients [25]. M.L. Rogal et al. (2017) [31] obtained the following results in the treatment of patients with blunt liver injury: NOM was effective in 100% of cases in 29 selected patients with grade I–III on the OIS scale;

5) availability of the necessary medical equipment and personnel for round-the-clock monitoring in the intensive care unit, multispiral computed tomography (MSCT) with angiocontrast, angiography with angioembolization (AE), endoscopic retrograde (ERCP) or magnetic resonance cholangiopancreatography, percutaneous interventions, the possibility of rapid access to blood products [3, 20, 23, 27–29, 38–40]. A.V. Shabunin et al. (2016) [27] concluded in their study that the widespread implementation of NOM with drainage under ultrasound control, ERCP, angiography with AE allows physicians to reduce overall mortality, shorten the time of patients' stay in hospital and cut treatment costs.

A systematic review of 11 publications (998 patients) from MEDLINE, SCOPUS and the Cochrane Library conducted by C.S. Green et al. (2016) [32] showed 93% overall effectiveness of AE in liver injury. A.E. Voynovsky et al. (2021) [13] estimated the effectiveness of AE at 50–94% in stable hemodynamics of patients with BAT. A.K. Dyukov et al. (2020) [14] on 12 hemodynamically stable patients with isolated blunt liver injury (grade I–III on the OIS scale) and unstable hematomas endovascularly achieved hemostasis in all cases without recurrent bleeding and fatal outcomes.

I. Afifi et al. (2018) [16] retrospectively analyzed the treatment of patients (257) with blunt liver injury and noted a statistically significant increase in the need for blood transfusion with increasing severity of liver injury ($p = 0.02$), as well as when comparing the NOM and operated groups [16]. Of 198 stable patients, NOM was effective in 192 (97%) [16]. Overall mortality was 7.8% (20), associated mainly with severe traumatic brain injury (TBI) and chest injuries [16]. The authors believe that the vast majority of grade I-III blunt liver injuries are subject to NOM; in cases of more severe injuries and the choice of NOM, close dynamic monitoring of patients is indicated.

M. Tarchouli et al. (2018) [33] analyzed the outcomes of NOM and surgical treatment of 83 patients with blunt and penetrating liver injuries (59 with BAT). Patients who underwent surgery had more severe liver damage, required more blood products, and a longer hospital stay; the effectiveness of NOM in 57 patients (including 47 with blunt hepatic trauma) was 89.5%.

L. Barbier et al. (2019) [34] evaluated the outcomes of NOM and surgical treatment of 116 patients with blunt liver injury. There were significant differences between the groups in signs of hemorrhagic shock, severity according to the OIS and the Scale for the Assessment of Positive Symptoms (SAPS), while there were no significant differences when comparing the groups according to the Injury Severity Score (ISS) scale. In the surgery group, patients with unstable hemodynamics, the need for red blood cell transfusion, and the lethal triad predominated [34]. The overall effectiveness of NOM was 67%, and among those initially selected, 96% [34]. The authors recommend dynamic MSCT examination in patients with grade III or higher liver injury for timely determination of indications for possible surgical treatment [34].

E. Schembari et al. (2020) [35] compared the outcomes of surgical and non-surgical treatment of 145 patients with blunt liver injury. Rehospitalization was required in none of the cases. The authors analyzed surgical tactics from 2001 to 2007 and from 2008 to 2017, and concluded that surgical activity decreased from 55.5 to 17.4% for grade II injuries, from 60 to 20.6% for grade III injuries (p=0.002), from 78.6 to 33.3% for grade IV injuries; with an increase in the NOM indicator by 38.1%, 39.4%, 45.3% (p=0.02) for grade II, III, and IV injuries, respectively [35]. NOM was performed in all cases of grade I injuries; while for grades V–VI, surgical treatment was almost always used [35]. The authors note the transformation of the surgical approach towards abdominal packing and non-resection methods, and an increase in the proportion of NOM with proper patient selection [35].

V.V. Suvorov et al. (2021) [8], thanks to the use of the treatment and diagnostic algorithm for abdominal trauma with damage to the liver and spleen, which was developed by them in the Clinic of Military Field Surgery of the S.M. Kirov Military Medical Academy and based on clinical and instrumental data with gradation of organ damage by severity, and severity of the condition of the victims themselves (151 with combined abdominal trauma, of which 82 with liver damage (5 (6.1%) with damage control surgery, 51 (62.2%) with early total care, 26 (31.7%) NOM)), obtained low mortality results - 4.8% and 3%, respectively, and came to the conclusion that NOM is effective in treating patients in a level 1 trauma center (the highest one according to the former gradation).

