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Application of Damage Control Tactics and Transpapillary Biliary Decompression for Organ-Preserving Surgical Management of Liver Injury in Combat Patient

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ABSTRACT The combat penetrating gunshot injury is frequently associated with damage to the liver. Bile leak and external biliary fistula (EBF) are common complications. Biliary decompression is commonly applied for the management of EBF. Also, little is known about the features of combat trauma and its management in ongoing hybrid warfare in East Ukraine.

A 23-year-old male was diagnosed with thoracoabdominal penetrating gunshot wound (GSW) by a high-energy multiple metal projectile. Damage control tactics were applied at all four levels of military medical care. Biliary decompression was achieved by endoscopic retrograde cholangiopancreatography (ERCP), endoscopic sphincterotomy (EST) and the placement of biliary stents. Occlusion of the stent was treated by stent replacement, and scheduled ERCP was performed. Partial EBF was diagnosed from the main wound defect of the liver and closed without surgical interventions on the 34th day after the injury.

A combination of operative and nonoperative techniques for the management of the combat GSW to the liver is effective along with the application of damage control tactics. A scheduled ERCP application is an effective approach for the management of EBF, and liver resection could be avoided. A successful biliary decompression was achieved by the transpapillary intervention with the installation of stents. Stent occlusion could be diagnosed in the early post-traumatic period, which is effectively managed by scheduled ERCP as well as stent replacement with a large diameter as close as possible to the place of bile leak.

INTRODUCTION

The armed conflict in certain districts of Donetsk and Luhansk administrative regions (oblast) within the Donbas area of Ukraine has been ongoing since 2014 and classified in Ukraine as Joint Forces Operation (JFO).[1–4] This ongoing warfare has demonstrated new challenges for military surgeons because of the frequent application of high-energy weapons (e.g., multiple launch systems, land mines, sniper rifles, etc.), which is associated with various clinical features and rare trauma cases.[1,2,5]

The wounding mechanism of gunshot projectiles hitting a liver is associated with the direct mechanical effect and hydrodynamic wave to the parenchyma.[1,6] Furthermore, thoracoabdominal gunshot wounds (GSWs) became a clinical challenge for military surgeons because of differential spread of projectiles, resulting in mismatch of the entrance wound and the localization of organ injury.[7] Gunshot wound (GSW) to a liver is frequently associated with a lethal outcome in patients who have not undergone an urgent surgical or selective nonoperative management (SNOM) during the golden hour after the injury.[8–10] Certain hepatic complications might be diagnosed in those who survived. These complications include a bile leak and an external bile fistula (EBF).[11,12] Also, the early application of transpapillary interventions is important for decompression of the biliary tree due to the relatively high frequency of EBF (up to 21% cases), as it has been shown in civilian cohorts.[13–16]

Currently, there is a controversy in the management of liver GSW with EBF in patients with thoracoabdominal injury.[8,10,13,17,18] To further elucidate the features to combat liver GSW and to share the experience of military surgeons, we report a case of combat patient with a thoracoabdominal GSW associated with a liver injury and EBF, who has been treated with damage control tactics and scheduled endoscopic retrograde cholangiopancreatography (ERCP). In this clinical case, we reported a closure of the EBF after the scheduled application of ERCP and without using resection methods, which is in line with other studies of civilian cohorts.[10,16,17,19] To the best of our knowledge, this is the first report to describe the EBF closure in case of thoracoabdominal GSW to the liver by using only ERCP without the liver resection. It is also worth to mention that based

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on our 6-year clinical experience with the management of combat-related trauma we came to the hypothesis of the high utility to perform transpapillary interventions every 7–10 days.[1,2,4] Such approach is considered as a programmed (scheduled) transpapillary intervention, which is in line with the principles of damage control tactics in cases of severe GSW to the liver as well as in line with the paradigm of early prediction and prophylaxis of post-traumatic complications.[13]

CASE REPORT

A 23-year-old healthy male soldier was injured by a high-energy weapon, resulting in GSW by multiple projectile fragments. Ballistic analyses indicated that these fragments originated from an X-tip-modified bullet from sniper rifle. Clinical management of the patient was performed according to the National Military Medical Doctrine adopted in Ukraine, which is based on the five levels of care as described previously.[1,2,4] The time course of the patient is summarized in Supplementary Table.

