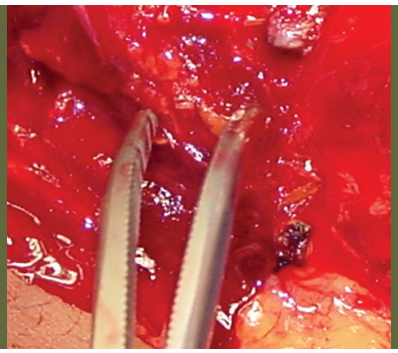
Chapter V
ABDOMINOPELVIC TRAUMA



V.1 Indirect Effects of Wounding

CASE PRESENTATION

This 15-year-old host nation male presented after reportedly having been shot once with an M-16. Three wounds were apparent. A left lateral abdominal wound was the suspected entrance wound (Fig. 1). Two exit wounds were created secondary to fragmentation (Figs. 1 and 2). The patient underwent exploratory laparotomy. In surgery, there was no evidence of penetration of the peritoneum (Fig. 3). Nevertheless, there was a 3-cm, full-thickness injury of the transverse colon (Fig. 4). This wound was likely caused by cavitation commonly associated with high-velocity gunshot wounds. Because of the patient's apparent good nutritional status and the isolated extent of injury, he was treated with extended right hemicolectomy and ileocolostomy. Host nation patients do not enter the Army evacuation system and instead necessarily receive their definitive care at a combat support hospital (CSH). This patient's wounds were left open and treated with dressing changes. He recovered without complications.

TEACHING POINTS

1. This is an example of nonuniform energy transfer of a high-velocity round. The width of tissue disturbance is an indication of the magnitude of energy transfer, which may increase along the trajectory of a projectile.
2. The specific effect involved is cavitation. The physical properties of the target tissue determine the dimensions of the temporary cavity. For example, the cavity may be small in the lung, but large in the liver. Cavity size can be impressive—as much as 20-fold greater than the diameter of the bullet that caused it.
3. This gunshot wound of the extraperitoneal abdominal wall, which caused an injury of the underlying bowel, is also an example of indirect effects of wounding. Presumed by its nature to be rare, the Wound Data and Munitions Effectiveness Team (WDMET)—a database of American casualties in the Vietnam War—records only five documented examples of similar injury of 299 surviving casualties with intraabdominal trauma.
4. This case also recognizes the not uncommon scenario in which, if local medical facilities are not available or a field hospital is not established for that sole purpose, the CSH becomes the highest level of medical care available for many allied military and civilians.

FIGURE 1. (Top)
M-16 entry and exit wounds.

FIGURE 2. (Bottom)
Close-up of M-16 entry and exit wounds.

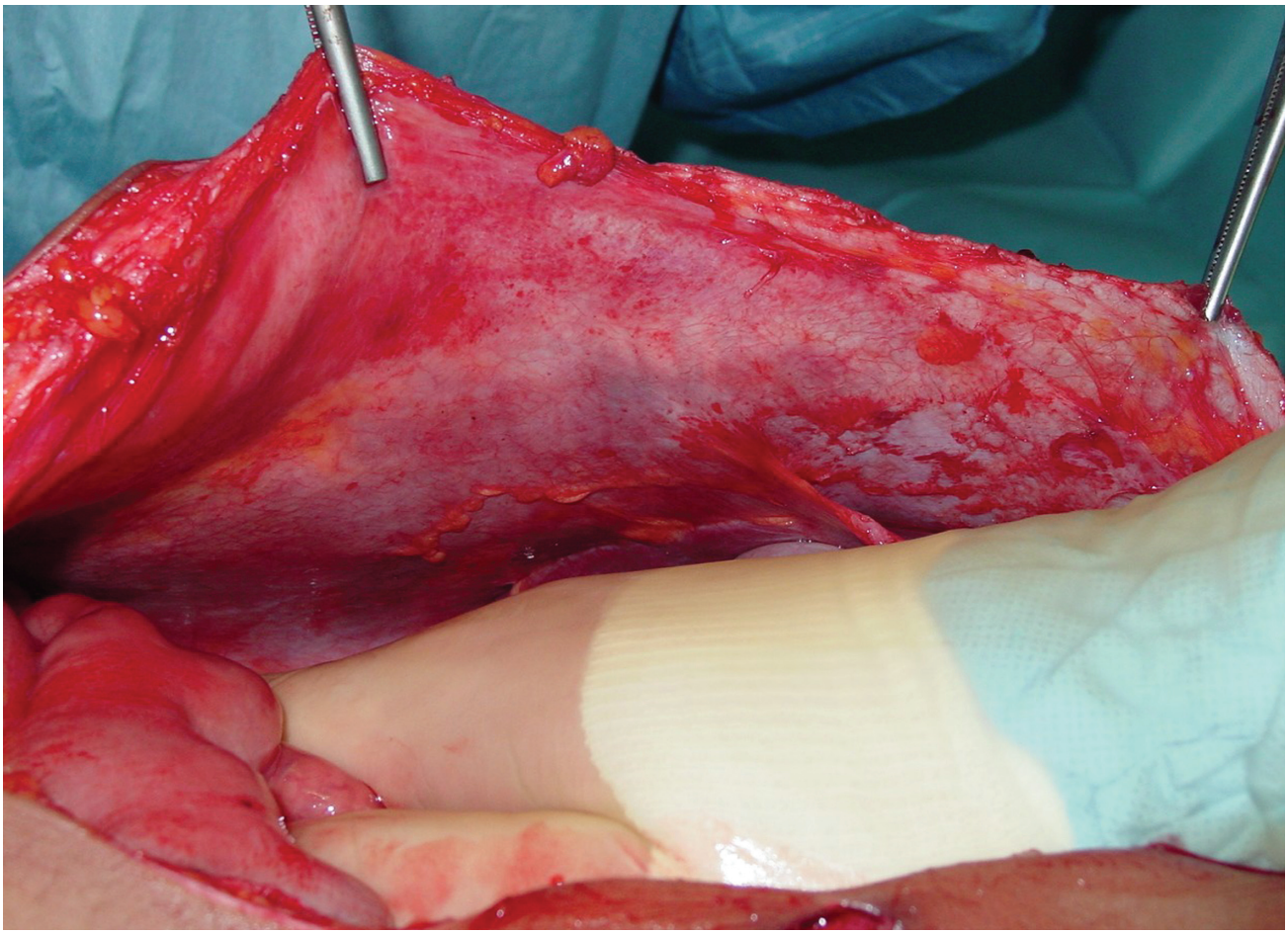


FIGURE 3. *Exploratory laparotomy. Note: There is no penetration of the reflected peritoneal wall.*

CLINICAL IMPLICATIONS

Simple, isolated colon injuries are uncommon. In host nation casualties and enemy combatants, poor nutritional status of these populations may preclude primary repair. Diversion with colostomy should be strongly considered in all patients in the presence of any of the complicating factors listed below:

1. Massive blood transfusion requirement.
2. Ongoing hypotension.
3. Hypoxia (secondary to a pulmonary injury).
4. Reperfusion (vascular) injury.
5. Multiple other injuries.
6. High-velocity injuries.
7. Extensive local tissue damage.

High-energy tangential wounds are prone to progressive soft-tissue devitalization and may evolve into necrotizing fasciitis. These wounds should be serially debrided and allowed to heal by either delayed primary closure or secondary intention.

DAMAGE CONTROL

1. In the unstable patient, control contamination with ligation/stapling of the bowel. Establishing intestinal continuity is not imperative.
2. Delay creation of the stoma until the patient is stable.
3. Document treatment for optimal follow-up through all levels of care.

SUMMARY

This is an uncommon case in which tangential injury by a high-velocity projectile presented with a relatively benign appearance. An understanding of the indirect effect of temporary cavitation in high-velocity wounds prompted formal laparotomy. Right hemicolectomy with ileocolostomy was performed. In this case,

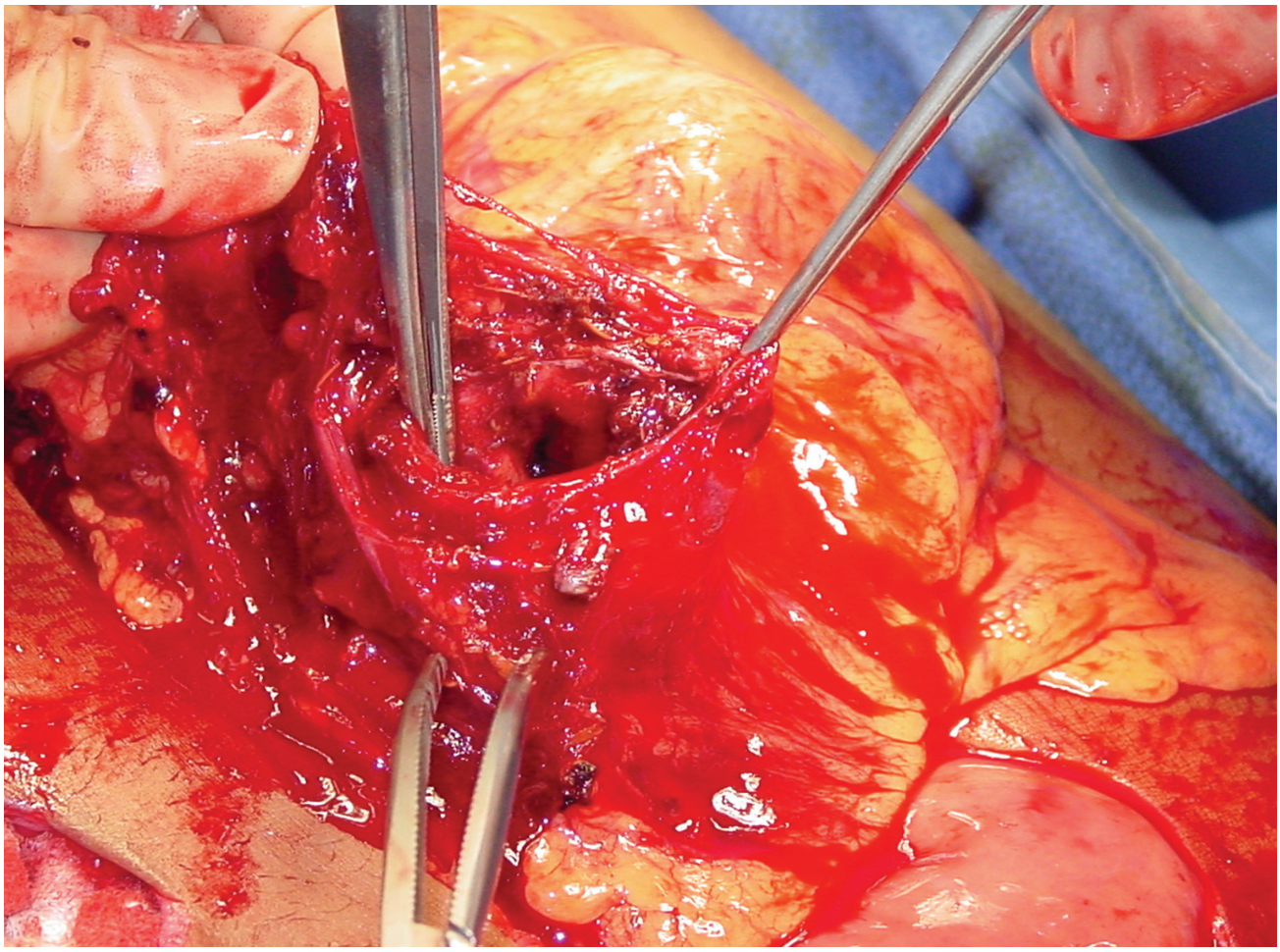


FIGURE 4. *The transverse colon has a large wound resulting from the indirect effects of the gunshot wound.*

prolonged care was necessary because the patient was a host national and could not be evacuated.

Note: See discussion of these cases on page 201.

SUGGESTED READING

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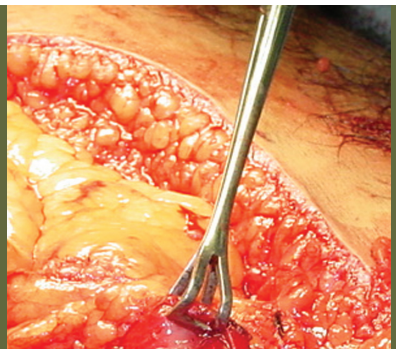

V.2 Penetrating Trauma to the Stomach and Pancreas

CASE PRESENTATION

A car bombing occurred near a combat support hospital (CSH). All staff prepared immediately for a mass casualty event. Initially, only patients with minor injuries came to the hospital. However, several hours later, a host nation policeman presented with facial, abdominal, and extremity injuries. He was awake and alert, with a mildly tender abdomen and multiple fragment wounds to the face overlying the parotid gland, the thoracoabdominal region, and the left leg (Fig. 1). His chest X-ray was significant for free air under the diaphragm (Fig. 2). During surgery, a single fragment was found that had entered the left abdomen, passed through the anterior and posterior walls of the stomach, and embedded in the pancreas. The anterior and posterior stomach wounds were closed in two layers (Figs. 3–5), and a distal pancreatectomy and splenectomy were also performed (Fig. 6). The parotid injury was minor, and the face laceration was closed. The leg wound required only washout, packing, and dressing changes.

TEACHING POINTS

1. This case is an excellent example of a patient who presented several hours after injury because of the confusion frequently encountered following an attack. At times, the CSH was notified of large-scale attacks and was informed to expect casualties. Surprisingly, these patients may not arrive for many hours.
2. In this case, enough time elapsed from the time of injury until presentation of the patient to allow free air to accumulate under the diaphragm and be visible on the chest X-ray. Patients with penetrating abdominal injury and free air under the diaphragm should undergo immediate laparotomy.
3. Penetrating injuries below the nipples, above the symphysis pubis, and between the posterior axillary lines must be treated as injuries to the abdomen and mandate exploratory laparotomy.
4. Stomach wounds require minimal debridement and are closed in two layers. The fragment that caused the injuries was found embedded in the distal pancreas. It caused significant tissue damage and therefore required distal pancreatectomy and splenectomy.