V. Kumar et al. (2021) [36] in their randomized clinical trial analyzed the results of NOM in 60 hemodynamically stable patients with blunt liver and spleen injuries discharged from a level 1 trauma center on the 3rd and 5th days. The effectiveness of NOM with proper patient selection, even in case of such early discharge from hospital, was 98.3%, which allows saving limited healthcare resources and reducing the likelihood of developing nosocomial infection [36].

A.A. Keizer et al. (2021) [37] retrospectively analyzed the outcomes of treatment for penetrating wounds and blunt liver injury (2012–2018, 808 patients). The authors concluded that NOM was effective in 2/3 of cases of blunt trauma and in less than 20% of cases of penetrating wounds; this difference was primarily due to multiple trauma. The authors did not obtain reliable differences in mortality and complications [37].

Ya.V. Gavrishchuk et al. (2023) [7] analyzed the treatment of 213 hemodynamically stable victims with blunt injuries of the parenchymal organs of the abdomen in isolated and combined trauma in a level 1 trauma center (according to the former gradation, the highest one); in the main group (118), ultrasound, MSCT with contrast, then angiography and AE of the damaged vessel were performed according to indications; in the control group (95), ultrasound, laparocentesis and laparotomy were performed. The use of contrast-enhanced MSCT and X-ray surgical treatment methods in hemodynamically stable patients with parenchymal organ injuries was effective: a significant decrease in the number of laparoscopies (30 (25.4%) versus 44 (46.3%), p<0.001), laparotomies (29 (24.6%) versus 60 (63.2%), p<0.001), and local complications (2 (1.7%) versus 12 (12.6%), p=0.003) was noted compared with conventional tactics [7]. In case of liver damage, conservative treatment was performed in 44.7% of patients in the main group compared to 9.7% in the control group (p<0.001) [7].

OUTCOMES OF VARIOUS SURGICAL INTERVENTIONS FOR BLUNT LIVER INJURIES

V.V. Maslyakov et al. (2016) [12] assessed the course of the early postoperative period in 123 patients with combined/multiple blunt liver injury with suturing of liver ruptures, and in 13 with laser coagulation [12]. The authors did not obtain statistically significant differences in the incidence of complications and mortality in these groups [12].

M.L. Rogal et al. (2017) [31] analyzed the treatment of 96 (67 underwent surgery) victims with blunt liver injury at the N.V. Sklifosovsky Research

Institute for Emergency Medicine. Mortality in victims with OIS I liver injury was 13.0%, OIS II — 10.7%, OIS III — 20.0%, OIS IV — 66.7%, OIS V — 100%. The cause of death was directly related to liver bleeding only in grade IV and V injuries [31]. The greatest contribution to the unfavorable outcome was made by the volume of blood loss (p=0.014) and the overall severity of injury according to the ISS scale (p=0.027) [31]. During laparotomy in victims with grade I liver damage, hemostasis was achieved using sutureless methods; for grades II and III, the rupture was sutured using local hemostatic agents (Tachocomb, Surgicel) [31]. For grade IV and V injuries, the authors recommend the use of J-shaped laparotomy and combined methods of hemostasis or abdominal packing [31].

V.S. Panteleev et al. (2023) [4] presented an interesting clinical case of a 31-year-old patient with a blunt liver injury, who developed quite rare complications that required great ingenuity and professionalism from the surgeons in diagnosis and treatment:

A) hematoma on the diaphragmatic surface of the entire right lobe of the liver — diagnostic laparoscopy — conversion, hematoma evacuation, U-shaped hemostatic sutures for liver rupture [4];

B) infected biloma detected on the 10th day — puncture with drainage under ultrasound control, patient discharged for outpatient follow-up care after 8 days [4];

C) acute destructive acalculous cholecystitis with mechanical jaundice (2 weeks after discharge). A possible cause of destruction may be intraluminal injury to the gallbladder during the injury. Mini-laparotomy and cholecystectomy without duct drainage were performed due to severe infiltration [4];

D) mechanical jaundice - antegrade percutaneous transhepatic drainage of the bile ducts after 4 days, hemobilia was detected [4];

E) hemobilia - angiography of the hepatic artery - saccular pseudoaneurysm of the segmental artery of the right lobe of the liver in the area of the previously sutured injured area with blood discharge into the bile ducts was confirmed. AE was performed, hemostasis was achieved. This clinical case clearly demonstrated the capabilities of modern minimally invasive treatment and diagnostic methods in eliminating complications that previously would have required more than one laparotomy [4].