Level I—First Medical Aid

First medical aid was provided immediately at the scene. Butorphanol 1.0 ml was administered to the patient, and aseptic bandage was applied at the site of the bullet inlet hole. At the basic level, major injuries were diagnosed, necessitating the need for evacuation as well as further triage and treatment at a higher level of medical care. Hence, the patient was evacuated by a military ambulance to a central district hospital in the city of Bakhmut (Donetsk province, Ukraine), which is a Level II hospital.

Level II—Qualified Surgical Care

The patient was admitted to a surgical department within 1 h after the injury, indicating that the golden hour principle was achieved. At admission, an inlet bullet hole of 2 × 2.5 cm in the area of the right paravertebral region at the level of ninth thoracic vertebra has been identified, indicating a penetrating GSW.

Other diagnosed injuries included a right-sided non-tension hemopneumothorax (1,050 ml of blood), wounds of the diaphragm, multifragmental gunshot fracture of the transverse processes Th_9, Th_{10}, and 9–10th ribs on the right, spinal cord contusion, and traumatic hemorrhagic shock.

To treat hemopneumothorax, thoracocentesis was performed. Drainage of the right pleural cavity was performed according to Belau and resulted in 1,050 ml of bright red blood. Although GSW was in the thoracic area, an abdominal injury was also suspected. At laparocentesis, we received bright red blood, indicating ongoing intra-abdominal bleeding. At laparotomy, 500 ml of fresh blood with clots were removed from abdomen. At further revision, multiple wounds with metallic shrapnel projectiles were detected in Sg_5–Sg_8 right liver lobe. The main wound canal was identified in Sg_7 with 4-cm diameter. Such liver injury was classified as grade III AAST scale according to the American Association for the Surgery of Trauma and AIS severity III (Liver Injury Scale, revision 2018).[8,20,21] Liver GSWs were stitched and five gauze tampons were inserted into the wound area (i.e., perihepatic packing), followed by drainage tubes application. Taking into consideration the severity of trauma, the decision to evacuate the patient to a higher level of medical care was made, followed by the evacuation to the Military Medical Clinical Center of the Northern Region (Level III) in the city of Kharkiv under the endotracheal intubation and mechanical ventilation.

Level III—Specialized Surgical Care

At admission to Level III, the patient was critical, but stable. To determine possible associated injuries, a whole-body computed tomography (CT) scan is routinely performed at Level III for all patients with penetrating GSW since July 2014. At Level II, CT scan is not available due to high risk of artillery strikes on Level II hospitals. Upon performing a whole-body CT scan, we observed multiple fragments of the metal density in the right lung lower lobe (5–9 mm in greatest diameter (GD) and within soft tissues of the patient's back on the right side (2–4 mm in GD) as well as the multifragmented fractures of the right transverse processes Th_9, Th_{10}, and 9th and 10th ribs on the right side (Fig. 1A). Analyses of abdominal CT scan showed pancreatic edema and signs of liver GSW by multiple fragments of metallic density (5–9 mm in GD) in Sg_5–Sg_8 (Fig. 1B, C) and between intestinal loops. Although the patient received an intensive resuscitation therapy during the first 3 days after the injury, he required an advanced management at higher level of medical care. Thus, the patient was evacuated by an airplane to Level IV at the National Military Medical Teaching Center (city of Kyiv) on the fourth day after the injury.