CLINICAL IMPLICATIONS

The stomach is well vascularized and usually heals well with primary closure. Arteries supplying the stomach are not end arteries and can be ligated. The following points should be emphasized:

FIGURE 1. *Abdominal entrance wound before surgery. The facial wound overlying the left parotid gland is also apparent.*

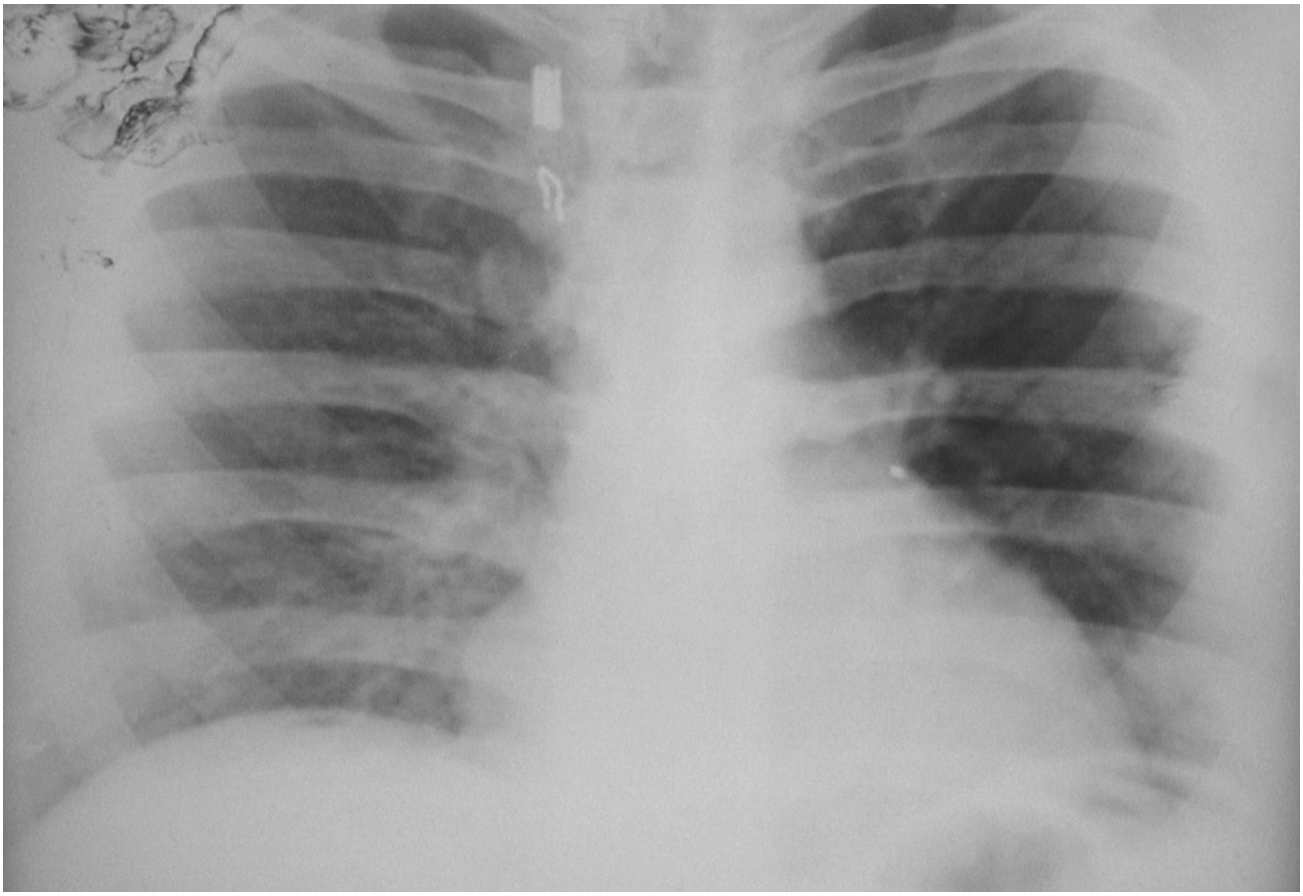

FIGURE 2. *Chest radiograph (AP) of free air under the diaphragm. (Objects are visible outside the body.)*

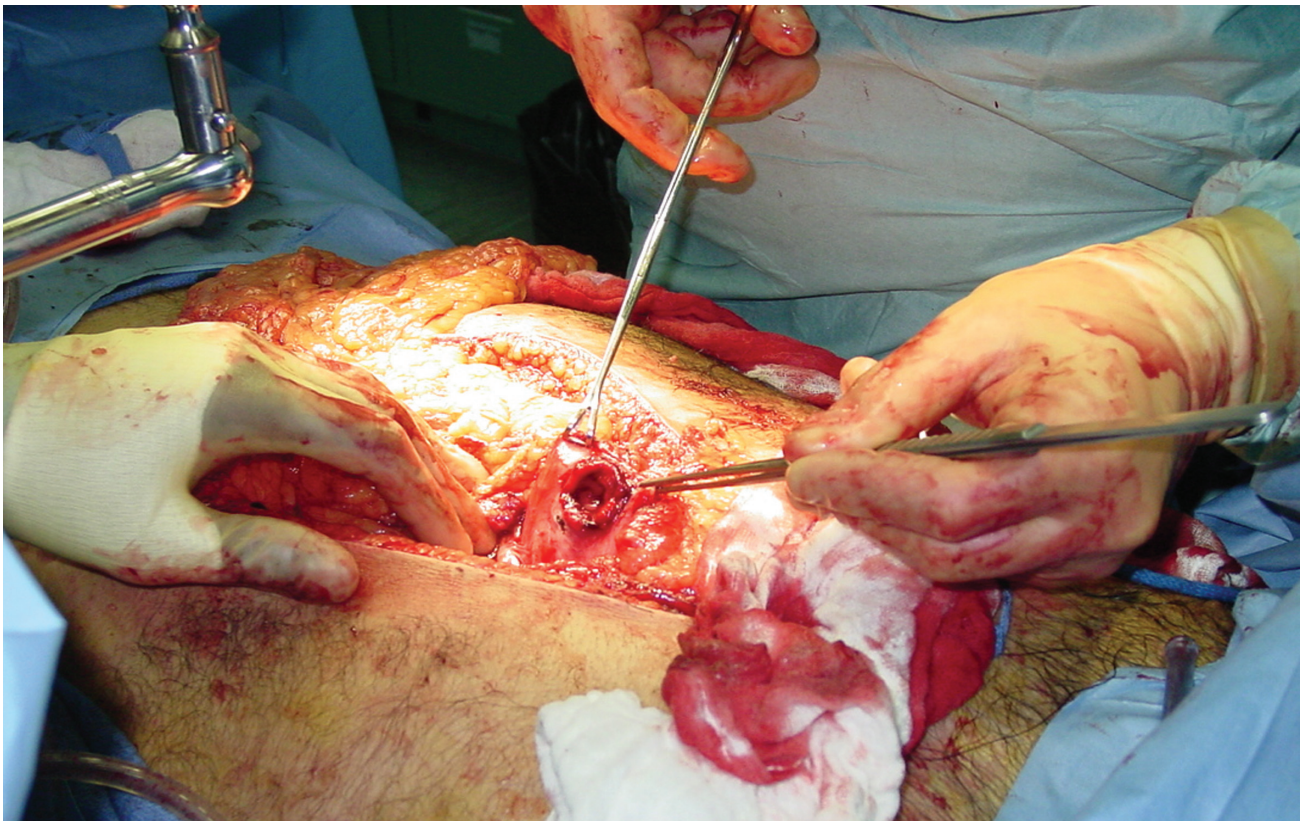

FIGURE 3. *Anterior stomach wound before closure.*

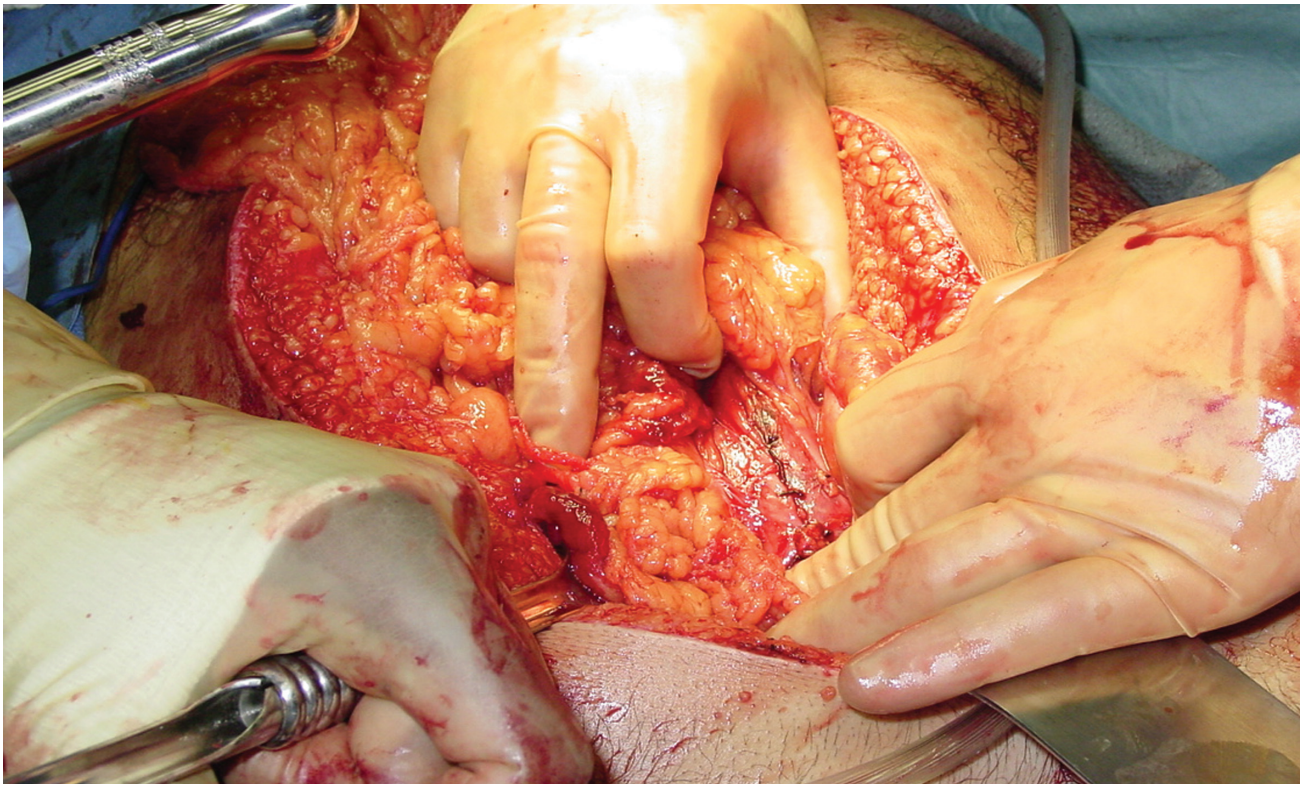

FIGURE 4. *Anterior stomach wound closed in two layers.*

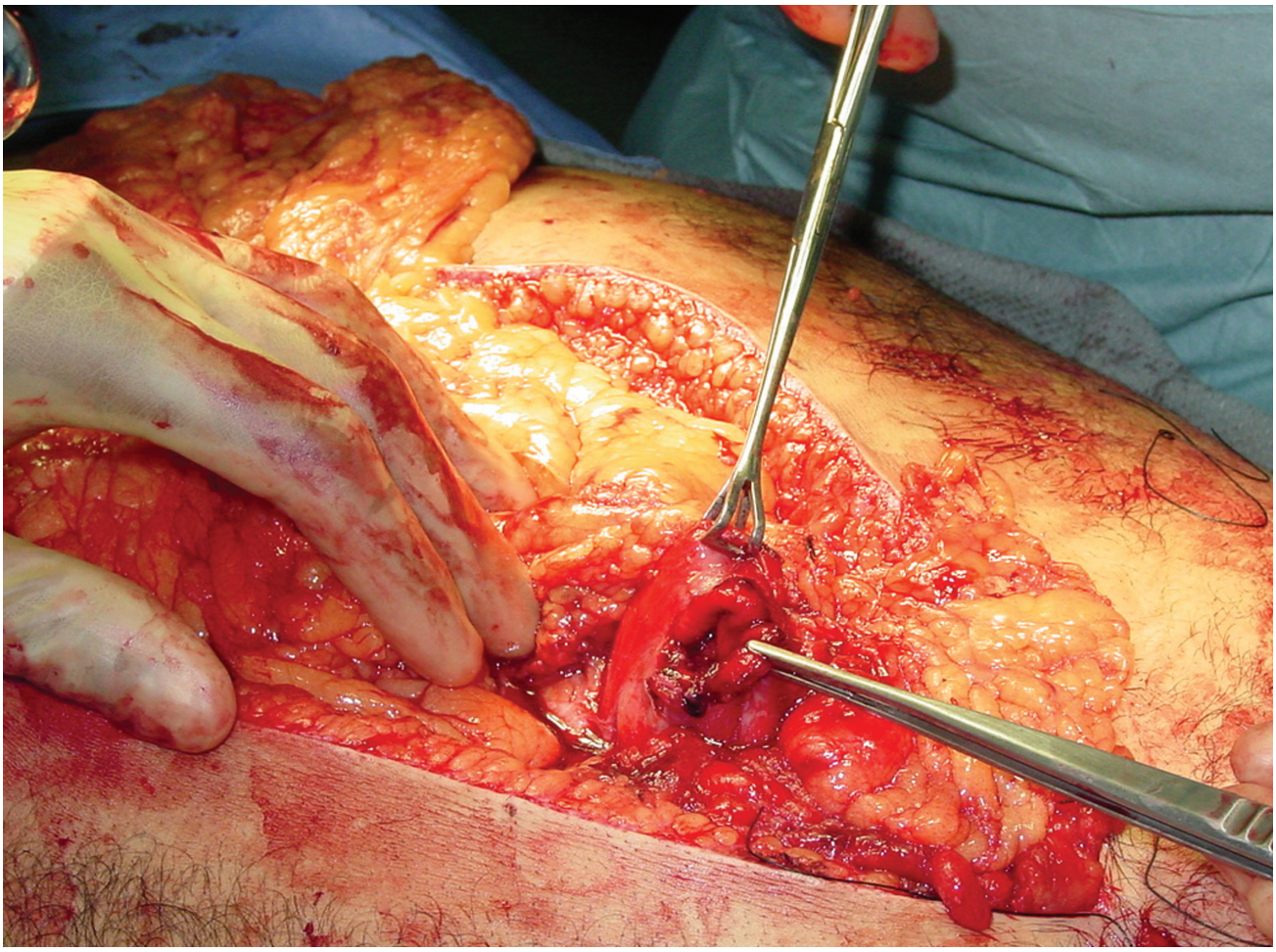

FIGURE 5. *Posterior stomach wound before repair.*

1. Enter the lesser sac to identify posterior stomach and pancreatic body and tail injuries. A Kocher maneuver should be performed to thoroughly evaluate the duodenum and head of the pancreas. Always examine the pancreas in cases involving penetrating trauma to the upper abdomen.
2. Drain all pancreatic injuries.
3. Treat transection or injury of the pancreatic duct by the following:
   a. Resection (distal pancreatectomy, as in this case).
   b. Oversewing or stapling the proximal pancreas segment.
   c. Roux-en-Y drainage of the injury.
4. The somatostatin analog, octreotide acetate (Sandostatin), administered subcutaneously (starting dose, 50 μg t.i.d.) can be initiated if a pancreatic leak occurs and may decrease output.

DAMAGE CONTROL

In an austere environment, once hemorrhage is controlled, pancreatic injury can be managed by drainage alone. If the clinical situation dictates, controlling bleeding with packing and limiting contamination by stapling off bowel injuries may be used.