B.V. Sigua et al. (2023) [43] in their combined (pro- and retrospective) study analyzed the treatment of patients with combined TBI and blunt liver injuries, noting that during laparotomy for grade I–III liver damage in hemodynamically stable victims with severe and extremely severe injuries to abdominal organs, primary suturing is indicated; and for greater degrees of organ damage, atypical resection or abdominal packing within the framework of damage control surgery.

Local hemostatic agents have also become widely known. However, their wide implementation in surgery is often hindered by their high cost. They are used in combination with other surgical measures or abdominal packing for venous or moderate parenchymal bleeding [26, 46, 47].

A.N. Maistrenko et al. (2018) [46] in their experimental study compared the hemostatic efficiency of hemostatic collagen sponges, Biatraum, Resorb-2, Ferroresorb, Ferrobiatravm, Surgicel, Surgicel NU-KNIT, mesh polypropylene endoprosthesis. The lowest volume of blood loss during the modeling of liver injuries was observed with the application of Ferrobiatravm, and during the modeling of spleen injuries - with the application of the Surgicel gauze [46].

I.G. Kurdyaev et al. (2017) [48] conducted a clinical and experimental study to evaluate the effectiveness of local application of thrombovar with monopolar electrocoagulation and catgut sutures to stop parenchymal superficial bleeding from the liver and spleen. The authors concluded that the use of thrombovar reduces the time to achieve hemostasis, is accompanied by less necrosis compared to electrocoagulation, promotes earlier activation of the fibroblastic reaction and angiogenesis, and allows achieving final hemostasis in liver and spleen damage up to grade II according to the OIS classification [48].

USE OF DAMAGE CONTROL SURGERY CONCEPT

In case of grade IV-V liver damage and large blood loss, hypothermia, acidosis, coagulopathy, hemodynamic instability, perihepatic packing is performed within the framework of the damage control concept with subsequent final hemostasis after stabilization of the condition [5, 9, 10, 15, 20, 21, 23, 24, 26-28, 39, 43, 49-51].

According to B.V. Sigua et al. (2015) (cited in [20]), the use of gauze tamponade within the framework of the damage control concept made it possible to reduce mortality from 100 to 50%.

J.J. Segura-Sampedro et al. (2019) [52] developed and successfully tested the VacBagPack vacuum device for perihepatic packing, which is devoid of the negative properties of conventional gauze tamponade, such as abdominal compartment syndrome (ACS) due to excessive tamponade or ongoing bleeding and hypovolemic shock in case of insufficient tamponade.

E.S. Vladimirova et al. (2016) [1] analyzed in their study the technique of aortic compression by N.K. Goloborodko (1976) with a vascular fork below the diaphragm, which is recommended when the Pringle maneuver is ineffective in case of damage to the hepatic veins and multiple trauma to the abdominal organs in critically ill patients to stabilize hemodynamics. Aortic compression allowed temporary hemostasis and completion of surgery in patients with extremely severe liver damage, in whom other methods of temporary hemostasis would be ineffective [1]. In unstable hemodynamics and large hemoperitoneum (2500–3000 ml), shutting off blood circulation at the level of the diaphragm made it possible to reduce intraoperative blood loss, while with conventional tactics, all patients died on the operating table [1]. Despite the 20-minute period of cessation of blood flow and subsequent reperfusion of ischemic tissues, the technique of aortic compression under the diaphragm leads to stabilization of hemodynamics and is not accompanied by severe homeostasis disorders in victims [1].

A.V. Evtikhov et al. (2020) [5] in two presented clinical observations emphasize the need to use the FAST protocol (Focused Assessment with Sonography for Trauma - a bedside ultrasound to be performed when accessing circulation issues of trauma patients) for rapid diagnosis and dynamic monitoring, as well as the concept of damage control surgery (in particular tamponade) to achieve positive results in severe liver damage.

Yu.G. Shapkin et al. (2020) [22] analyzed the treatment outcomes of 65 and 3 patients with combined blunt liver injury of grades IV and V, respectively. The authors came to the conclusion that the active introduction of primary tamponade into the clinical practice within the framework of damage control surgery concept improved the treatment outcomes for victims with multiple injuries. Refusal to perform liver resections and the use of gauze tamponade to achieve primary hemostasis made it possible to reduce mortality to 46% in severe blunt liver injuries (number of degrees of freedom - 12, Pearson $\chi 2$ criterion - 36.286, critical values of $\chi 2$ at a significance level of $p<0.01$ - 26.217).

If the intensity of bleeding does not decrease with compression of the hepatoduodenal ligament, and the liver rupture is located on the posterior surface of the organ, then its source is most likely damage to the retrohepatic part of the IVC or hepatic veins [1, 6, 19, 20, 23].