Level IV—Highly Specialized Surgical Care

The patient underwent relaparotomy at admission to Level IV. A Rio-Branco incision was chosen to get an optimal exposure to the right upper quadrant zone, taking into consideration

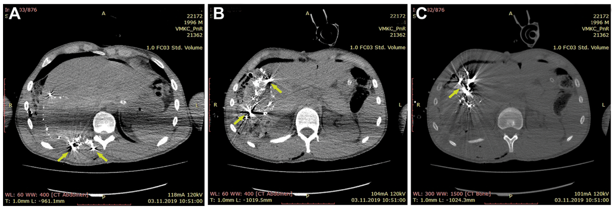

FIGURE 1. Abdomen computed tomography (CT) scan of the patient on the fourth day after the multiple projectile bullet gunshot thoracoabdominal injury. (A) Illustration of the multiple shrapnel of metallic density and bone fragments after gunshot multifragmented fracture of the transverse processes of Th9, Th10, and 9th and 10th ribs on the right in the area of the inlet bullet wound (marked by the arrows); (B, C) Illustration of the multiple shrapnel of metallic density (indicated by the arrows) within the right liver lobe with the background of traumatic destruction and post-traumatic edema of the liver parenchyma.

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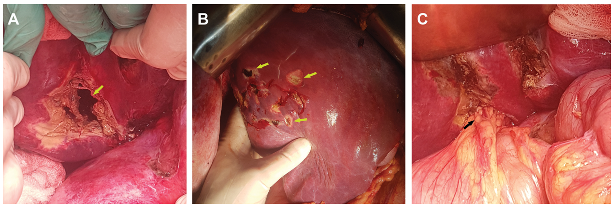

FIGURE 2. Intraoperative photographs of the liver on the fourth day after a gunshot injury (gauzes from the perihepatic space removed): (A) the main wound channel on the visceral surface in the liver in Sg_6 and Sg_7 (indicated by the arrow); (B) illustration of multiple inlet gunshot wounds after projectile injury of the right liver lobe (marked by the arrows) on the diaphragmatic surface of the liver; (C) the view of the visceral liver surface after the secondary surgical debridement; visualization of omentum flap packing to the wound canal (marked by the arrow).

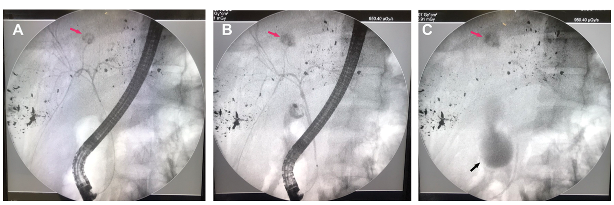

FIGURE 3. Photograph of endoscopic retrograde cholangiopancreatography (ERCP) on the fourth day after the injury and immediately after the programmed relaparotomy. The multiple fragments of foreign bodies with metallic density are visualized in the projection of the shadow of the right liver lobe: (A) the phase of moderate contrast media filling; a slight extravasation of contrast media is determined along the diaphragmatic surface (at the border between Sg_1 and Sg_8 [marked by upper arrow]); (B) at the phase of tight contrast media filling the extravasation zone became more intensive (marked by the upper arrow); (C) 5 min after stopping the injection of contrast media; the extravasation area was preserved and became more intensive (marked by upper arrow); the contrast media from the biliary tree was completely evacuated into the gallbladder (marked by lower arrow) and duodenum.

a liver GSW and damaged diaphragm. The intraoperative revision showed no active bleeding from a liver GSW in $Sg_{6\text{-}7}$ (Fig. 2A). Further inspection showed multiple small GSWs; however, neither bleeding nor bile leaking was determined. Small traumatic tissue defects on the diaphragmatic surface of the liver right lobe in $Sg_{5\text{-}7}$ were identified, stitched, and coagulated (Fig. 2B), followed by closing GSW track with an omentum flap (i.e., hepatoomentopexy) (Fig. 2C). Abdominal cavity was drained with several separate 5-mm drainage tubes.