SUMMARY

This case is an example of a single fragment passing through the anterior and posterior walls of the stomach and embedding in the pancreas. Management of this case was relatively straightforward, because the patient presented with a significant abdominal wall injury, tenderness, and free air under the diaphragm. This case also demonstrates that a significant delay can occur between time of actual attack and arrival of patients at a CSH, even if that hospital is within close proximity of the attack. Medical staff should

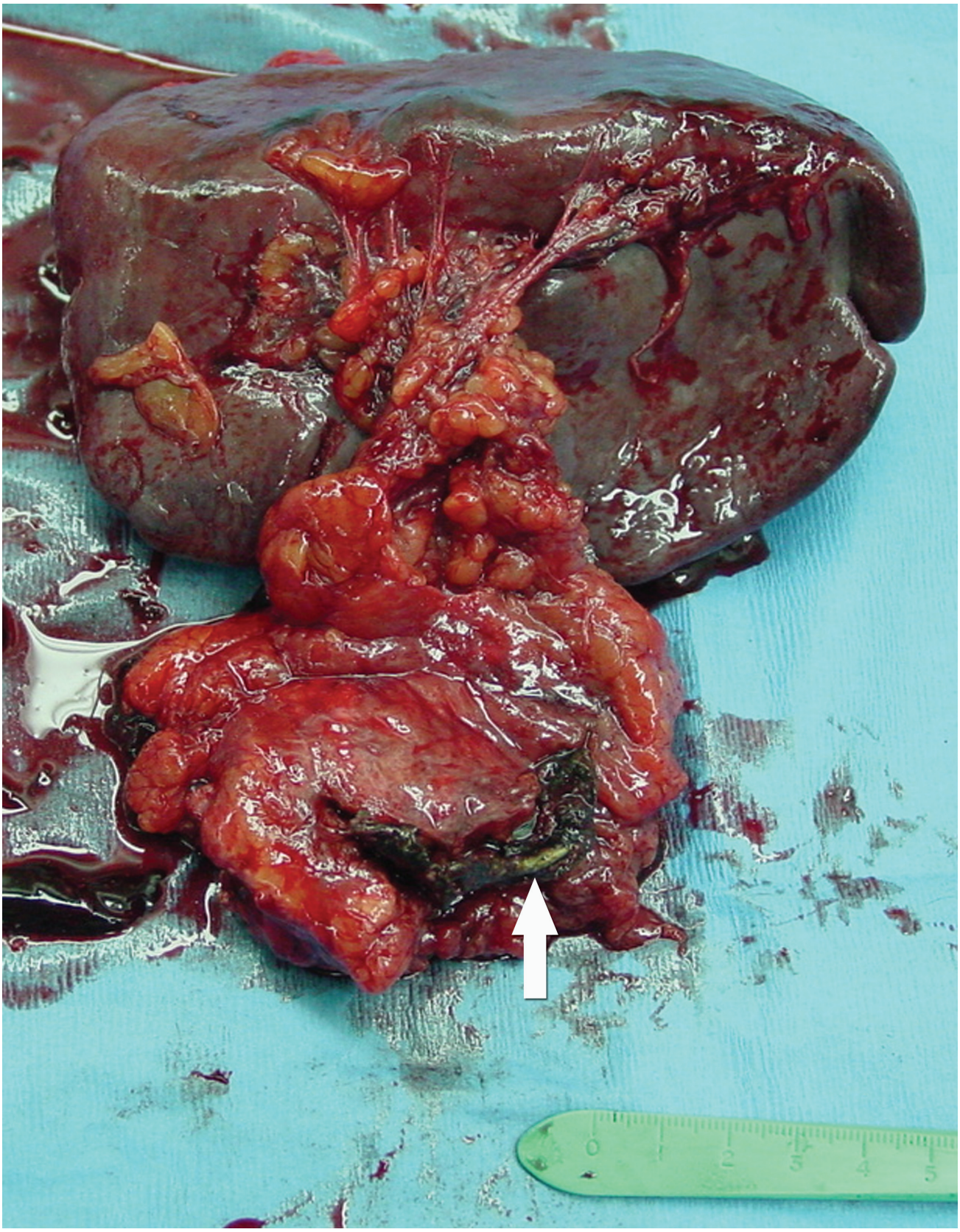

FIGURE 6. *Distal pancreatectomy and splenectomy. Fragment is visible* (arrow) *within the parenchyma of the pancreas.*

consider this when anticipating a mass casualty event. A trauma system should be in place to ensure that rest cycles are maintained and that personnel do not exhaust themselves waiting for patients to arrive.

Note: See discussion of this case on page 201.

SUGGESTED READING

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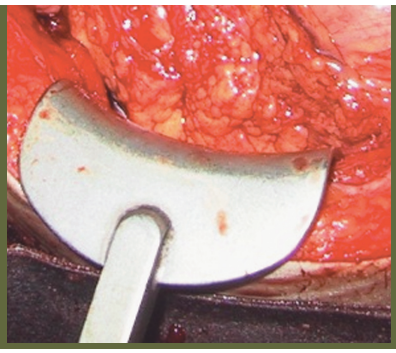

V.3 Blunt Abdominal Trauma

CASE PRESENTATION

This male patient was involved in a motor vehicle crash. He was transferred to a combat support hospital (CSH) after an initial evaluation at a host nation medical facility. Typical of these types of accidents, details were not available when the patient arrived at the hospital. On admission, he was hemodynamically and neurologically uncompromised. He had a tender abdomen. Imaging capability was limited to a cervical spine series, a portable chest X-ray, and a pelvis radiograph (all normal). A decision was made to explore the patient's abdomen. On entering the abdomen, vegetable matter was noted throughout the peritoneal cavity, as well as 500 mL of blood. The abdomen was thoroughly explored, and all injuries were limited to the upper abdomen. The most apparent injuries were to the stomach and duodenum. The stomach was almost completely transected between the body and antrum, and only 1 cm of stomach remained intact along the lesser curvature (Fig. 1). The duodenum was completely disrupted between the second and third portions. The superior mesenteric vein (SMV) was also injured just caudal to the pancreas, and the tributary veins had been torn flush with the SMV. Bleeding from the SMV was managed with fine Prolene sutures at the sites of the avulsed branches. The bleeding ends of the tributaries were managed with ligation, and the SMV remained patent after the repair. On visual inspection, the pancreas was injury-free. No other abdominal injuries were identified. Damage control laparotomy was performed. No effort was made for primary repair of the gastrointestinal tract. The open end of the proximal stomach was stapled closed. The open end of the distal stomach was also stapled. In addition, the two transected ends of the duodenum were stapled. This anatomical configuration left the patient with a blind pouch consisting of the distal stomach and the proximal duodenum. Temporary abdominal closure was performed, and the patient was resuscitated in the intensive care unit. After resuscitation, he was taken back to the operating room. Immediate restoration of his gastrointestinal anatomy was not performed. The proximal stomach was managed with tube gastrostomy, and the distal stomach and proximal duodenal pouch were managed with tube drainage. A 24-French Malecot catheter was placed through a purse-string stitch in the anterior wall of the distal stomach, and the catheter advanced through the pylorus into the duodenum. The distal stomach was brought up to the right upper quadrant of the abdominal wall and secured to the

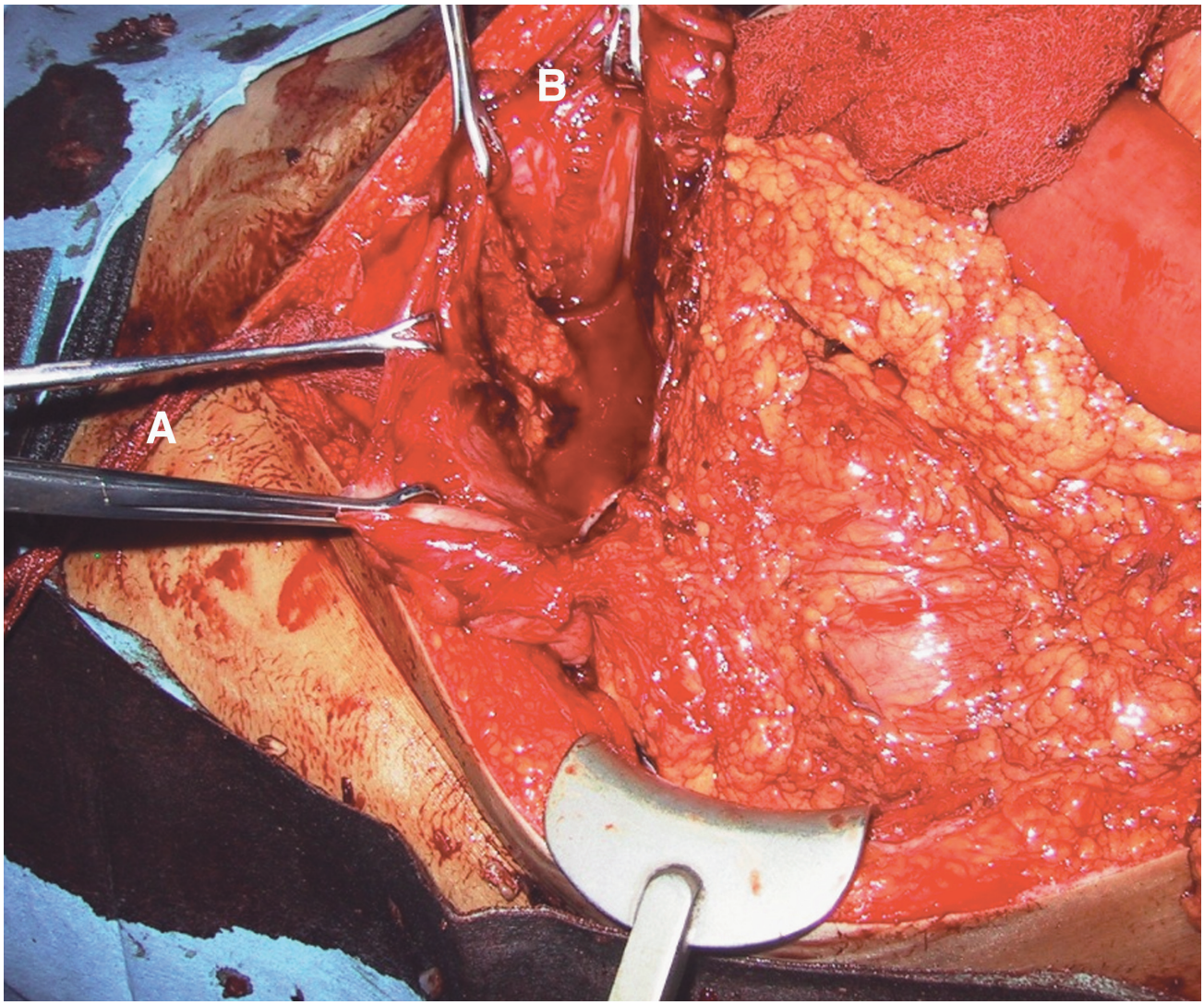

FIGURE 1. *With the patient's head to the left, the Babcock on the patient's right* (A) *is on the distal stomach remnant. The two Babcock clamps on the left side of the patient are on the proximal gastric remnant* (B). *The duodenal injury is not shown.*

parietal peritoneum. Although the pancreas had not been injured, two drains were placed adjacent to the pancreas, and the abdominal wall fascia was left open. After two more days, the patient underwent a third operation. The SMV remained patent. Nonetheless, bowel edema prevented abdominal wall closure. Abdominal integrity was restored with VICRYL mesh. Vacuum dressing was applied to promote granulation. Two days later, a tracheostomy was performed to assist in weaning the patient from the ventilator. The patient was transferred to a host nation medical facility. He had good respiratory function, jejunostomy feedings at goal, and no evidence of sepsis at the time of transfer.

TEACHING POINTS

1. Blunt injuries to the duodenum may be associated with massive upper abdominal trauma, as in this case. Early during the initial operation, consideration should be given for staged damage control surgery.
2. When produced by blunt force, gastric ruptures are often large with copious intraperitoneal soiling.
3. With massive proximal intestinal injury at initial operation, only bowel that is unquestionably devascularized or necrotic should be resected. Although bowel of questionable viability can be assessed intraoperatively (Doppler flow, fluorescein), a second-look operation in 24 hours is recommended.

CLINICAL IMPLICATIONS

1. Even though Army medical assets can be geared toward combat trauma in a combat zone, noncombat trauma still occurs. Approximately 40% of surgeries performed by one CSH during combat deployment were noncombat related.[1]
2. Army medical personnel deployed in the combat zone are resourced to provide care for combat casualties. However, many trauma patients will be host nationals depending on the medical rules of engagement and resources available. When resources are available and security measures in place, providing care to the local population may be possible.

DAMAGE CONTROL

1. This case is typical of the type of damage control surgery that is required in combat hospitals.
2. Clinical practice guidelines suggesting damage control laparotomy include the following:

    a. Multiple life-threatening injuries.
    b. Acidosis (pH < 7.2).
    c. Hypothermia (temperature < 36°C).
    d. Hypotension and shock.
    e. Combined hollow viscus and vascular injury.
    f. Coagulopathy.

SUMMARY

This patient had a combined hollow viscus and a major vascular injury. He required 8 units of packed red blood cells. His perioperative status included hypotension, and he presented a triad of hypothermia (34.6°C), acidosis (pH 7.27), and coagulopathy (partial thromboplastin time, 54 seconds). The patient's Injury Severity Score (ISS) was 16. He was treated with damage control laparotomy, and damage control techniques used early in his treatment resulted in a successful outcome. Teams preparing for deployment need to anticipate providing care to the local population and to noncombat trauma patients.

Note: See discussion of this case on pages 201–202.

REFERENCE

1. 86th Combat Support Hospital. Experience of the 86th Combat Support Hospital. Operation Iraqi Freedom-1. January 2003 through June 2003. Unpublished data.

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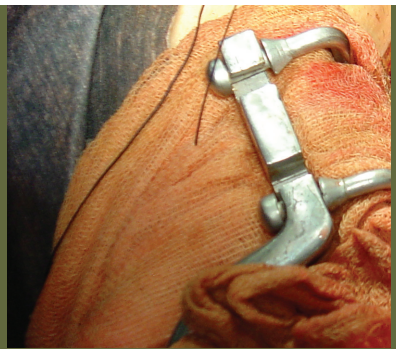

V.4 Missed Duodenal Injury

CASE PRESENTATION

This 20-year-old marine was transferred—after laparotomy and repair of penetrating gastric injury—from a level II Forward Surgical Team (FST) to a level III combat support hospital (CSH) medical treatment facility. While awaiting aeromedical evacuation, he exhibited tachycardia and hypotension, with a small amount of bilious drainage from the posterior exit wound (lower back). The patient's abdomen was reexplored prior to aeromedical evacuation. At laparotomy, bile staining was noted at the site of gastric repair. A Kocher maneuver was performed. A missed through-and-through duodenal injury was also discovered (Fig. 1). In addition, a superior pole laceration of the right kidney was found (Fig. 2). The duodenal injury was repaired with a two-layer closure anteriorly and posteriorly (Figs. 3 and 4). The renal injury was debrided, and bleeding was controlled with electrocautery. Both injuries were externally drained. The patient improved clinically and was later evacuated.

TEACHING POINTS

1. Level II surgery units (eg, FSTs) operate in austere and resource-constrained environments. Often, they perform lifesaving operations in very difficult conditions. It is critically important that medical personnel perform a thorough exploration (if time permits) when operating on penetrating abdominal trauma.
2. If the clinical situation or condition of the patient does not permit this examination, it is essential that the level II medical treatment facility communicate in some way (even if it involves writing on the abdominal dressing; Fig. 5) with the receiving level III facility to make sure that the next level of care personnel understand that reexploration prior to further evacuation is mandatory.
3. It is critical that level III medical treatment facilities carefully reevaluate patients received and consider early reoperation when patients remain unstable or deteriorate after arrival. Serial examinations and attentive observation of postoperative patients are mandatory throughout the MEDEVAC system.

CLINICAL IMPLICATIONS

Injuries to the duodenum are often associated with massive upper abdominal trauma. Damage control techniques should be considered early.