V.A. Reva et al. (2021) [17] performed an experimental temporary endoprosthesis of the IVC with a removable stent graft after modeling damage to the site of entry of the middle hepatic vein into the IVC, without reducing the preload on the heart and quickly achieving temporary hemostasis, which makes it possible to use the technique within the concept of damage control surgery. In combination with the Baron-Pringle maneuver, the operation to finally eliminate the source of bleeding is performed in a dry field [17].

S. Martellotto et al. (2022) [51] analyzed the treatment outcomes of 59 hemodynamically unstable patients with grade III–V blunt liver injury (out of 206, mean ISS 42.54±14.61 (20–75)), who were treated at a top-level trauma center from 1998 to 2019 and underwent perihepatic packing within the framework of the damage control surgery concept (in some cases supplemented by AE at the second stage). The mean volume of hemoperitoneum was 2.2 l (0.2–9.0 l), the duration of the operation was 46 minutes (20–140), from 2 to 29 tampons were used (mean 6.6). Seven patients (11.9%) required relaparotomy and replacement of tampons, five of them due to ACS, in half of the patients the tampons were removed on average after 2 days [51]. The mortality rate was 57.6% (34), of which 26 died in the first 24 hours, in 70.5% of cases this was due to combined injuries, in particular TBI and chest trauma [51]. The average duration of hospital treatment for surviving patients was 36.6 days, in the intensive care unit - 9.1 days, 12 patients developed surgical complications, four required reoperation (2 - abscesses, 2 - bile leakage). The authors compared the main characteristics of the deceased and surviving patients: prehospital cardiac arrest (15 vs. 0, $p<0.001$), Glasgow Coma Scale score (6.9±3.8 vs. 12.3±3.8, $p<0.001$), ISS (52.7±12.5 vs. 32.9±8.9, p<0.001), prothrombin time (30.1±14.6 vs. 46.4±17.1, p=0.01), pH (7.0±0.2 vs. 7.2±0.8, p<0.001), lactate (10.3±6.1 vs. 4.7±2.3, p=0.004) and bicarbonate (12.3±4.2 vs. 16.3±2.7, p=0.003) were statistically significantly associated with increased mortality [51]. The authors emphasize the importance of early tamponade in such patients, reduction of the time of the primary operation, and joint work of surgeons, endovascular surgeons and anesthesiologists at the second stage of the damage control surgery.

G.D. Odishelashvili et al. (2023) [53] presented a clinical case of severe combined grade V blunt liver injury with 2 liters of hemoperitoneum. After clamping the hepatoduodenal ligament, large intraparenchymatous segmental vessels were clipped, and the parenchyma itself was sutured with figure-8 sutures developed by the authors [53]. It was not possible to suture the ruptures of the organ along the posterior surface, so a gauze tamponade was performed with subsequent removal of the tampon on the 13th day, and the patient was discharged on the 16th day [53]. The authors emphasize that with such injuries, the use of any one option for final hemostasis would have been impossible [53].

In case of liver crushing, its fragmentation, damage to lobar vessels with a high probability of liver tissue necrosis, atypical resection is indicated [6, 9, 10, 20, 21, 23, 27, 50], which is considered a forced measure [43], since it is accompanied by a mortality rate of up to 70% due to intraoperative bleeding, liver failure, and parenchyma necrosis [20, 23, 28].

H. Küçükaslan et al. (2022) [49] presented 5 clinical cases of severe blunt liver injury, four of them had grade V damage, one underwent lobe resection, the rest underwent various types of segmental resections, in one case preliminary perihepatic packing was ineffective. One patient died of hemorrhagic shock, three patients underwent reoperations, in-hospital complications developed in two of the four survivors, the average time of stay in the intensive care unit and hospital was 12.4 days (1–48 days) and 28.2 days (1–65 days), respectively [49]. The authors emphasize that despite the widespread use of tamponade for such injuries, it is usually most effective for venous injuries [49]. In case of arterial bleeding and impossibility of direct visualization of the vessel, they recommend performing tamponade and immediate angiography with AE [49]. If these measures are ineffective, vascular isolation of the liver and resection of damaged areas are indicated [49].

K. Ishida et al. (2022) [54] analyzed the relationship between angiography and in-hospital mortality - they compared two groups (562 each) of patients from the Japan Trauma Data Bank (2004-2018) with grade III-V liver injuries, with angiography (ISS 27 (17–35.5)) and AE if indicated (321, 57.1%), and without it (ISS 25 (17–35)); moreover, angiography was also performed in hemodynamically unstable patients. Mortality in the first group was 15.4% (87/562) versus 25.4% (143/562), odds ratio 0.544 (95% confidence interval 0.398–0.739) [54].