After relaparotomy, ERCP was performed to evaluate bile ducts and to perform their decompression. In addition, an indication to perform ERCP in the absence of jaundice or damage of hepatic ducts was a high risk of secondary liver necrosis, intrahepatic edema, and EBF formation due to the ballistic effect of high-energy multiple projectiles hitting a liver that we have frequently observed during 6 years of managing similar cases with combat patients. Contrast-enhanced ERCP demonstrated common bile duct (CBD) with diameter 3 mm, whereas right and left hepatic ducts were 1 mm in diameter (Fig. 3A). The contrast media extravasation to the perihepatic space was revealed at the border between Sg_1 and Sg_8, followed by the subsequent intensification after tight filling (Fig. 3B). As we expected, a deposition of the contrast media was seen in the gallbladder, indicating insufficient bile outflow. An attempt was made to insert the thinnest (7 Fr) stent into the right lobar duct, but it was not successful. To achieve sufficient bile outflow into the duodenum, the endobiliary decompression of the biliary system was performed by endoscopic sphincterotomy (EST). The CBD was subjected to the placement of an endobiliary Teflon stent (7 Fr, 50 mm), and free bile outflow into the duodenum was detected (Fig. 3C).

On the seventh day after the injury, liver ultrasonography (US) revealed unechogenic area with a heterogeneous content and dimension of 66 × 39 mm, indicating intrahepatic hematoma. Laboratory findings showed leukocytosis—15.6 × 10^9/L, serum amylase—224 U/L, and urinary amylase—2,653 U/L, indicating post-traumatic pancreatitis. During the next 2 days, the patient received conservative treatment, which resulted in the significant reduction in blood amylase to 205 U/L and urinary amylase to 1,772 U/L (day 9 after the injury). Meanwhile, parameters of severe inflammation remained high, demonstrating a fever up to 38°C and leukocytosis—19.2 × 10^9/L, and an acute abdominal pathology was suspected. An acute cholecystitis was diagnosed in abdomen multislice CT scan. Taking into consideration high risk of surgery and the damage control principles, the US-guided percutaneous cholecystostomy was performed to treat acute cholecystitis.

On the next day after cholecystostomy, the daily volume of bile leak from the partial EBF (i.e., drainage tube from the main GSW) was significantly increased, indicating the inefficiency of previously placed endobiliary CBD stent. Hence, we decided to perform the ERCP in order to check the endobiliary stent and to install a stent with a larger diameter. At the contrast-enhanced ERCP, absence of filling defects was seen, and further inspection showed CBD diameter of 3–6 mm and both right and left hepatic ducts diameter of 1 mm (normal). However, a new zone of extravasation of the contrast media was identified in liver at the border between Sg_5 and Sg_6, whereas the previous place of extravasation at the border between Sg_1 and Sg_8 was not visualized even in the phase of tight filling (Fig. 4A). Taking into consideration such ERCP findings, a stent obstruction was suspected, and the decision was made to replace previously installed stent into CBD with a larger stent (8.5 Fr, 70 mm). After the stent replacement, a free bile outflow to the duodenum was observed.

Two days after the replacement of CBD stent, the bile leak through the partial EBF was decreased from 250 to 160 mL/day, suggesting a good function of the new CBD stent. During the next days followed by CBD stent replacement, we detected a stabilization of bile leak through the EBF from the main wound cavity in liver in a volume of about 200 mL/day (third to seventh day after the CBD restenting). This evidence suggested that either inadequate

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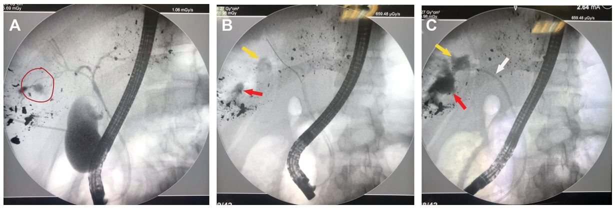