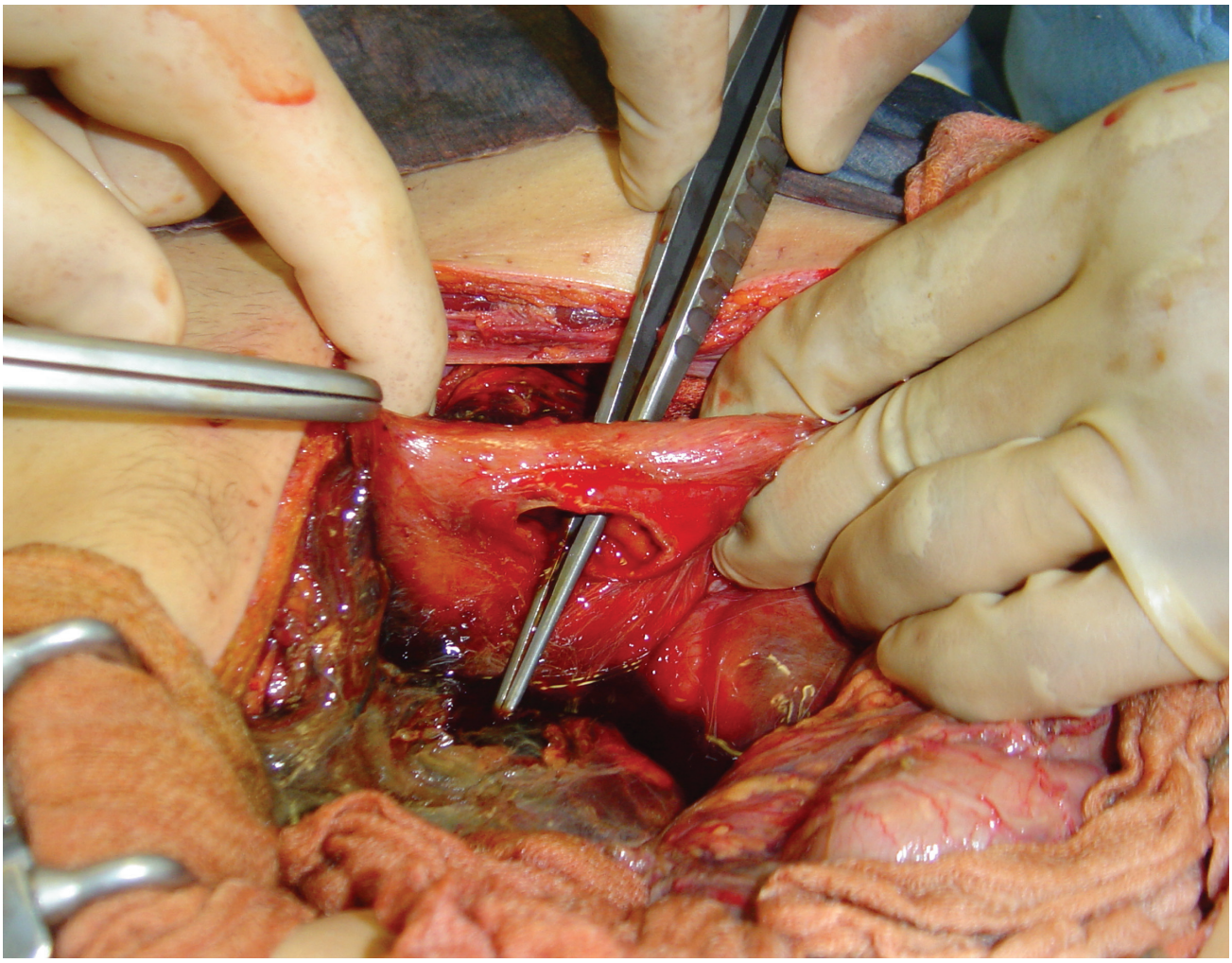

FIGURE 1. *Through-and-through injury to the duodenum after Kocher maneuver. Note bile staining of surrounding tissue.*

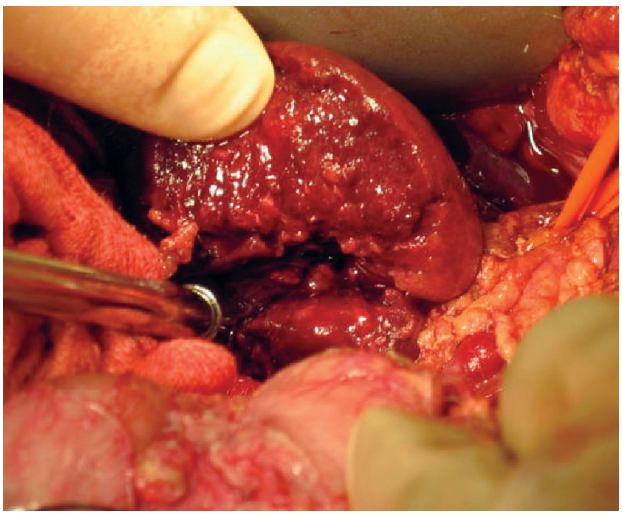

FIGURE 2. *Injury to the kidney.*

1. Missed injuries to the duodenum have devastating morbidity and are associated with high mortality.
2. Bile staining or hematoma in the periduodenal tissues mandates full exploration of the duodenum.
3. Minor injuries can be repaired primarily.
4. Major injuries should be repaired if the lumen will not be narrowed by more than 50%.[1]
5. Consider the following for injuries involving more than 50% of the lumen[1]:
   a. Drain the injury through a Roux-en-Y jejunal limb.
   b. Avoid pancreaticoduodenectomy.
   c. Divert the gastric stream with a gastrostomy and close the pylorus. Do not divide the pylorus.
   d. Widely drain all injuries with closed-suction drains.

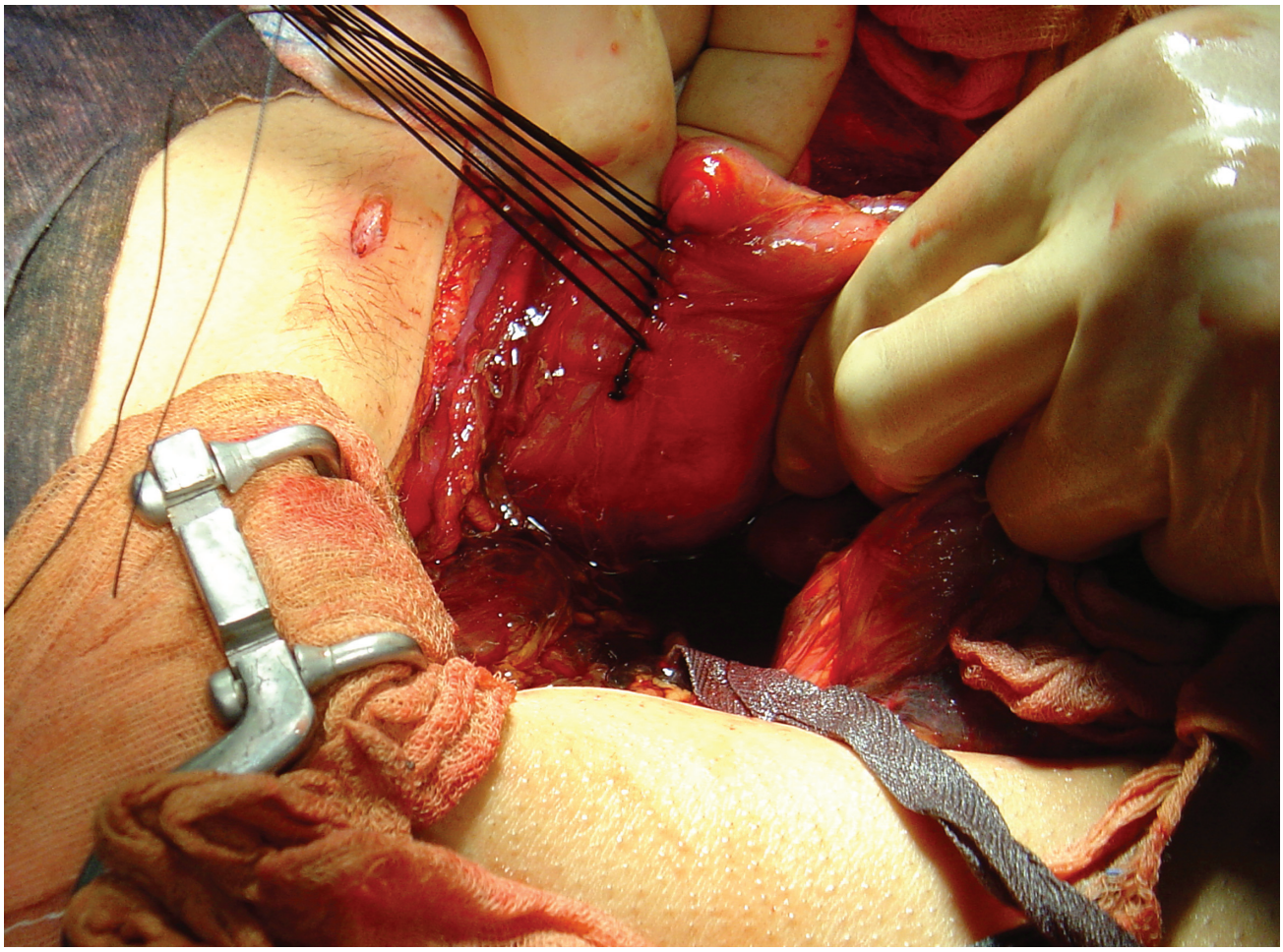

FIGURE 3. *Duodenal injury in the process of being closed.*

e. Close the duodenum around a Malecot catheter using 2-0 VICRYL (tube duodenostomy).

DAMAGE CONTROL

1. Penetrating renal injuries can be managed by debridement and drainage. There should be a low threshold for nephrectomy in the unstable patient.
2. Duodenal injuries should be closed primarily if feasible and narrowing of the lumen less than 50% can be obtained. All duodenal injuries should be drained.

SUMMARY

In this case, despite the lack of communication frequently encountered in combat environments, surgeons correctly determined that this patient required reexploration. This action prevented further worsening of his condition, especially at the outset of prolonged evacuation.

Note: See discussion of this case on page 202.

THE KOCHER MANEUVER

Named for Nobel Prize-winning surgeon Dr Emil Theodor Kocher (1841–1917), the Kocher maneuver (or Kocher's maneuver) is a surgical procedure to expose structures in the retroperitoneum behind the duodenum and pancreas. In this maneuver, the head of the pancreas is mobilized and accessed during an operation. To be truly called a Kocher maneuver, the whole second part of the duodenum has to be mobilized with the retroperitoneum bare for inspection all the way to the aorta.

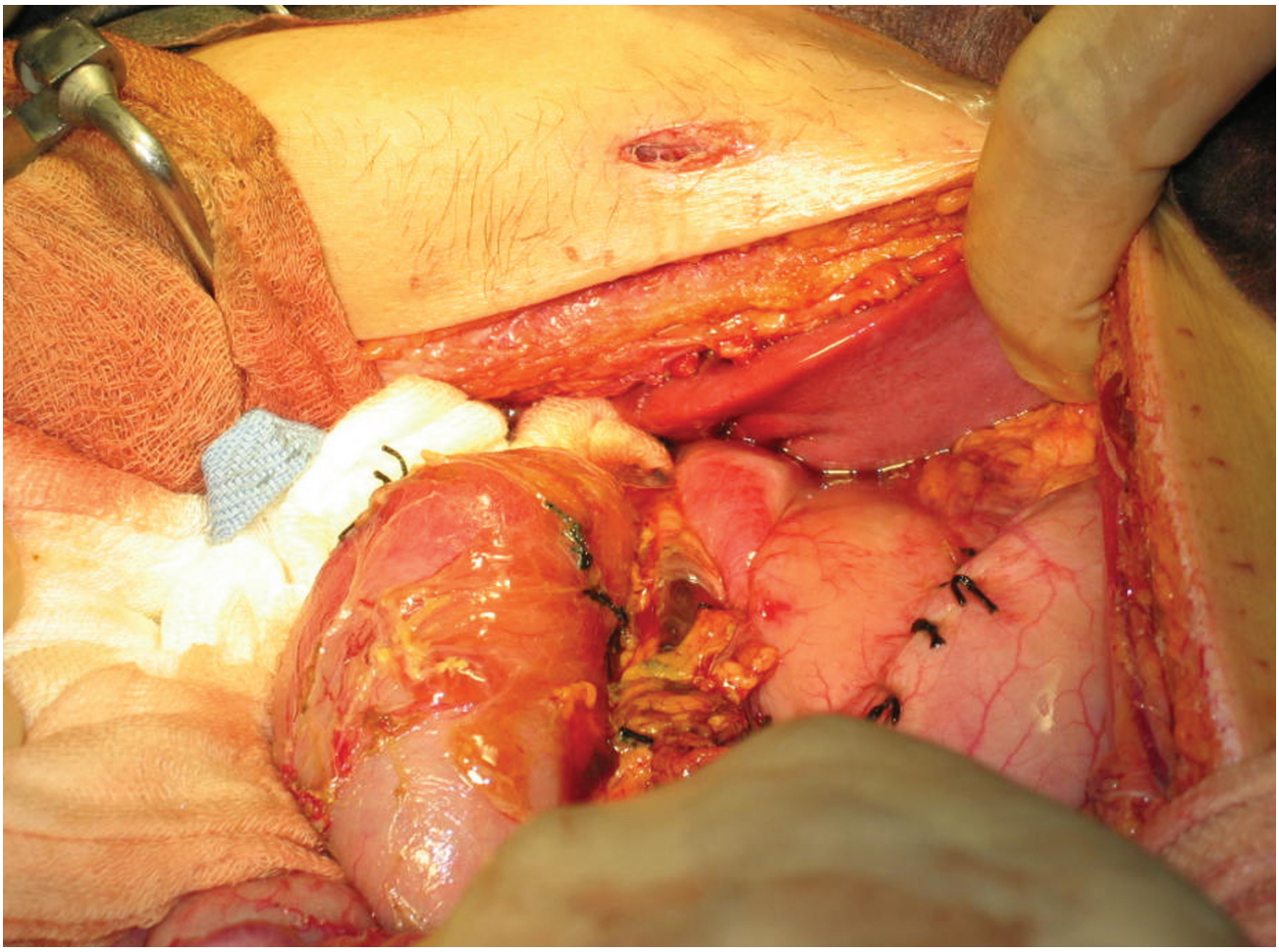

FIGURE 4. *View of closed duodenum.*

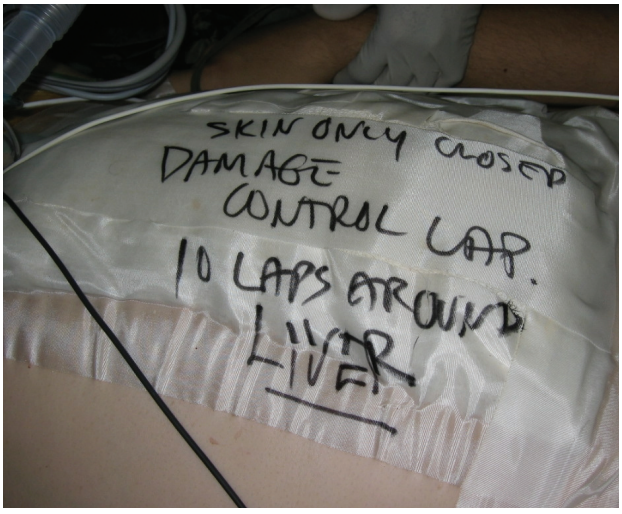

FIGURE 5. *Communication involving writing on abdominal dressing from level II to level III medical treatment facility.*

REFERENCE

1. Chapter 17: Abdominal injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004: p. 17-9.

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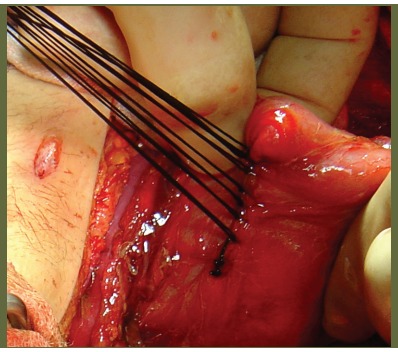

V.5 Traumatic Evisceration

CASE PRESENTATION

A 30-year-old host nation male sustained a blast injury to his flank. It took 12 hours to reach the Forward Surgical Team (FST) operating base. A field dressing had been placed over the wound, but no other resuscitative efforts were initiated. When the patient arrived, he was alert and oriented, with normal vital signs and no tachycardia. A secondary survey revealed a significant abdominal wall injury with eviscerated small bowel (Fig. 1). He had multiple enterotomies in the eviscerated segments of the small bowel. There was an episode of bilious emesis, and a nasogastric tube was placed to decompress the stomach. The patient was started on intravenous fluids and given a second-generation cephalosporin intravenously. He was then taken to surgery. The abdomen was explored through a midline incision, and no gross fecal contamination of the peritoneum was found. There were no other visceral or vascular injuries noted. The eviscerated small bowel was addressed by first closing the enterotomies temporarily with silk sutures outside of the abdomen and then reducing the bowel into the abdominal cavity. The bowel was assessed for ischemia, and grossly ischemic-appearing bowel and nonviable bowel were resected (Fig. 2). Bowel continuity was reestablished during surgery with primary anastomoses. The abdomen was washed out with 6 liters of normal saline and then closed. He was extubated and transferred to the intensive care unit (ICU). The patient had an uneventful postoperative course; was started on a regular diet on postoperative day 4; and had no short-term, postoperative complications.

Courtesy David Leeson, *The Dallas Morning News*

TEACHING POINTS

1. Prehospital management should be limited to covering eviscerated abdominal contents with moistened gauze or other sterile dressings and then securing the contents with tape to prevent further evisceration. Medics should not attempt reduction of contents, because this can result in reduction of gangrenous or perforated bowel into the peritoneal cavity.
2. When the patient arrives with evisceration of abdominal contents, the physician should not be distracted by the obvious injury and should proceed with Advanced Trauma Life Support (ATLS) protocol. Only after thorough primary and secondary surveys is the traumatic evisceration addressed.