Liver transplantation in trauma was considered casuistry in the last century, the indications for it are tissue necrosis after perihepatic packing or resection with an increase in acute liver failure [20, 23, 28, 29]. M.A. Jr Ribeiro et al., 2015 (cited in [20, 28]) analyzed the outcomes of 46 patients in whom, due to the severity of organ damage, it was impossible to perform other hemostasis options; the survival rate was 76%. Other described cases do not have such a survival rate. Thus, B. Ringe et al. (1995) (cited in [19]) performed transplantation on 8 patients, of whom two survived, the main cause of death was multiple organ failure (MOF). D. Chiumello et al. (2002) (cited in [19]) described a successful clinical case when, after perihepatic packing, bleeding did not stop, total hepatectomy with portacaval shunt were carried out, and 36 hours later, liver transplantation was performed.

THE ROLE OF LAPAROSCOPY IN THE TREATMENT FOR BLUNT LIVER INJURIES

Laparoscopic operations with a low probability of conversion are performed in victims with low hemoperitoneum, no signs of ongoing intense intra-abdominal bleeding and shock [2, 6, 9, 10, 11, 20, 21, 23, 27, 39, 43, 44].

B. V. Sigua et al. (2015) (cited in [45]) achieved laparoscopic hemostasis using electrocoagulation in 16 victims (6.5%) with stable hemodynamics, and in 17 cases (6.9%), diagnostic laparoscopy revealed liver damage without ongoing bleeding, and only abdominal drainage was performed.

U.U. Erov et al. (2018) [56] successfully used laparoscopy for the diagnosis and treatment of combined gastrointestinal tract infections; in case of minor bleeding from the liver and spleen, coagulation was performed; in case of large liver ruptures and intestinal damage, laparotomy was carried out

A. Ivanecz et al. (2018) [55] presented a clinical case of successful treatment of a 20-year-old patient with isolated grade III liver injury. Considering hemodynamic stability, the presence of free fluid in the abdominal cavity up to 700 ml according to ultrasound, and a rupture of the left lobe without contrast extravasation according to MSCT, conservative therapy was started [55]. On the second day, due to negative dynamics, percutaneous drainage under ultrasound control was performed, evacuating 2.5 liters of bile with a slight admixture of blood [55]. Over the next two days, bile secretion continued at a rate of up to 700 ml per day; magnetic resonance imaging revealed bile leakage from a rupture in the left lobe of the liver [55]. On the 5th day, laparoscopic resection of the left lobe of the liver was performed using a LigaSure device, while no bleeding from the liver rupture sites was noted, and the resection line was sealed with a TachoSil plate [55]. The patient was discharged without complications on the 4th day after surgery.

A. Elkbuli et al. (2019) [57] presented a clinical case of a road traffic injury in a 30-year-old man who was diagnosed with grade V rupture of the right lobe of the liver with contrast extravasation. After stabilization of hemodynamics, he underwent selective AE of the branches of the right hepatic artery, but on the 4th day, due to increasing abdominal pain and an increase in intra-abdominal fluid, laparoscopy was performed, 4 liters of bile mixed with blood were removed, the liver was found to be viable, and the patient was discharged 7 days later. The authors believe that the combination of AE and delayed laparoscopy may be considered in stable patients regardless of the degree of liver injury [57].

H. Yazici et al. (2023) [58] performed laparoscopy in a patient with grade IV liver rupture due to a decrease in blood pressure (90/62 mm Hg), hemoglobin (84 g/l), and the development of tachycardia. There were no signs of active bleeding during the operation, an absorbable Surgicel mesh was fixed over the rupture, and the intervention was completed with debridement and drainage of the abdominal cavity. No complications arose in the postoperative period [58]. The authors believe that laparoscopic interventions for BAT should be used more widely, including in hemodynamically unstable patients, but all this requires further research [58].

COMPLICATIONS AFTER BLUNT LIVER INJURIES

In general, complications after blunt liver injury occur in 12–14% of patients [29]. These are intra-abdominal abscesses (0.6–9%), liver cysts, hepatic artery pseudoaneurysms (1%), hemobilia (0.7–3.4% [28]), bile leakage, and bile peritonitis (0.5–30% [20, 29, 54, 58]). Liver failure of varying severity develops in almost all victims [23, 28]. The most common complications after perihepatic packing of the damaged liver are exudative pleurisy (19.8%), bile leakage (17.3%) [5], localized bile accumulations (9.9%), liver abscess (1.6%), liver failure (1.6%), recurrent bleeding (14.9–16.7%), purulent complications (16.7%), and intra-abdominal hypertension [22].