FIGURE 4. Photographs of endoscopic retrograde cholangiopancreatography (ERCP) illustrating the biliary tree and gallbladder at the 9th (A) and 16th day (B, C) after the primary endobiliary stenting (13th and 20th days after the injury, respectively): (A) ERCP illustration at the phase of tight contrast filling at the 13th day after the injury, showing the zone of contrast media extravasation at the border of Sg_1 and Sg_8 of the liver that was not determined even in the phase of tight contrast filling, but the new zone of extravasation appeared at the border between Sg_5 and Sg_6 (marked by a red circle in the left upper 1/3 of image). The stent of common bile duct (CBD, 7.0 Fr) was replaced by a stent with a larger diameter (8.5 Fr); (B) illustration of ERCP on the 20th day after the injury—two zones of the contrast media extravasation are shown: the first zone is located at the boundary of Sg_5 and Sg_6 of the liver (marked by the lower red arrow) and second zone is located at the Sg_7 of the liver and closer to the eighth segment of the liver (marked by the upper orange arrow). The phase of not tight contrast filling; (C) illustration of ERCP on the 20th day after injury: another 7 Fr stent was installed into the right hepatic duct (marked by the right [white] arrow) without removing the stent within CBD. There was a phase of not tight contrast filling. The extravasation zones were more contrasting (marked by the red left and orange lower arrows).

drainage occurred in the right hepatic duct or a new leak site of bile extravasation was presented. To check that hypothesis on the 20th day, after the injury, the patient underwent contrast-enhanced ERCP showing new zones of contrast media extravasation within the border of the Sg_5–Sg_6 and in Sg_7 area, indicating insufficient bile outflow (Fig. 4B, C). An additional stent (7 Fr, 150 mm) was installed into the right hepatic duct parallel to the stent in CBD, and a free bile flow toward the duodenum was detected (Fig. S1). In the next 3 days after the procedure, there was a significant decrease in the bile leak rate from 200 mL/day to 30 mL/day through the EBF. On the 14th day after stenting into the right hepatic duct, the bile leak through the drainage tube from the main GSW canal in the liver was very low, thus drainage tube was removed.

The cholecystostomy tube was removed on the 43rd day after the injury. On the 45th day after the injury, a contrast-enhanced ERCP was performed, showing neither change in the biliary system nor extravasation of contrast media. Therefore, a decision was made to remove both endobiliary stents. After the completion of rehabilitation measures, the patient was discharged from the hospital on the 52nd day after the injury in satisfactory condition.

DISCUSSION

Damage control tactics is a standard approach for the management of combat and civilian patients with severe GSW.[22,23] In this case, a rapid initial bleeding control was achieved by temporary packing, although a resection of the affected liver segments could also be considered in combat cases.[13,24,25] Liver packing as a part of damage control tactics was performed at lower levels of military medical care, which is also confirmed in our earlier reports and in line with others, suggesting anatomical hepatic resection only at the Level IV.[1,26–28] However, similar to other studies, we did not apply nonoperative approach in this case, because of the hemodynamic instability of the patient.[9,24,26,29]

Liver injury in the combat patients is usually associated with the bile leak and EBF, which is a clinical challenge.[30,31] Analyses of publications showed that EBF is commonly described in non-combat liver injury, but it is not demonstrated in the military cohorts.[13–16] Still, our findings are consistent with those of Cannon et al., demonstrating a successful endoscopic management of thoracobiliary fistula.[32] In this study, we presented an effective approach for the biliary decompression in case of the multiple liver GSW associated with the bile leak and EBF. A biliary decompression could be achieved by application of various techniques and their combination such as EST and biliary stenting.[10,13,26] The application of one or several above-mentioned methods is aimed to minimize the pressure gradient between the biliary system and the lumen of the duodenum in order to provide a free bile flow into the digestive tract, but not into the EBF. Studies show that a permanent decrease in the bile leak rate through EBF is the main condition for its spontaneous closure.[16,17] In our opinion, the most optimal approach for the bile duct decompression in the liver GSW injury is a combination of EST and endobiliary stenting, which is in contrast to Chandra et al., suggesting performing an EST alone, but in line with other studies.[13,15,31] It is worth to mention that conventional treatment of non-combat liver injury is associated with less severe trauma of the patient, therefore EST alone could be considered.[10,13,17,19]