FIGURE 1. *Wound showing evisceration of the small intestine.*

CLINICAL IMPLICATIONS

Once the decision is made to take the patient to the operating room, management of a simple evisceration is straightforward.

1. The patient can be prepped widely, and the eviscerated bowel can be prepped with betadine after thorough irrigation.
2. Any other immediately life-threatening abdominal injuries should be addressed first—then reduce the bowel and assess viability.
3. The procedure should begin with a midline incision.
4. The eviscerated bowel can be examined outside of the abdominal cavity. If there are enterotomies, control contamination by closing the defects with a simple suture before reducing the bowel back into the abdomen.
5. Remember, as in an incarcerated hernia, simple reduction of the intestines may be all that is needed to return blood flow to ischemic areas.
6. All frankly necrotic bowel is removed, and a primary anastomosis or an ostomy may be performed. Choice of primary anastomosis versus ostomy and delayed primary repair depends on many factors (eg, the presence of associated injuries, hypotension, and degree of intraabdominal contamination). Primary repair in young, healthy patients who are hemodynamically stable is acceptable. An ostomy and delayed repair are reserved for unstable patients or severe, gross fecal contamination, as in a left colon or rectal injury.

DAMAGE CONTROL

1. Control airway and hemorrhage first in hemodynamically unstable patients.
2. Control gross contamination by closing enterotomies with simple sutures or staples.
3. Resect dead and ischemic bowel and delay anastomosis or creation of an ostomy until patients are hemodynamically stable.

FIGURE 2. *Removal of necrotic and ischemic bowel.*

SUMMARY

In the combat setting, the management of eviscerated abdominal contents is stratified into two categories: (1) early mandatory laparotomy and (2) nonurgent laparotomy. Unlike in the civilian setting, nonoperative treatment of these patients is not appropriate.

Note: See discussion of this case on page 202.

SUGGESTED READING

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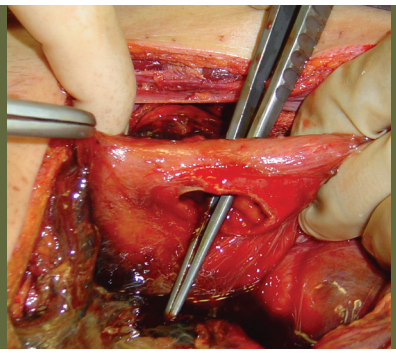

V.6 Penetrating Rectal Injury

CASE PRESENTATION

This 35-year-old male patient was riding in a military vehicle when an improvised explosive device (IED) was detonated. He was treated by medics in the field and then brought to the combat support hospital (CSH) by MEDEVAC helicopter. He arrived awake and complaining of pain in his left leg. A thorough examination revealed an obvious left femur fracture with a lateral entrance wound and a medial exit wound. The patient's pulses were normal, with no evidence of arterial injury. Further examination revealed a second penetrating wound that entered the left buttock, created a large subcutaneous tract with palpable crepitus, and exited through a larger wound in the right buttock. Examination of the perineum showed no bruising, and no other injuries were noted. The patient required external fixation of the femur fracture and exploration of the sacral wound. It was clear that the procedure would take some time to perform. A blood drive was initiated for 8 units of whole blood. Because there was minimal bleeding from the sacral wound, external fixation of the femur fracture was performed to minimize blood loss from that wound. Then the patient was placed in the prone position. The sacral wound was addressed by opening the wound tract between the entrance and exit wounds. The projectiles (rocks) had passed through the sacrum at the S2 level and completely divided the bony sacrum (Fig. 1). The muscular bleeding was packed. A full-thickness, 50% circumferential posterior rectal injury—with gross fecal contamination—was identified. There was bleeding from the patient's left side between the rectum and left lateral pelvic wall. The severed ends of the hypogastric artery were identified with difficulty and ligated. The presacral venous plexus of the upper and lower sacral fragments was compressed with packs. With hemorrhage controlled, the patient's physiological status was assessed. His temperature was 34°C, and he was clinically coagulopathic and acidotic. The decision was made therefore to proceed with damage control by rapidly closing the rectal wound with VICRYL suture, applying QuikClot hemostatic agent, and packing the wound. The skin was closed over the packs to apply pressure (Fig. 2), and the patient was then taken to the intensive care unit (ICU) for resuscitation and warming (Fig. 3). At that time, the CSH did not have active warming devices (eg, Bair Huggers), so intravenous catheter bags heated in a microwave oven and activated MRE (Meal, Ready-to-Eat) heaters wrapped in towels were used to warm

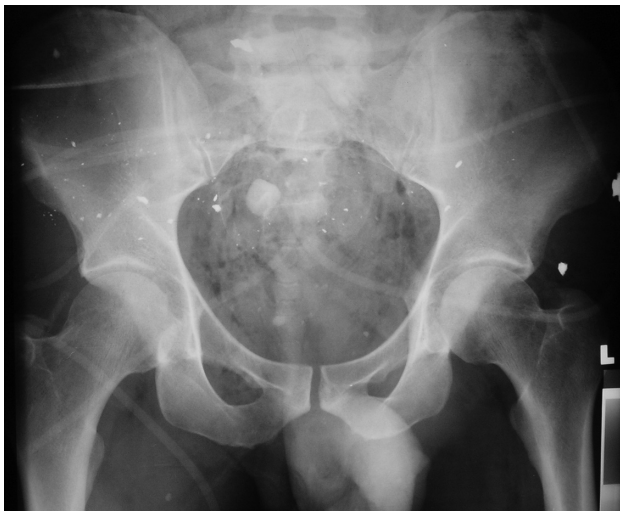

FIGURE 1. *Pelvic radiograph. Note numerous foreign bodies. The sacrum is transected at S2.*

FIGURE 2. *Damage control. Skin temporarily closed over packing.*

the patient. He was given whole blood transfusions until his platelet level was above 50,000 plts/mL. With resuscitation, the patient's temperature and vital signs normalized and acidosis improved. However, the patient's abdomen became increasingly distended, and serial ultrasound examinations revealed increasing amounts of intraperitoneal fluid. Once stabilized, the patient was returned to the operating room (OR) for laparotomy to rule out intraabdominal hemorrhage and to perform a diverting colostomy to treat the rectosacral wound. No intraabdominal wound was identified, and an end descending colostomy was performed (Fig. 4). The distal colon was closed, followed by closure of the abdomen. The following morning, 24 hours after initial injury, the patient was hemostatic. Evacuation was planned, but the timing of theater evacuation is unpredictable; therefore, the patient was taken back to the OR for washout and debridement of the rectal wound. The sacral packs were removed (Fig. 5). The raw surfaces were hemostatic, with the sandlike remnants of the QuikClot in place. Copious irrigation was used to remove the particles and necrotic tissue. Manipulation of the upper sacral body revealed a cerebrospinal fluid leak, and intraoperative consultation with a neurosurgeon was obtained. Definitive treatment of that injury was deferred to level V. Therefore, the wound was closed over closed-suction drains. Later that evening, the patient was evacuated to a level IV medical treatment facility with his surgeon attending and with CCATT (Critical Care Air Transport Team) assistance.

TEACHING POINTS

1. Combat-injured patients often present with multiple complex wounds. All variables must be considered when caring for these patients. It can be argued that the sacral injury should have been addressed first. However, it was clear that, when this patient presented, he would require staged procedures and damage control techniques.
2. The need for whole blood and other blood product transfusions must be identified early.
3. The need for damage control surgery must be made before irreversible acidosis and coagulopathy develop. Use all of your resources—physicians, nurses, and anesthetists—to resuscitate and stabilize the patient.
4. Ligation of internal iliac arteries may be effective in managing otherwise uncontrollable pelvic hemorrhage. It can be performed through the posterior wound in some situations. Bilaterial ligation of the internal iliac arteries is to be avoided, if possible.
5. In the combat setting, perform the least amount of surgery possible. In this case, the cerebrospinal fluid leak was controlled, and definitive repair was deferred to a level V medical treatment facility. If possible, attempt primary closure of the thecal sac. In many cases, this cannot be done because direct access may be difficult, or because the dura tends to be diaphanous and attempts at stitching can enlarge the tear. Instead, consider a dural substitute (eg, DuraGen). Follow with a fibrin sealant.

6. CSHs are designed to treat combat trauma. Predeployment and peacetime training must include patient care within the field treatment facilities. In this case, equipment as fundamental as patient warmers were not included in this hospital's inventory. Army surgeons must discipline themselves to participate in predeployment training and the process that develops field hospitals and the equipment set.

CLINICAL IMPLICATIONS

When caring for patients with multiple complex wounds, remember the basics:

1. Control the airway, obtain adequate intravenous access, and resuscitate the patient with warm fluids, including whole blood when appropriate.
2. Identify sources of hemorrhage and control hemorrhage by the simplest means available. This may include stabilizing extremity and pelvic fractures. Hemostatic agents (eg, chitosan) may be useful. Fresh frozen plasma and recombinant factor VII may be available. Trauma surgeons need to understand the preparation and use of all available blood products.
3. Control gross contamination and liberally defer definitive repair of bowel injuries until the patient is stable. A temporary closure with packs and drains in place is often helpful. When the patient is stable, planned reoperation is useful.
4. Rectal wounds can be difficult to diagnose. Injury should be suspected if trauma has occurred in proximity to the rectum, if there is an abnormal rectal examination, or if a radiograph suggests injury. The following principles apply:
    a. All rectal injuries should have proximal diversion. Sigmoid end colostomy is usually adequate. If the injury has not violated the peritoneum, exploration of the extraperitoneal rectum should not be done at laparotomy unless indicated for an associated nonbowel injury. This avoids contaminating the peritoneal cavity with stool.
    b. All rectal wounds should be drained. Presacral drains should be used for extraperitoneal rectal injuries. Fecal contamination of the perirectal space mandates presacral drainage.
    c. Distal washout of the rectum is usually necessary to assess the injury. Gentle pressure when irrigating will minimize contamination of the perirectal space.

FIGURE 3. *Rewarming and stabilization of the patient in ICU.*

    d. Debridement and closure are not necessary in small- or medium-sized wounds that have been diverted and drained.
    e. Hematoma in the perirectal space should be drained either transluminally by leaving the injured rectum open or by placing drains transabdominally or through presacral drains.
    f. Peritonealized rectal injuries are easily accessed transabdominally and should be repaired and protected with diversion.

DAMAGE CONTROL

This case aptly illustrates the principles of damage control. Damage control is defined as the rapid initial control of hemorrhage and contamination, temporary closure, resuscitation to normal physiology in the ICU, and subsequent reexploration and definitive repair. Concerning the cerebrospinal fluid leak: sew in a patch graft or lay one down and separate it with fascia and fat.

FIGURE 4. *Surgery; exploratory laparotomy and diverting colostomy.*

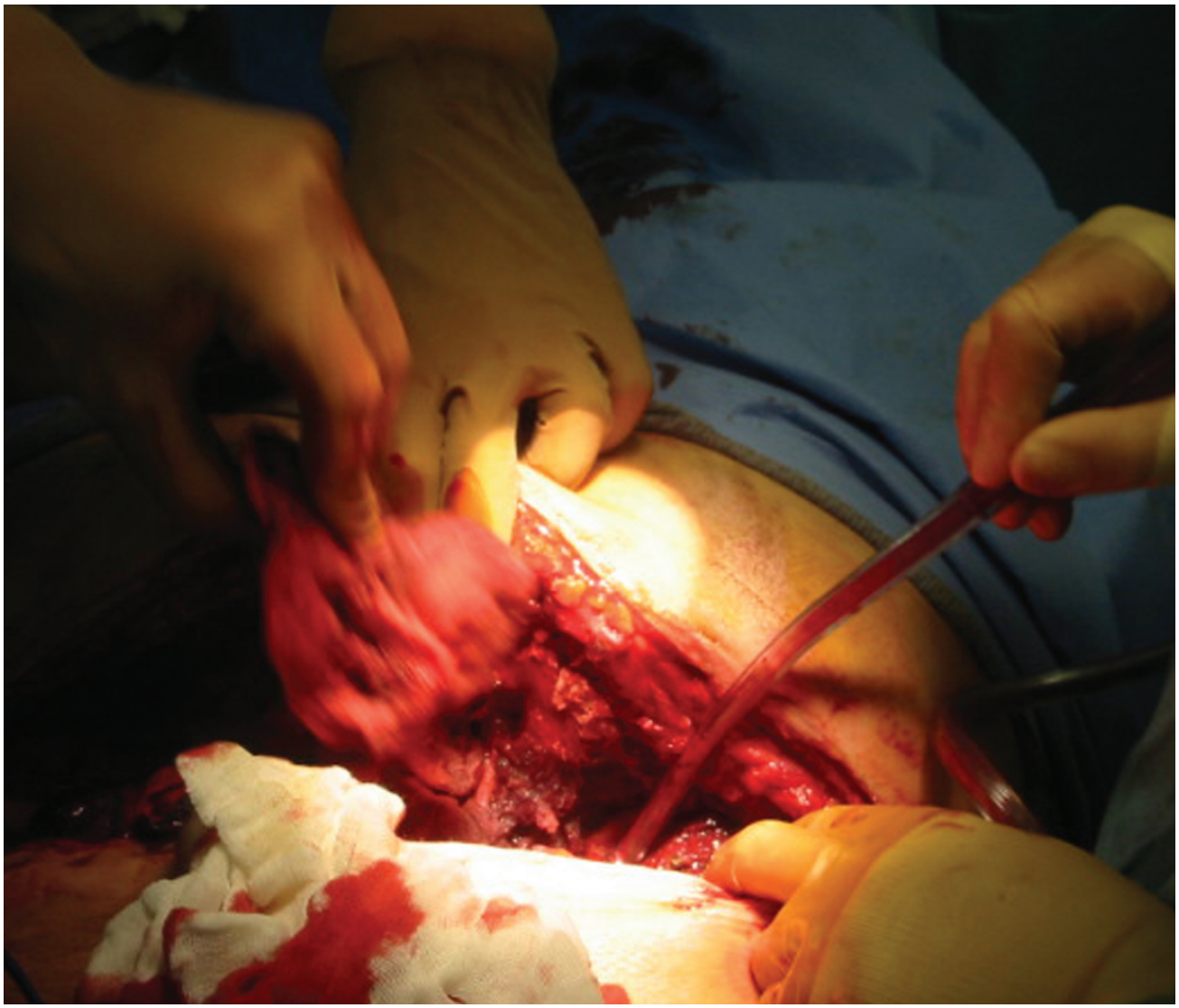

FIGURE 5. *Third surgery; sacral packs are removed.*

Divert cerebrospinal fluid with a lumbar drain. Pack the wound. Keep the patient flat.

SUMMARY

In this case, a patient with severe injuries survived those wounds by effective use of damage control techniques, including early aggressive resuscitation with whole blood and control of hemorrhage and gross contamination. When stable, the patient was returned to the OR for further required surgery and then evacuated. Perform CT/myelography at level V to rule out pseudomeningocoele.

Note: See discussion of this case on pages 202–203.

SUGGESTED READING

Chapter 4: Aeromedical evacuation. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 6: Hemorrhage control. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 12: Damage control surgery. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

THREE PHASES OF DAMAGE CONTROL

The goal of damage control is to restore normal physiology rather than normal anatomy. It is used for the multiply injured patient, with combinations of abdominal, vascular, genitourinary, neurological, orthopaedic, and/or thoracic injury in three separate and distinct phases.

1. Primary Operation and Hemorrhage Control—surgical control of hemorrhage and removal of contamination; laparotomy terminated, abdomen packed, and temporary closure; definitive repair is deferred.
   a. Control of hemorrhage.
   b. Exploration to determine extent of injury.
   c. Control of contamination.
   d. Therapeutic packing.
   e. Abdominal closure.
2. Critical Care Considerations—normal physiology restored in the ICU by core rewarming, correction of coagulopathy, and hemodynamic normalization.
   a. Core rewarming.
   b. Reversal of acidosis.
   c. Reversal of coagulopathy.
3. Planned Reoperation—reexploration to complete the definitive surgical management or evacuation.