T.C. Fabian et al. (1991) [50] in their RCT analyzed the results of treatment of 482 patients with liver injuries, of which 168 had blunt injuries. The authors concluded that passive drainage was associated with a significantly higher incidence of bile leakage compared with active aspiration or no drainage ($p<0.01$), as well as with the formation of intra-abdominal abscesses ($p<0.03$ and $p<0.1$, statistically insignificant differences) and an increase in the length of hospital stay compared with the other two groups ($p<0.03$) [50]. The need for blood transfusions was also an important factor in the development of abscesses [50]. The presence of three or more injured abdominal organs is associated with a threefold increase in the incidence of intra-abdominal abscesses [50].

A.L. Charyshkin et al. (2016) [59] analyzed the course of the early postoperative period in 190 patients with isolated blunt liver injury after laparotomy and suturing of its ruptures. In patients with liver damage in BAT, the following complications were more frequently observed: post-traumatic hepatitis (visible mechanical jaundice, increase in total bilirubin over 32 μmol/l, transaminase activity by 1.5 times) - 65 (34.2%), biliary fistulas - 12 (6.3%), abdominal abscesses - 11 (5.8%), purulent-inflammatory complications of the postoperative wound - 24 (12.6%); 68 (35.8%) patients had more than one complication. Postoperative mortality was 0.5% [59].

S.N. Styazhkina et al. (2021) [18] presented a clinical case of treating a female patient with extensive damage to the right lobe of the liver and a rupture of the right kidney. The liver rupture was sutured with greater omentum flap tamponade, and a nephrectomy on the right was performed. Subsequently, she underwent 5 relaparotomies for generalized biliary peritonitis, subdiaphragmatic and subhepatic abscesses, external biliary fistula. As a result, a fistula-jejunal anastomosis was formed on the transhepatic drainage according to Praderi, the drainage was subsequently removed, the patient recovered. The authors emphasize the need for adequate treatment of liver ruptures, blood replenishment by reinfusion in the first 6 hours, even despite the admixture of bile, external drainage of the bile ducts in severe liver injury [18].

DISCUSSION

F. Iacobellis et al. (2019) [60] retrospectively analyzed the results of MSCT examination of 212 patients with blunt liver injury (grade I in 34.9% (74), grade II in 25.9% (55), grade III in 21.6% (46), grade IV in 11.8% (25), and grade V in 5.6% (12)) [60]. Vascular injuries were detected in 9.4% of cases (20: 7 - pseudoaneurysms or arteriovenous fistulas, 13 - active bleeding) [60]. All pseudoaneurysms and arteriovenous fistulas were visible in the arterial phase of the examination, while in the venous phase they were detected only in 28.5% of cases (p=0.02); active bleeding, on the contrary, was detected more often in the venous phase (13/13 compared to 10/13, p=0.22) [60]. The use of dual-phase MSCT increases sensitivity and accuracy in detecting vascular liver damage, which in turn can help determine patient management tactics [60].

K. Malloum Boukar et al. (2021) [61] conducted a systematic review (28 studies from 1985 to 2020, no RCTs, 2646 patients) to assess the need for repeat MSCT in NOM patients with BAT (most studies evaluated patients with liver and spleen injuries) to detect changes in patients' condition before clinical deterioration, to ensure timely treatment before serious complications occur, and to avoid emergency surgery. 2421 examinations (91.5%) did not reveal any other lesions than those initially detected, only 7 of the selected studies (254 MSCT) provided information on whether repeat MSCT was performed routinely or according to emerging indications [61]. Of these, 188 examinations (74%) were routine, but 8 (4.25%) led to a change in patient management tactics (5 - enhanced monitoring, 2 - emergency surgeries, 1 - AE); the remaining 66 examinations (26%) were performed for clinical indications: subcapsular hematomas, increased pain, bleeding or decreased hematocrit, which led to a change in tactics in 31 patients (47%, emergency surgeries, embolizations, blood transfusions) [61]. The most common complications identified on repeat CT were hemoperitoneum/confined hematomas, pseudoaneurysms, intra-abdominal abscesses/peritonitis [61]. The authors conclude that repeat MSCT examinations in NOM for BAT are necessary when appropriate clinical indications arise [61].