In this case report, we demonstrated that a routine ERCP is performed only at Level IV. Level II is not appropriate to establish the ERCP facility because of a high risk of reactive artillery strikes within a 20-km zone from the frontline. On the other hand, Level III is also considered as inappropriate for routine ERCP because hospitals at this level must have beds reserved for specialized surgical care in case of admissions large number of injured military presonell from the frontline. In this case, patients with transpapillary interventions would have been out of appropriate surveillance due to the involvement of all medical stuff into urgent operative interventions on heavily injured patients. An example of such situation occurred before during the hot phases of armed conflict in the Battle of Ilovaisk (2014) and the Battle of Debaltseve (2015). Considering such features of this armed conflicted, the most appropriate was chosen to be Level IV for routine transpapillary interventions.

In this case report, we demonstrated the utility of both repeated ERCP and stent replacements for biliary decompression for the management of biliary fistula, which is supported by the data from severe liver trauma studies as well as from the studies on hepatic resections.[33,34] According to published series, ERCP is associated with better results for EBF and

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early healing without major hepatic resections.[17,33] Similar to Anand et al., we also consider ERCP as a safe technique and effective nonoperative tool for management of penetrating injury to the liver.[17] Our results are also in line with Zarutskyi et al., demonstrating the excellent results for ERCP application in cases of severe liver injury due to the combat casualties.[34] Barabino et al. also showed the effectiveness of routine ERCP in the management of biliary fistula and reported a higher rate of EBF in case of major liver resections.[33] Also, analyses of published series showed that damage control surgery and application of SNOM are associated with improved survival and decreased rate of complications in the patients with penetrating injury to the liver.[29,35,36] Utility of SNOM over the operative management has also been reported by Navsaria et al. and Bala et al. in their analyses of liver injury, including liver-related complications such as bile leak and biliary fistula.[8,9]

Occlusion and migration are the frequent complications of biliary stents. In line with Kwon et al., we hypothesized that the stent occlusion in the early post-traumatic period was due to the obstruction of its lumen by inspissated bile with desquamated ductal epithelium and necrotic mass accumulation.[37] According to the published studies, it is recommended to perform a scheduled stent replacement with a larger diameter, which was also performed in the current study.[38,39]

CONCLUSIONS

To summarize, in this case report we presented a case of a combat patient, who was treated according to the damage control tactics and our 6-year experience with the management of combat GSW. In this study, we have shown a case with a successful management of the combat patient who had a severe injury associated with the liver GSW caused by multiple high-energy projectiles. This case report is an example of effective application of damage control surgery as well as transpapillary biliary decompression in the patient with multisystem causality in hybrid warfare. Furthermore, this case report is a new evidence on specific features of combat trauma and its management in the combat area of JFO in East Ukraine, which is consistent with previous publications.[1,2,21] In our opinion, this case report presented the evolution of the pathomorphosis of combat liver injury, which is associated with the improvement of high-energy weapon (e.g., multiple launch systems “Grad”, “Smerch” and “Tornado-C”).

A combination of operative techniques and SNOM to combat liver GSW is effective along with the application of damage control tactics. Liver-related complications could be effectively managed by nonoperative techniques such as scheduled ERCP.

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SUPPLEMENTARY MATERIAL

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

INFORMED CONSENT

Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

AUTHOR CONTRIBUTIONS

I.K.—study conception and design, and acquisition of data; IT—acquisition of data, analysis and interpretation of data, literature search, and drafting of manuscript; KH—acquisition, analysis, and interpretation of data; HM—acquisition, analysis, and interpretation of data; DR—acquisition, analysis, and interpretation of data; AS—acquisition, analysis, and interpretation of data, VS—acquisition, analysis, and interpretation of data, and preparation of figures; YY—analysis and interpretation of data, and drafting of manuscript; SS—acquisition, analysis, and interpretation of data, DD—acquisition, analysis, and interpretation of data, preparation of figures, and literature search; OB—analysis and interpretation of data, critical revision, drafting of manuscript, literature search and analyses, and drafting of manuscript; and AD—study conception and critical revision of manuscript.

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