Chapter 17: Abdominal injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 22: Soft-tissue injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

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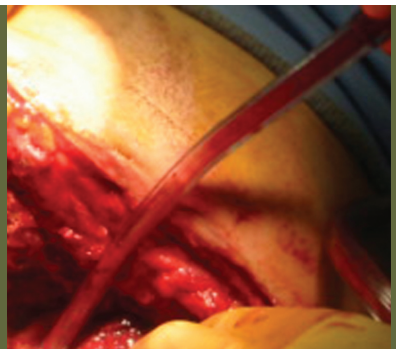

V.7 Renal Trauma

CASE PRESENTATION

A 23-year-old host nation male presented with a single gunshot wound following a sniper incident. The patient was alert and responding appropriately to questions. Initial vital signs revealed the following: blood pressure, 90/60 mm Hg; heart rate, 115 beats per minute; and temperature, 36°C. Primary and secondary surveys revealed diffuse abdominal tenderness and rebound, and a single entrance wound in the posterior axillary line on the left just below the 12th rib. The patient went directly to surgery, without imaging, based on the clinical examination. Exploratory laparotomy was negative, to include no obvious retroperitoneal hematoma. The patient received 2 units of packed red blood cells intraoperatively. Postoperatively, his vital signs stabilized. Approximately 10 hours postoperatively, the patient's vital signs became unstable, with blood pressure of 80/60 mm Hg and a heart rate of 130 beats per minute. Repeat laboratory evaluation revealed the following: hemoglobin, 7.5 g/dL; international normalized ratio (INR), 3.1; and partial thromboplastin time (PTT), 68 seconds. A CT scan was obtained (Fig. 1) and revealed a grade III right renal injury (Table 1) with no urinary extravasation and intact vessels. The bullet is shown. Because of the recent onset of hemodynamic instability and coagulopathy, a trial of nonoperative management was elected. The patient was given 2 additional units of packed red blood cells, 4 units of fresh frozen plasma, and 7,500 µg of activated Factor VII. Fluid resuscitation continued. Over the next several hours, urine output increased and vital signs stabilized. The coagulation parameters also normalized. The patient was discharged home on postoperative day 5.

TEACHING POINTS

1. Significant retroperitoneal injuries can be missed at exploratory laparotomy. Consider early imaging with negative findings at exploration.
2. The majority of grade III renal injuries do not require operation. Coagulopathy was a complicating factor in this case.
3. In patients with grade III or IV renal injuries—with no other indication for operative exploration—a trial of aggressive resuscitation with crystalloid and blood products is the first line of intervention. Operative exploration of the retroperitoneum is reserved for nonresponders.

Table 1. *Renal Injury Scale*

Grade	Type of Injury	Description
Minor		
I	Contusion Hematoma	Microscopic or gross hematuria; urological studies normal Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma Laceration	Nonexpanding perirenal hematoma confined to renal retroperitoneum <1.0-cm parenchymal depth of renal cortex without urinary extravasation
Major		
III	Laceration	>1.0-cm parenchymal depth of renal cortex without collecting system rupture or urinary extravasation
IV	Laceration Vascular	Parenchymal laceration extending through renal cortex, medulla, and collecting system Main renal artery or vein injury with contained hemorrhage
V	Laceration Vascular	Completely shattered kidney Avulsion of renal hilum that devascularizes kidney

4. The use of activated Factor VII is controversial; in this case, it may have been organ-sparing.

CLINICAL IMPLICATIONS

1. Management of blunt and penetrating renal trauma is directed by the grade of injury. Grades I to III involve varying degrees of laceration and hematoma with no disruption of the major vessels or collecting system. Grade V represents avulsion of the pedicle and is almost always managed operatively. Grade IV involves varying degrees of collecting system and/or vascular injury. Management of grade IV injuries can involve either immediate operative exploration or a trial of aggressive resuscitation with crystalloid and blood products, depending on the availability of resources and the level of expertise of available surgeons.
2. Renal trauma patients should have a Foley catheter in place and should remain on bed rest until gross hematuria clears.

DAMAGE CONTROL

In the absence of a CT scanner, a FAST examination of the retroperitoneum may detect a retroperitoneal hematoma. If no imaging is available, a high index of suspicion for retroperitoneal injury must be maintained based on the location of entrance and exit wounds. If the patient responds to fluid and blood product resuscitation, immediate evacuation to the next level of care should be initiated. If hemodynamics remains unstable, emergent operative intervention is required, with careful attention to assessment of the retroperitoneum. Nephrectomy may be the best solution for major renal injuries when other life-threatening injuries are present. Determining the function of the contralateral kidney (confirmed by contrast study) is desirable prior to nephrectomy.

SUMMARY

The kidneys and other retroperitoneal structures are at risk with blunt and penetrating abdominal, back, and flank trauma. If operative management is not immediately indicated, the imaging modality of choice is a three-phase CT scan of the abdomen and pelvis. Based on CT scan findings, renal trauma can be graded on a scale of I to V. Grades I to III and many grade IV

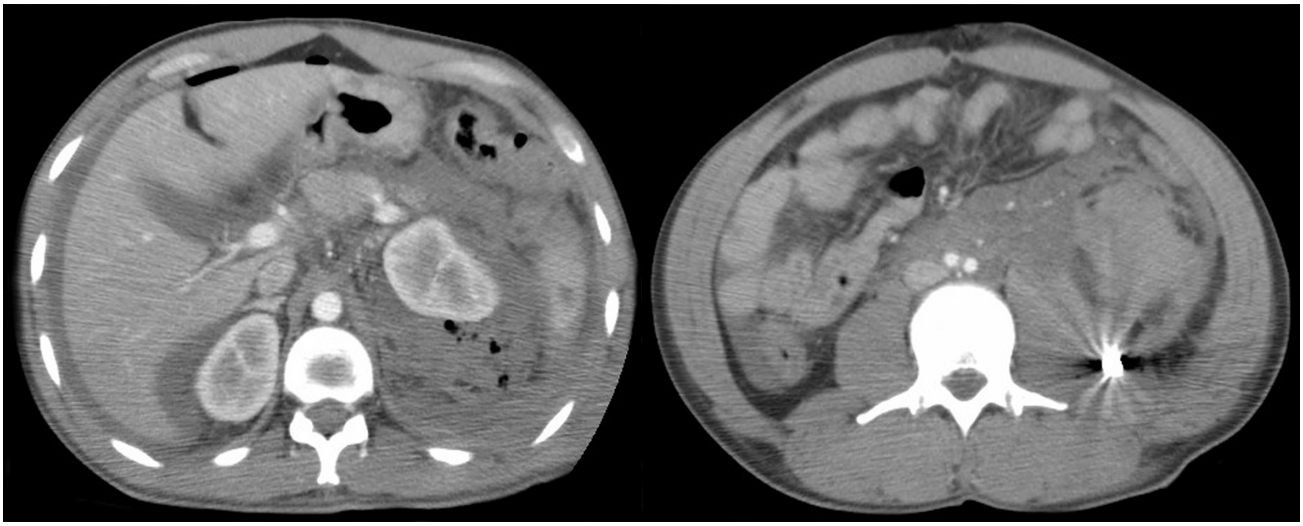

FIGURE 1. *Abdominal CT images obtained postoperatively. A large perinephric fluid collection and air lucencies* (Left)*, as well as bullet fragment* (Right) *are evident.*

injuries can be managed nonoperatively with aggressive fluid and blood product resuscitation.

SUGGESTED READING

Chapter 17: Abdominal injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 18: Genitourinary tract injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

V.8 Penetrating Pelvic Trauma

CASE PRESENTATION

A 27-year-old male sustained injuries after exposure to a blast from an improvised explosive device (IED). He was the front-seat passenger in a vehicle, and the blast occurred at the right front tire. On arrival, he was alert and answering questions appropriately. Vital signs were stable. Primary and secondary surveys revealed a right ankle blast injury and penetrating wounds to the upper posterior right thigh (Figs. 1 and 2) and medial left thigh. Abdomen, genitourinary, and rectal examinations, as well as the remainder of the physical examination, were normal. A plain film was obtained of the right foot and ankle and the right thigh. An anteroposterior pelvis radiograph was ordered. Two large shrapnel fragments were identified overlying the pelvis (Fig. 3). With this information, a CT scan was then obtained of the abdomen and pelvis. The CT scan showed two fragments: one fragment was adjacent to the base of the bladder on the right, and the other fragment was adjacent to the inferior pubic ramus and posterior aspect of the right corpus cavernosum (Fig. 4). The location of the fragments raised concern for the integrity of both the urinary tract and lower gastrointestinal (GI) tract. He was brought to the operating room for washout of the right ankle and further investigation of the lower urinary and GI tracts. Proctoscopy was negative. Cystoscopy and retrograde contrast studies revealed no injury in the urethra, bladder, or distal right ureter. He was observed overnight and evacuated in 24 hours to the next higher level of care.

TEACHING POINTS

1. IED fragments may have a significant distance of excursion from the entrance wound. Consequently, plain films should be obtained liberally in the trauma bay.
2. When pelvic fragments are identified, the integrity of the urinary and lower GI tracts must be considered. Further diagnostic testing should be planned based on radiographic and physical examination findings.

CLINICAL IMPLICATIONS

Penetrating injuries to the pelvis are often associated with abdomino-pelvic organ injury. Diagnosis of associated injuries may require

FIGURE 1. *Penetrating blast injury, right ankle.*

FIGURE 2. *Penetrating wounds, right posterior thigh.*

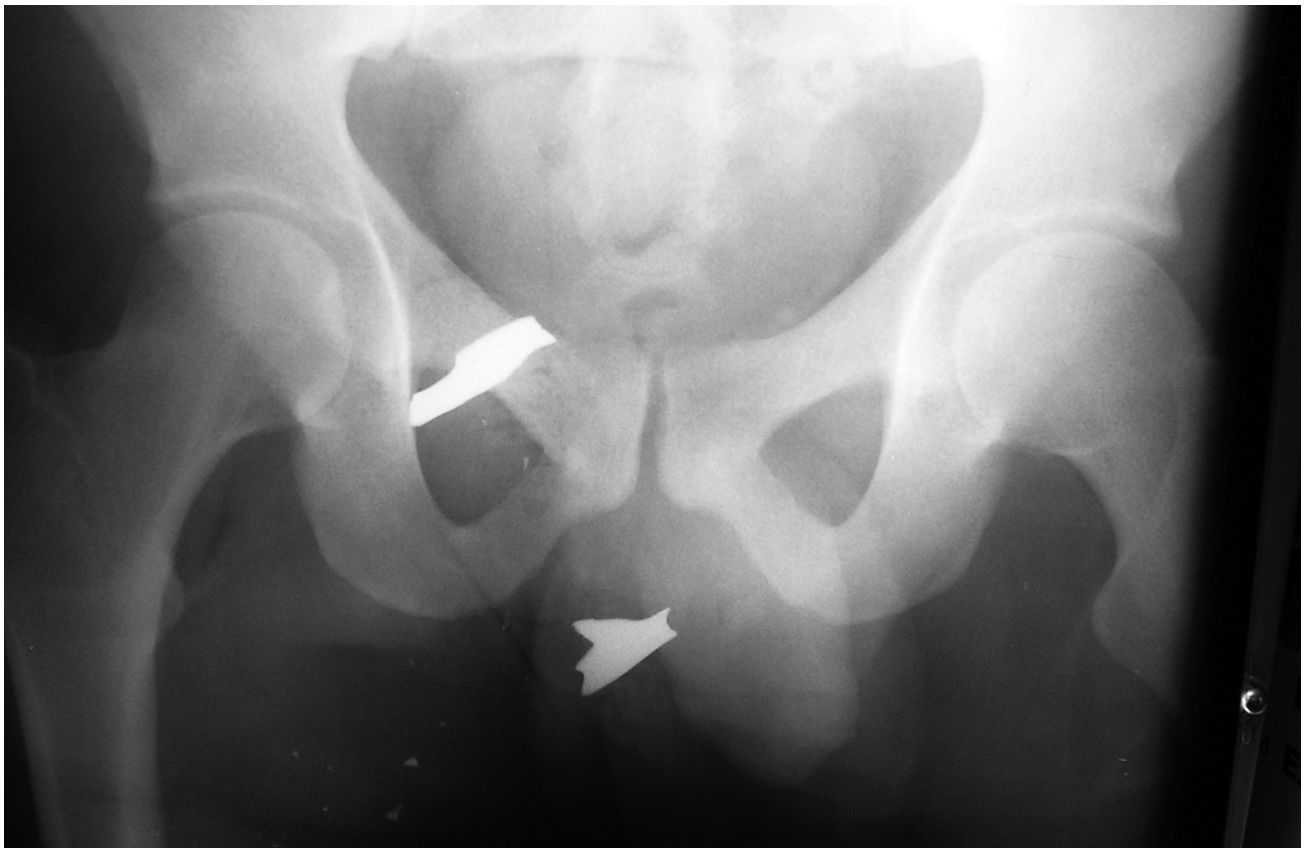

FIGURE 3. *AP pelvis radiograph. Note the two fragments.*

FIGURE 4. *Pelvic CT image. Note fragment (with associated scatter effect) at right posterior corpus cavernosum.*

exploratory laparotomy. Catheterization is contraindicated until urethral integrity is confirmed by retrograde urethrography.

DAMAGE CONTROL

For cases of suspected urethral trauma (blood at the meatus, scrotal hematoma, high-riding prostate), a retrograde urethrogram should be performed prior to insertion of a Foley catheter. If a urethral injury is discovered, a suprapubic catheter is recommended.

SUMMARY

IED blasts are the most common mechanism of injury in Operation Iraqi Freedom. They may result in multiple sites of trauma for a given patient. The location of the entrance wound prompts varying levels of concern for adjacent structures based on location. It must be emphasized that fragments may come to rest a significant distance from their entrance wounds. Liberal use of plain radiography and cross-sectional imaging should be utilized with this mechanism of injury.

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Chapter 18: Genitourinary tract injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 21: Pelvic injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 22: Soft-tissue injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

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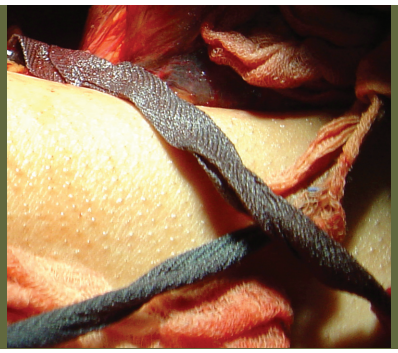

V.9 Penetrating Scrotal Trauma

CASE PRESENTATION

A 23-year-old host nation male presented as part of a mass casualty event after a suicide bomb attack. The patient was alert and complained of right hand, right groin, and right thigh pain. His injuries included a right-hand fracture and an avulsion of skin and subcutaneous tissue in the proximal/medial right thigh with a foreign body evident on examination (Fig. 1). The penile and scrotal examinations revealed diffuse edema and ecchymosis. The left testicle was palpable and unremarkable. The right testicle was nonpalpable. A radiograph of the pelvis/lower extremities revealed a foreign body superimposed on the inferior pubic ramus on the right (Fig. 2). A CT scan of the abdomen and pelvis revealed an abnormal appearance of the right testicle, air in the scrotum, and the foreign body posterior to the scrotum (Fig. 3). The patient was brought to the operating room for stabilization of the right hand, washout of the right thigh wound, and—based on radiographic findings and physical examination—scrotal exploration. On exploration, the foreign body was removed and was consistent with a human rib fragment with attached intercostal musculature (Fig. 4). The scrotum was explored through a midline incision at the median raphe. The patient had a ruptured right testicle. An orchiectomy was performed. He recovered well and was discharged on postoperative day 2.