E. Segalini et al. (2022) [62] conducted a systematic review to assess the outcomes of AE in liver injury. In total, of 3643 patients (11 studies, hemodynamically stable), 1703 (46.7%) were selected for NOM. In 10% of cases, they underwent AE (364; of whom 143 (39%) had grade II–III liver injury, 117 (32%) had grade IV, and 41 (11%) had grade V–VI liver injury) followed by liver parenchyma necrosis in 15.6% of cases (57): 15 patients underwent conservative therapy (1 fatal outcome from MOF), 18 - liver resection/lobectomy, 24 - necrectomy, drainage (3 patients died during surgery from massive bleeding, MOF and sepsis, 2 - from sepsis and MOF after multiple necrectomy) [62]. The authors conclude that in hemodynamically stable or stabilized patients with liver injury and contrast extravasation on MSCT, selective or superselective AE is an effective method, despite the risk of complications [62].

A. F. Virdis et al. (2022) [63] in their systematic review (1990–2020, 19 studies without RCTs, 2656 patients/185 children) analyzed the results of NOM for liver injury without AE. The effectiveness of NOM varied from 85 to 99%, the complication rate was 6.5% (174): intrahepatic abscesses, bilomas - 2.6% (69), bile leakage - 1.46% (39), liver hematomas - 0.5% (14), bleeding - 0.56% (15), fistulas (external biliary, arteriovenous, bile-pleural) - 0.33% (9), pseudoaneurysms of the hepatic artery - 0.4% (11), ACS - 0.2% (6), peritonitis - 0.07% (2), etc. [63]. When analyzing these complications in patients with grade III and higher liver damage, the authors of this review did not obtain statistically significant differences compared with the results of previous systematic reviews that analyzed the outcomes of NOM with AE [63]. In general, when analyzing complications, regardless of the degree of liver damage, their incidence is lower in NOM without AE, with the exception of bile leakage and the formation of limited fluid accumulations; but these results should still be interpreted with caution due to the small number of studies [63].

M. Chu et al. (2022) [64] selected 28 (108 patients, including 1 RCT) from 910 potentially relevant studies and conducted a systematic review devoted to the analysis of the feasibility of delayed laparoscopy within the framework of the NOM strategy for BAT (60 with liver injuries). On average, laparoscopy with abdominal cavity sanitation was performed on the 5th day (2–35th day), the indications for it were systemic inflammatory response syndrome (SIRS) and sepsis, hemodynamic instability, signs of peritonitis, intra-abdominal hypertension, suspected infection of the fluid in the abdominal cavity, etc. [64]. The authors conclude that in the case of large biliohemoperitoneum, delayed laparoscopic sanitation and drainage of the abdominal cavity allow for faster cessation of SIRS, normalization of clinical and laboratory parameters, and reduction of the length of hospital stay, which requires further research in prospective studies [64].

To summarize the above, it should be emphasized that the hemodynamic status of the victim plays a more important role in the choice of tactics than the instrumentally established degree of organ damage [28, 41, 42]. These conclusions were reached by P. Ruscelli et al. (2019) [65] in a retrospective analysis of conservative treatment of 111 patients with liver injury (100% success) and spleen injury (94.7%). The factors determining the effectiveness of NOM are as follows: correct selection and repeated clinical and instrumental examination of victims [29, 41, 42]. Two-phase MSCT with intravenous contrast is absolutely indicated for dynamic observation of patients during NOM, it allows physicians to identify structural changes in organs and monitor the dynamics, especially in case of liver damage above grade III, with a decrease in hemoglobin levels, an increase in SIRS, body temperature, abdominal pain, the appearance of hemobilia, jaundice [28–30, 40]. Non-surgical management of patients with blunt liver injuries in large specialized centers with a wide range of diagnostic and therapeutic capabilities available 24/7 is effective in more than 85% of cases with proper initial patient selection, and reduces the likelihood of surgical treatment and hospital stay. Despite the presence of a number of specific complications, AE is absolutely indicated in cases of arterial extravasation of contrast, pseudoaneurysms, and hemobilia [29, 30, 40–42], and is accompanied by lower mortality compared to a cohort of patients without it, while the need for its implementation increases with the severity of liver damage. There are also publications on the use of AE in hemodynamically unstable patients, but this question has not yet received a clear answer. There is also an increase in publications on the possibility of NOM in patients with penetrating liver wounds, but the effectiveness of the technique is much lower [29].

The use of delayed laparoscopic sanitation and drainage of the abdominal cavity in patients during NOM is mentioned more and more often, and many authors even consider it as a stage of this strategy [29, 44]. This is especially relevant in the case of increasing bilioperitoneum after successful AE, when repeated MSCT shows no signs of contrast extravasation, but the patient's condition worsens due to increasing SIRS. There is also an increase in publications on the possibility of using laparoscopy for severe liver damage, including in hemodynamically unstable patients, although so far these are isolated cases. In critical patient conditions, perihepatic packing is effective within the concept of damage control surgery. In large trauma centers, mortality with its use reaches 52% [51], while performing extended interventions in such conditions increases mortality to 60–88% [20, 22, 24]. Tamponade is most effective in cases of parenchymal or venous bleeding from intrahepatic veins, and the addition of AE as indicated at the second stage of damage control surgery tactics increases the chances of recovery and reduces the number of complications [29, 30].