TEACHING POINTS

1. Patients injured in suicide bomb attacks are at risk for both mechanical injury from blast effects and fragments. They are also at biological risk from "missile-ized" body parts.
2. The absence of a palpable testicle after blunt penetrating trauma should prompt scrotal exploration.

CLINICAL IMPLICATIONS

1. In many cases of scrotal trauma, as in this case, there are associated injuries prompting CT scan. CT scan and ultrasound of the scrotum are insensitive for testicular rupture and other scrotal pathology. A high index of suspicion based on mechanism of injury and physical examination findings should prompt scrotal exploration.
2. Testicular salvage after rupture is possible. Determining factors are the degree of remaining vascular supply to the tubule mass and

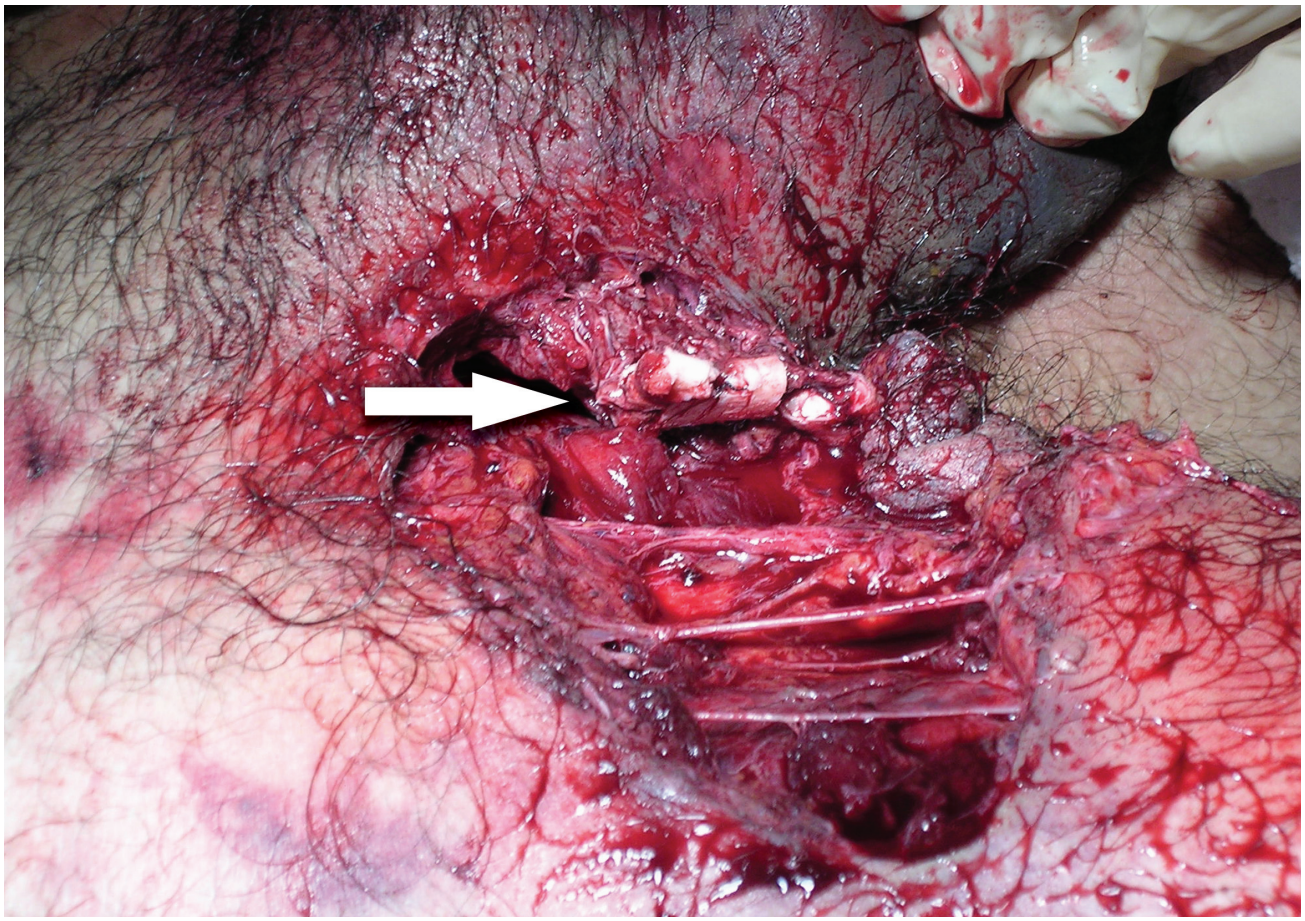

FIGURE 1. *Scrotum reflected to show proximal medial thigh wound. Note foreign body in wound* (arrow).

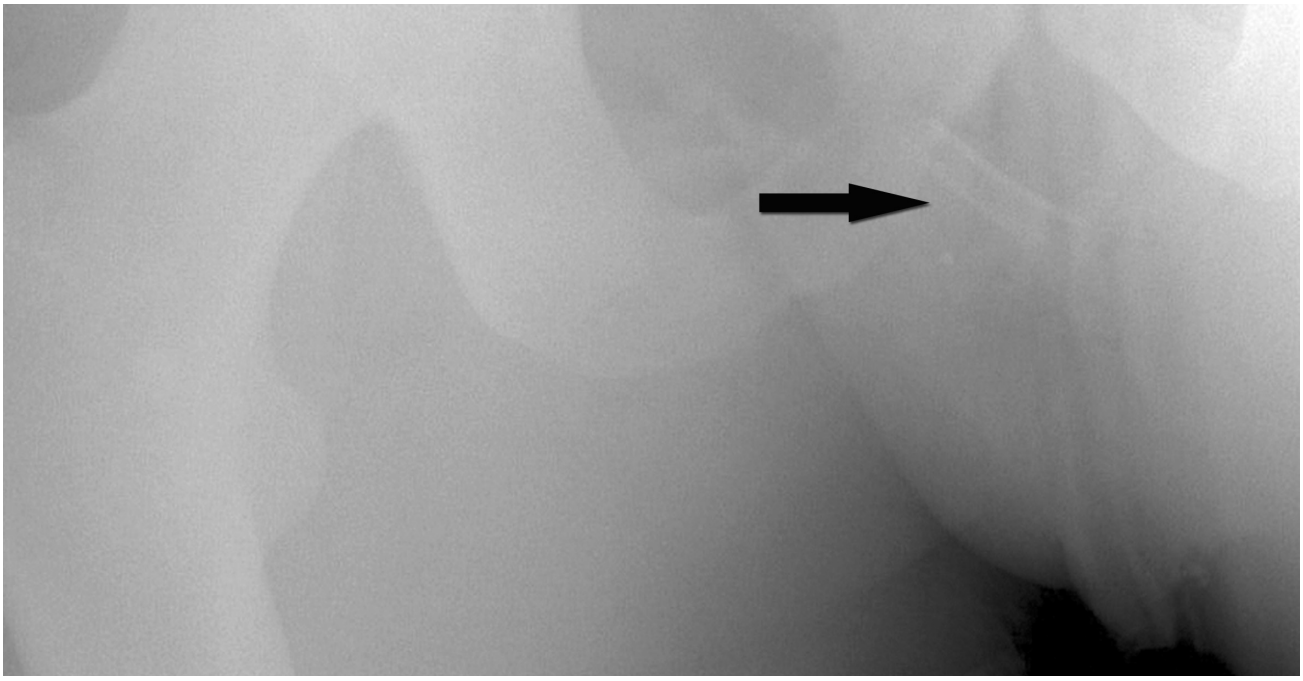

FIGURE 2. *Coned pelvic radiograph demonstrates foreign body overlying the right pubic ramus* (arrow).

FIGURE 3. *Pelvic CT image demonstrates air in right scrotum with the foreign body located posteriorly. Right testicle is abnormal.*

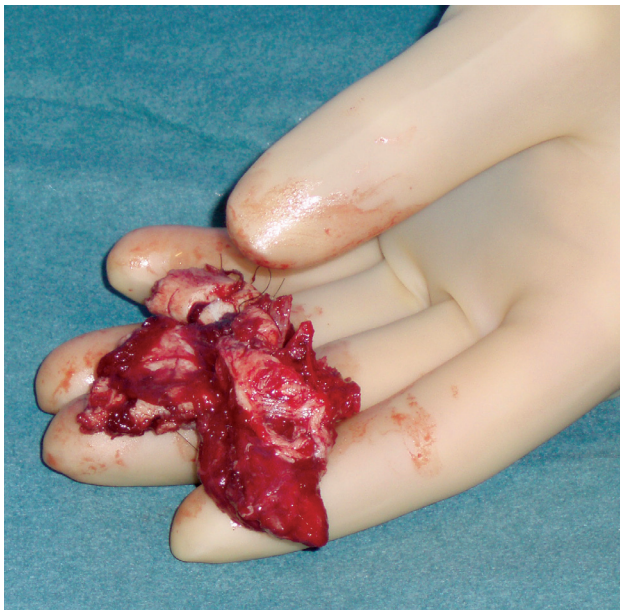

FIGURE 4. *Fragment of human rib removed from right scrotum.*

FIGURE 5. *Avulsed right testicle.*

the availability of remaining tunica albuginea to reconstruct the testicle. In this case, there was almost complete avulsion of the tubule mass (Fig. 5); therefore, orchiectomy was performed. However, as soon as the tunica albuginea (or epididymis or vas deferens) is violated, there is a breach of the blood–testis barrier, and there exists potential for the formation of antisperm antibodies regardless of the disposition of the testicle (salvage or removal). This does not guarantee infertility, but creates the risk of subfertility. If fertility becomes a clinical problem for these patients in the future, early referral to an infertility specialist is indicated.

3. In terms of testicular function, the remaining normal testicle produces enough testosterone for normal male physiological function.

DAMAGE CONTROL

In austere conditions, scrotal injuries are not emergent as long as hemostasis is achieved. If testicular salvage is to be entertained, the patient should be seen by a surgeon within 3 to 4 hours of injury. If the mission precludes immediate referral to a surgeon, it could be managed conservatively indefinitely until urological evaluation is possible.

SUMMARY

Patients injured in suicide bomb attacks are at risk for both mechanical and biological injuries. The examining provider must develop an index of suspicion for testicular injury based on mechanism and physical examination findings. CT scan and ultrasound are often unsatisfying in diagnosing testicular injury. Testicular salvage should be the goal, if mission allows, and the patient should be evacuated to the nearest urologist within 3 to 4 hours of injury. If immediate referral is not possible, and operative facilities are not immediately available, scrotal injuries can be managed conservatively indefinitely until referral is possible.

SUGGESTED READING

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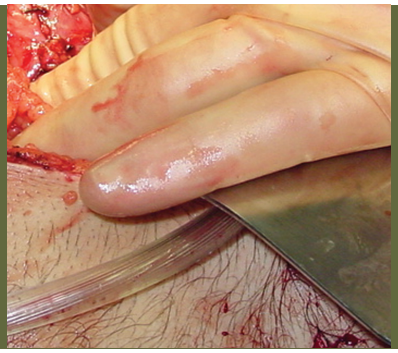
Chapter 18: Genitourinary tract injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.



V.10 Genital Soft-Tissue Trauma

CASE PRESENTATION

While on patrol, a 29-year-old male soldier sustained multiple blast injuries when his vehicle was struck by an improvised explosive device (IED). He was resuscitated at the Forward Surgical Team (FST) facility and transferred to a level IV medical facility. In addition to dramatic soft-tissue injuries to the penis and scrotum, he suffered head, face, right hand, and bilateral lower extremity injuries. The patient underwent wound debridement and genital reconstruction that included a left orchiectomy, repair of the ruptured right testicle, urethral reconstruction over a 12-gauge French urethral catheter, penile glans reconstruction, and skin closure (Fig. 1). He was evacuated to the United States on the fifth day following his injury. The penile and urethral reconstructions failed with progression of nonviable tissue, and the repairs were taken down for additional debridement (Fig. 2). Delayed reconstruction was started 2 weeks after the injury by placement of a split-thickness skin graft to the wound bed (Fig. 3).

TEACHING POINTS

1. High-energy injury to the soft tissue of the genitalia can cause delayed tissue necrosis.
2. Early reconstruction has a greater risk of failure.
3. Closure of the corpus cavernosum is advisable for small injuries.
4. Tension-free approximation of the urethra and corpus spongiosum with absorbable suture is recommended.
5. Genital skin should be reapproximated loosely at its anatomical site.
6. Generous use of drains is recommended.

CLINICAL IMPLICATIONS

1. Genital wound debridement can be done quickly during damage control surgery. This is accomplished through judicious removal of nonviable tissue with copious irrigation or pressure lavage of the wound. Tissue devitalization from high-velocity projectiles is not always apparent at initial evaluation. Delayed necrosis can jeopardize early reconstructive efforts. Definitive wound closure should, therefore, not be attempted in this early period. Final cosmetic and functional results, however, are enhanced if loose approximation of the tissue is accomplished with several widely separated nylon sutures that can be removed at the next surgery for further debridement. The

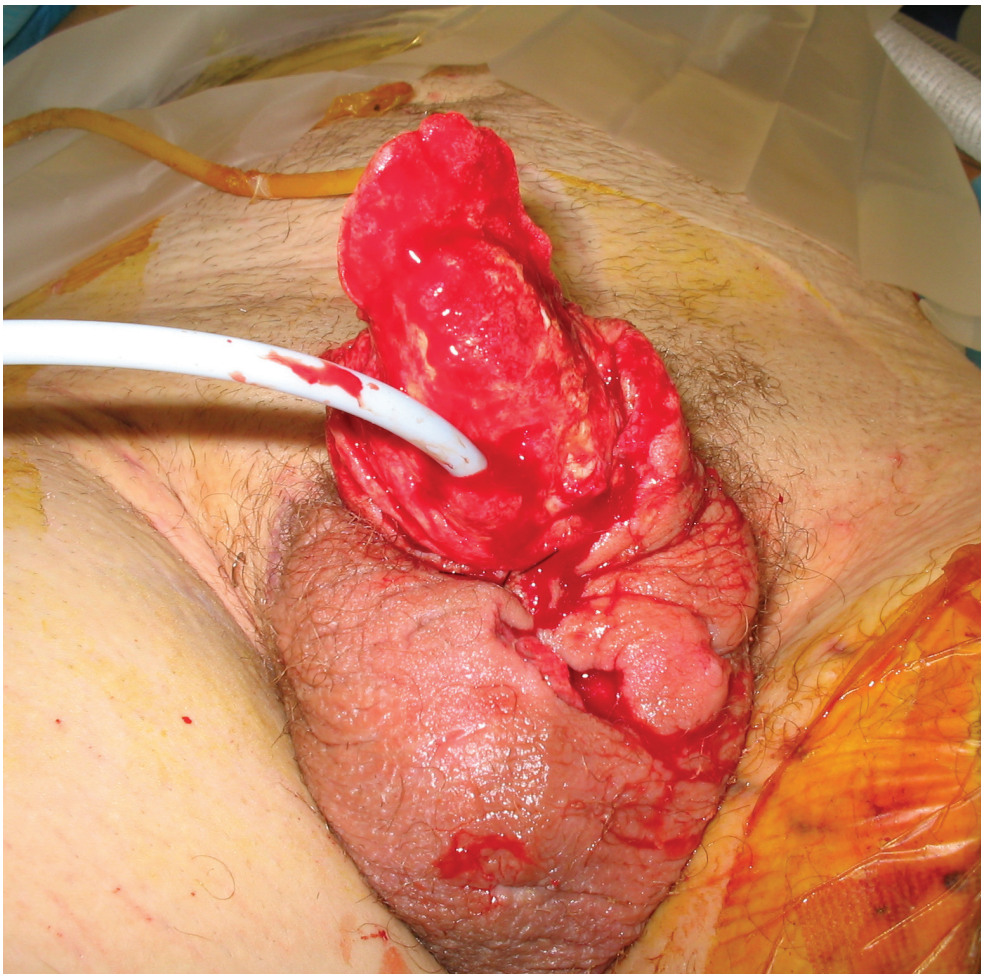


FIGURE 1. (Top Left) *Intraoperative appearance of genital trauma from blast. The left testicle has been removed and the right one repaired. The glans penis is traumatically divided with half partially attached by a skin bridge. The transected corpus cavernosum is visible below a small intact segment of glans. The proximal urethral opening is visible at the base of the shaft near the penoscrotal junction.* (Top Right) *An aggressive, early attempt at reconstruction. Little of the reconstructed tissue would survive.*

FIGURE 2. (Bottom) *Subsequent intra-operative appearance of the injury after all nonviable removed. The scrotum is nearly reapproximated in this image.*

FIGURE 3. *Final reconstruction after staged buccal and split-thickness skin grafts are formed into a new urethra.*

loosely approximated wound should be drained completely with Penrose drains, small suction drains, or a wound vacuum.

2. Injury to the corpus cavernosum and urethra requires more detailed attention at the time of injury. The integrity of the urethra can be determined by retrograde urethrography or urethroscopy. Cavernosal injuries should be suspected when a large penile hematoma is present. Exploration and repair of the tunica albuginea can improve final function. This repair can be completed through the penile wound, by penile skin degloving, or by a vertical incision in the penis at the site of corporal injury. It is important to remember that the neurovascular bundle to the glans runs along the dorsum of the penis. A ventral approach to the tunica albuginea can reduce injury to these structures.
3. Small fragment injuries to the penis may not require extensive debridement. Experience shows that aggressive exploration for these small fragments is not warranted in the acute setting and can be accomplished later if symptomatic.

DAMAGE CONTROL

Genital wounds are seen frequently with concurrent wounds to the abdomen and lower extremities. Initial treatment often requires damage control principles. Rapid removal of obvious devitalized tissue, copious irrigation of the wound, loose approximation of penile skin with maximal wound drainage, and Foley catheter placement—when feasible—can be accomplished swiftly in the seriously injured patient. Repair of the urethra and corpus cavernosum with absorbable sutures may reduce bleeding and aid in damage control. Delaying closure, however, is sometimes necessary when tissue loss is severe, tissue viability is uncertain, or the patient is hemodynamically unstable.

SUMMARY

Soft-tissue injuries to the genitalia are devastating. Early surgical intervention should entail judicious wound debridement that favors observation of tissue of uncertain viability rather than aggressive removal. Delayed reconstruction appears superior to premature attempts at penile and scrotal skin closures. Loose approximation of tissue with liberal use of drains aids future reconstruction. Early approximation of urethral and corpus cavernosal injuries may assist in hemorrhage control and improve future function.

SUGGESTED READING

Chapter 18: Genitourinary tract injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

Chapter 22: Soft-tissue injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

COMMENTARY

Damage Control

by COL George E. Peoples, MD

A theme of this chapter is damage control surgery as it pertains to the injured abdomen. Usually applied to the unstable patient, and revisited throughout this book, this approach is a well-accepted concept among civilian and military trauma surgeons. Its basic requirement is a staged approach to the severely injured patient at risk for the lethal triad of hypothermia, acidosis, and coagulopathy. In general, there are three phases to damage control surgery: (1) primary surgery that assesses the extent of injury and controls hemorrhage and gross contamination; (2) intensive care unit resuscitation to address warming, to reverse acidosis, and to correct coagulopathies; and (3) planned reoperation for more definitive management of injuries. The latter steps may need to be repeated as often as necessary to correct the injuries without unduly stressing the patient.

There are, however, some notable differences in the civilian and military applications of the damage control concept. The most prominent among these is overall management of the patient. In the civilian realm, a single surgeon usually manages the entire damage control sequence. He knows firsthand the extent of the injuries, what was and was not done at the first surgery, and when best to take the patient back to the operating room, based on carefully observed and measured physiology. Contrast that to the combat-wounded soldier who may have his first procedure performed in a tent at the Forward Surgical Team (FST) facility, is then evacuated immediately to a Combat Support Hospital (CSH) for aggressive resuscitation, then flown to a level IV medical treatment facility where the next procedure is performed, and finally receives definitive repair at a level V hospital in the United States. Further compound this sequence by compressing it into 4 to 5 days. For optimal care, the military sequence requires precise communication and coordination. Unfortunately, this chain of communication is not always feasible, given the constrictions of the tactical situation, the necessity of establishing intermediary levels of care, and the uncertainty of uncontested aeromedical evacuation. In the absence of seamless transfers, military trauma surgery is dependent at its core on the understanding, practice, and flexible application of damage control surgery by all participating military surgeons.

Even with this doctrine firmly established in the military realm, deployed military surgeons must still be extra conservative in their surgical decisions. Patients must be thoroughly reassessed at each level of evacuation. Most importantly, military surgeons must be flexible and innovative in their management of injured soldiers.

Many of the concepts that have been advanced in civilian trauma centers leading to nonoperative management of certain injuries (splenic laceration), reliance on specialized services like interventional radiology (embolization), and earlier definitive repair (colon repair vs colostomy) may be impossible in combat-wounded personnel because of the unavailable imaging or intervention technologies, and/or ill-advised because of the inability to conduct continuous close follow-up, as outlined in the sequence above. Combat wounds are also different from those seen in civilian trauma centers where these advances in technology have been implemented. Combat trauma is often a result of high-energy projectiles. Multiple complex injuries are the norm. Initial management often occurs in an austere environment with limited resources and prolonged evacuation times. The patient's condition on arrival to the military surgeon is often not comparable with the civilian emergency department.

One of the greatest challenges of any evacuation system is the requirement to maintain the flow of relevant medical information through each level of care in pace with the

patient's movement. The disruption of this information flow results in missed injuries, compartment syndromes, delayed treatments, and potentially unnecessary procedures. The evacuation system must strive to improve the conveyance of real-time treatment information from level to level. Follow-up information sent backwards, so that surgeons and medical units can assess and adjust their overall quality of care, is also an essential requirement.

A military-relevant algorithm of how best to care for any specific injury, including the intraabdominal injuries cited in this chapter, is virtually impossible because there are too many variables that are uncontrollable. Many of the treatment decisions for a specific injury will be necessarily influenced by the following:

- patient's condition,
- resources available (most often determined by which level of care the surgeon finds himself),
- availability of the next higher level of care (often dictated by the phase of the conflict), and
- time to evacuation (determined by the tactical situation and weather).

A surgeon at a FST who is faced with the same injury as a colleague at a CSH, may—by necessity—treat it completely differently. In the absence of pertinent and useful treatment algorithms, we rely on principles.

The military version of damage control surgery, as well as the overall surgical management of the injured soldier, relies on the premise that the patient should have only that surgery necessary to stabilize him for safe evacuation to the next level of care. This may mean *no* surgery at an FST facility if the patient is stable. The principle guiding which injuries should be addressed and when is that of escalating intervention. For a vascular injury, escalation may mean ligation if necessary, repair if circumstances permit, or bypass if not reparable (shunt if expedience is required). For a colon injury, escalation might be simple repair, exterioration, formal colostomy, repair with protective ostomy, resection with ostomy, or resection with anastomosis. This general concept is applicable to most injured organs and pairs the increasing complexity of the procedure with the sophistication of resources available, and the time required to complete it. The decision of what procedure to perform for any given injury will be dictated not only by the usual parameters of the patient's condition, severity of the specific injury, and associated injuries; but also by the level of care, resources available, tactical situation, and availability of evacuation. Military surgeons must have a working knowledge of escalating interventions for the wide array of specific intraabdominal injuries. They must embrace the concept of damage control surgery, understand the levels of care and the evacuation system, and appreciate and anticipate the constantly changing environments in which they may find themselves when caring for the combat wounded.

COMMENTARY

Abdominopelvic Trauma, Cases Review

by LTC Brennan J. Carmody, MD

The cases in this chapter highlight the vast differences between abdominal trauma encountered in military and civilian settings. High-velocity projectiles and combinations of blast and penetrating injuries can result in extensive tissue destruction that may not be immediately apparent. An understanding of these injury patterns and the application of damage control principles are crucial in minimizing morbidity and mortality.

CASE V.1 (Indirect Effects of Wounding) is an excellent example of the effects of combined blast-penetrating injuries. Despite the absence of peritoneal entry, the cavitation produced by this high-velocity abdominal wall injury led to a full-thickness colon injury. The need to rule out intraperitoneal entry led to abdominal exploration and management of the colon injury. A high level of suspicion must be maintained with these mechanisms of injury, because military bullets travel in excess of 3,000 f/s. Despite a relatively benign-appearing wound and the absence of objective evidence of intraabdominal penetration, one should have a low threshold for laparotomy. These high-energy tangential wounds are prone to progressive soft-tissue devitalization and may evolve into necrotizing fasciitis. These wounds should be serially debrided and allowed to heal by either delayed primary closure or secondary intention.

Another important teaching point involves the differences in management of colon injuries, depending on whether the patient will remain in theater or enter the evacuation chain. Most surgeons would consider it reasonable to perform a segmental colectomy with ileocolostomy in the absence of hypotension, significant fecal soilage, and significant associated injuries in any patient who would remain in theater under close supervision. In patients who will be evacuated to higher echelons of care, end colostomy should strongly be considered, given the potential for prolonged evacuation times, the break in continuity of care, and the high-injury mechanisms of energy frequently encountered.

CASE V.2 (Penetrating Trauma to the Stomach and Pancreas) illustrates the high likelihood of associated injuries in upper abdominal penetrating trauma. It is critical to explore all areas of the abdomen, including the lesser sac. Routes to access this space include the gastrocolic and gastrohepatic ligaments. Additionally, a Kocher maneuver should be performed routinely to assess the posterior aspects of the duodenum and pancreas. In damage control settings, drainage of pancreatic fluid is all that should be done. More definitive interventions can be performed when the patient has been appropriately resuscitated. Given the propensity for pancreatic anastomoses to leak, distal pancreatectomy should be considered before using pancreaticojejunostomy to the distal pancreatic remnant. The somatostatin analogue octreotide acetate (sandostatin), administered subcutaneously (starting dose: 50 µg t.i.d.), can be initiated if pancreatic leak occurs and may decrease outputs; the dose can be titrated to the point of cholestasis.

CASE V.3 (Blunt Abdominal Trauma) eloquently describes staged management of a complex duodenal injury. Combined gastrointestinal and vascular injuries are common, and patients who have sustained such trauma often present in shock with elevated Injury Severity Scores, hypotension, coagulopathy, acidosis, and hypothermia. Surgeons managing this case took the appropriate initial actions to control hemorrhage and gastrointestinal soilage, and made no efforts to reestablish gastrointestinal continuity. Following resuscitation and return to the operating room, drainage of the isolated portions of the foregut was established, along with placement of a jejunostomy for enteral feeds. Visceral edema precluded

definitive abdominal wall closure, and an absorbable mesh was placed with plans for subsequent skin graft and planned ventral hernia. The patient was then transferred to a host nation medical facility.

This case illustrates several teaching points. First, definitive gastrointestinal reconstructions should only be performed after adequate resuscitation, resolution of visceral edema, and restoration of protein stores. This patient's status resulted in transfer to a local hospital prior to meeting these criteria. In patients entering the evacuation chain, temporary abdominal closure should be established in theater with definitive reconstruction performed at higher levels of care (where the patient will be more likely physiologically ready for such complex surgery). Definitive reconstruction options would include Roux-en-Y gastrojejunostomy with duodenojejunostomy to allow for drainage of biliopancreatic fluids.

Second, proper management of the open abdomen continues to evolve. Whereas placement of absorbable mesh with skin grafting and planned ventral hernia remain an option, other techniques that avoid the morbidity of the planned ventral hernia are becoming more widely used. Vertrees and colleagues[1] reported their experience with serial abdominal closure using polytetrafluoroethylene mesh as a temporary closure. In this technique, the mesh allows abdominal domain to be reestablished, and the mesh is tightened at intervals leading to early definitive abdominal closure. Such closures involved either primary closure or an onlay interposition using polypropylene mesh. No fistulae developed, although the average time from initiation of serial abdominal closure to definitive closure was 45 days (range: 15–160). A more novel approach involves the use of bioprotheses, such as AlloDerm (an acellular dermal matrix that can be used to reconstruct abdominal wall defects). This prosthetic supports vascular and collagen ingrowth. It is relatively resistant to infection and can be used for definitive abdominal closure. Advantages include a potential shorter interval between injury and definitive abdominal closure, and use in previously contaminated fields. More long-term data regarding its durability are needed. Regardless of the technique used for abdominal closure, key principles include early use of a vacuum-assisted, nonadherent covering for the abdomen (ie, the VAC Abdominal Dressing System) or a Bogota bag that protects the viscera and allows full access to the entire abdomen. Vacuum and suction dressings also improve visceral edema and allow quantification of fluid losses. Such early management will allow a full range of options for abdominal closure.

CASE V.4 (Missed Duodenal Injury) reiterates the need for thorough exploration following penetrating upper abdominal injury. The close proximity of gastrointestinal, vascular, and urological structures makes concomitant injury likely. Delay in diagnosis of duodenal injuries is associated with substantial morbidity and mortality. Occasionally, inflammatory changes will preclude primary repair of an otherwise minor injury. In such cases, placement of an appropriately sized Malecot drain can convert the injury to a tube duodenostomy that allows control of secretions. This option should be combined with a gastrostomy tube and wide drainage. Alternatives include repair with duodenal diverticularization or pyloric exclusion. This case also highlights the need for prompt communication between surgeons and facilities in cases in which full exploration was not feasible. Regardless of the thoroughness of prior procedures, a low threshold to reexplore unstable or deteriorating patients should be maintained, given the potential for missed or evolving injuries, recurrent or persistent hemorrhage, or undrained collections. This is especially critical in patients who will enter the evacuation system where continuity of care can be compromised.

In **CASE V.5** (Traumatic Evisceration), surgeons encounter and manage traumatic evisceration following blast injury. Key points include prehospital management (saline gauze, no efforts to reduce the viscera), control of enterotomies prior to reduction, full abdominal exploration, and resection of frankly nonviable intestine. When viability is questionable, the abdomen can be temporarily closed with reassessment in 24 to 48 hours. Occasionally, edema of the eviscerated bowel may require enlargement of the fascial defect (analogous incarcerated ventral hernias). Management of the fascial defect at the evisceration site can be problematic, especially in the setting of blast injury or high-velocity projectiles. Prostheses such as VICRYL or AlloDerm reestablish abdominal wall integrity and decrease the likelihood of postoperative evisceration through the entrance wound. Progressive devitalization of soft tissue is common, and the wound should be serially washed out and debrided as necessary.

CASE V.6 (Penetrating Rectal Injury) includes many of the war surgery tenets previously described: damage control techniques for combined visceral and vascular

injuries, early resuscitation and rewarming, and return to the operating theater for further required surgery. Prompt initiation of a whole-blood drive was a key decision. As similar devastating injuries have become more common, deployed laboratories and blood banks have become incredibly efficient in acquiring and preparing whole blood. Activated Factor VII is also now widely available and has a role in similar situations. Ligation of the internal iliac arteries is effective in managing otherwise uncontrollable pelvic hemorrhage and can be performed through the posterior wound in some situations. It is more commonly performed transabdominally. Rectal injury should be suspected in nearly all settings of penetrating buttock wounds and ruled out with rigid proctoscopy. Small extraperitoneal rectal wounds do not need to be repaired; proximal diversion, presacral drainage, and gentle distal rectal washout should suffice.

This case illustrates the creativity displayed by hospital personnel to actively rewarm their patient using MRE (Meal, Ready-to-Eat) warmers. I have also personally seen space heaters and hair dryers used in similar scenarios. It is such innovation that we must constantly use as we care for the wounded, with increasingly severe injuries, in austere environments.

REFERENCE

1. Vertrees A, Kellicut D, et al. Early definitive abdominal closure using serial closure technique on injured soldiers returning from Afghanistan and Iraq. *J Am Coll Surg*. 2006;202: 762–772.

Courtesy David Leeson, *The Dallas Morning News*