In case of arterial bleeding and impossibility of direct visualization of the vessel, tamponade, immediate angiography with AE [49] or selective ligation of the hepatic artery [20, 22, 28–30] are indicated, which increases patient survival to 65.5% [28]. If these measures are ineffective, there is necrosis and devascularization of segments, vascular isolation of the liver and atypical resection of damaged areas are indicated [29, 30, 49].

As far as damage to the retrohepatic part of the IVC or hepatic veins, there are two options, each of which provides a mortality rate of at least 50-80%. The first method is vascular isolation of the liver (the Heaney maneuver) [23]. The second is atriocaval shunt (ACSH) [19, 22]. Then, the vein rupture is searched for and sutured. Such operations require widening the access and mobilizing the liver, but with significant blood loss, shock, and increasing coagulopathy, the chances of success are virtually zero [29]. Although S.C. Khaneja et al. (1997) (cited in [19]) reported 7 out of 10 survivors after ACSH, in general, according to the literature, the number of successful operations is 19-22% [20, 22]. J.P. Hazelton et al. (2015) [66] compared the effectiveness of liver tamponade and ACSH in combination with tamponade by modeling damage to the suprahepatic IVC in an experiment. The survival rate of animals with perihepatic packing was significantly higher than that of those that underwent ACSH in addition to packing [66].

D. Zargaran et al. (2020) [19] in their systematic review assessed the outcomes of various open interventions for retrohepatic IVC injuries (25 studies, 319 patients). Mortality using the entire arsenal of modern surgical interventions and tactics was 52% (165).

In this situation, temporary endoprosthesis of the IVC with a removable stent graft [28, 67] in combination with the Pringle maneuver is very promising, which makes it possible to somewhat stabilize the patient's hemodynamics, perform adequate access, and suture the vein defect.

M.B. Wikström et al. (2020) [68] conducted an experimental modeling of damage to the retrohepatic IVC, when a combination of endovascular balloon occlusions of the aorta and IVC was used for hemostasis, and the effectiveness of this method for temporary stopping of bleeding without a systemic drop in pressure while maintaining cardiac output was demonstrated [29, 68]. However, when using this technique, it is possible to develop ischemia-reperfusion syndrome of distal areas; it can be mitigated by partial occlusion, which consists of maintaining a small volume of blood flow at the site of balloon inflation and observing time restrictions during complete occlusion of the aorta with the balloon.

Complications in surgery for hepatic injury are quite common, their number increases with the severity of the trauma. Intrahepatic and intra-abdominal abscesses, infected bilomas in most cases are amenable to percutaneous drainage [29]. In case of repeated bleeding without hemorrhagic shock, in the presence of pseudoaneurysms of the hepatic artery, AE is successfully used [29]. In case of prolonged bile leakage, laparoscopic techniques and various options of endoscopic stenting are effective [29].

LIMITATIONS OF THE STUDY

The first limitation is the small number (2) of RCTs, although their search was carried out without time restrictions, but in the three specified medical databases. The search for non-RCTs was carried out using a bilingual approach from January 2016 in three medical databases, and then in the literature lists of the studies found, which also introduced certain limitations, but presented the most modern trends in the treatment for liver damage. In many studies, there is no detailed gradation of outcomes and complications clearly depending on the degree of liver damage and hemodynamic status, which makes it difficult to systematize.

Moreover, it is necessary to state sufficient heterogeneity of the compared cohorts in the analysis of non-operative and operative treatment options. At present, NOM is effective in the treatment for liver injuries up to and including grade III in hemodynamically stable or stabilized patients; further on, the risk of surgical intervention increases proportionally to the severity of organ damage.

CONCLUSION

In modern surgery for blunt liver injuries, as well as for polytrauma in general, there are tendencies towards non-surgical management of victims in case of hemodynamic stability or their rapid stabilization. But, naturally, surgical interventions occupy their niche, and are absolutely indicated when it is impossible to stabilize the patient's hemodynamics, hemoperitoneum increases, and other injuries require emergency surgery. It is indisputable that, in addition to the degree of liver damage, when choosing a method of surgical treatment, it is necessary to take into account the hemodynamic status of the victim, concomitant injuries, determine the indications for damage control surgery, quickly achieve temporary hemostasis, and then determine the extent of the final intervention at this stage or at the next one. More well-designed randomized clinical trials are needed to refine the treatment approach for patients with liver injury.

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