Visceral Vascular Injury

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Objectives: At the completion of this module fellows will be able to:

1. **Describe the anatomic boundaries of the retroperitoneal zones of injury that characterize abdominal vascular injury.**
2. **Describe the approach to visceral vascular injury based upon retroperitoneal zone.**
3. **Differentiate management priorities for trauma patients presenting with active hemorrhage, contained hemorrhage and thrombosis of major abdominal vasculature.**
4. **Describe alternatives for management of individual visceral blood vessels including indications for repair, bypass and ligation.**
5. **Describe indications for adjunctive treatments including the use of massive transfusion protocols and damage control principles.**
6. **Describe the utility of endovascular therapy for visceral vascular injury.**

Background:

- The management of traumatic injuries to the visceral vasculature requires a thorough knowledge of the anatomy of the retroperitoneum.
  - Zone I: Includes the upper midline retroperitoneum and is subdivided into the supramesocolic (above the transverse mesocolon) and inframesocolic region.
    - Supramesocolic region: contains the origins of the celiac axis and its major branches as well as the superior mesenteric artery and vein
    - Inframesocolic region: inferior mesenteric artery and vein
  - Zone II: Includes the upper lateral retroperitoneum and consists of the kidneys and renal vasculature, although the origins of the renal arteries and veins lie within Zone I.
  - Zone III: Includes the pelvic retroperitoneum and contains the common, external and internal iliac vessels and their branches.
  - Porta hepatis: The origin of the portal vein at the confluence of the splenic and superior mesenteric vein occurs behind the pancreas; the portal vein travels posterior to the hepatic artery and bile duct in the portal triad. The retrohepatic vena cava also lies posterior to these structures.
- Abdominal vasculature injury occurs in approximately 20-25% of civilian gunshot wounds. Visceral vascular injury is much less common after blunt trauma (< 5%).
- Injury to the renal arteries may occur from blunt or penetrating trauma. Blunt injury is generally a deceleration injury in which the kidney is relatively mobile and the renal artery orifice is relatively fixed on the aorta. The sudden movement of the kidney away from the aorta through a direct blow or intraabdominal trauma may result in partial to complete vessel wall disruption. This may present as an anatomically intact vessel without flow to a complete disruption of the artery with retroperitoneal blood loss and every variety of vessel disruption in between. Complete avulsion is seen in about 10% of renal artery injuries.

Evaluation/Diagnostics:

- Visceral vascular injury can present with free hemorrhage, contained hematomas, arteriovenous fistulae or thrombosis
  - Deceleration injuries can cause avulsion of branches of major vessels at sites of fixation. These tend to present with free hemorrhage or a contained hematoma. Alternatively, deceleration can cause intimal injuries in major vasculature and present with acute thrombosis or late pseudoaneurysm formation.

    - Crush injuries (e.g. lap belts) can cause avulsion with hemorrhage or intimal injury with thrombosis. The classic description of "seat belt aorta" is an example of crush injury leading to infrarenal aortic thrombosis.
    - Penetrating injuries can cause direct trauma leading to complete transections or lateral wall injuries. These present with free hemorrhage or thrombosis, or rarely in the case of lateral wall injuries arteriovenous fistulae.
    - Blast injuries with intimal damage and thrombosis are also thought to occur but are not common outside the military setting.
    - Iatrogenic injuries can occur during diagnostic procedures, therapeutic interventions (aortic balloon pumps, REBOA), open abdominal operations, or spinal operations.
- The initial presentation and subsequent evaluation of patients relate to the presence or absence of free intraabdominal hemorrhage.
    - Ongoing hemorrhage from major abdominal vasculature is generally associated with the classic "non-responder" physiology described in Advanced Trauma Life Support. These patients have persistent and refractory shock with signs of intra-abdominal hemorrhage. Physical exam and analysis of bullet trajectory with plain radiography, supplemented with bedside diagnostics (FAST, diagnostic peritoneal aspirate) as needed should lead to early operation prior to cardiovascular collapse.
    - Patients with contained hematomas, especially those with a major venous injury, may be stable initially. The majority of patients with a transperitoneal gunshot wound are operatively explored. Stable patients with stab wounds, blunt mechanisms, or isolated right upper quadrant gunshot wounds may be candidates for appropriate adjunctive imaging and subsequent observation or endovascular intervention.
    - Patients presenting with thrombotic complications of their injury will generally have lower extremity pulse deficits or significant abdominal pain. Urgent contrasted CT scan or angiography can delineate the extent of injury or be performed if immediate operative intervention is not indicated.
- Patients may present in profound shock. Damage control resuscitative techniques including the use of massive transfusion protocols with empiric high fixed ratio component therapy and limited crystalloid infusion should be employed.
- For patients in extremis, the use of pre-laparotomy thoracotomy has fallen out of favor in the last two decades. Salvage rates for Emergency Department Thoracotomy for patients presenting with signs of life after penetrating trauma to the abdomen are relatively low but this invasive technique may be worthwhile in selected patients. Alternatively, Remote Balloon Occlusion of the Aorta (REBOA) may also be attempted if it is within the surgeon's skill set. Penetrating injury to major abdominal vasculature may complicate catheter placement. There is limited long term data on the use of this technique specifically in patients with visceral vascular injury.
- In patients with renal artery injuries, if patient hemodynamics allow a radiographic evaluation, an abdominal CT with intravenous contrast will identify the degree of disruption and most importantly inform the clinician as to the presence and size of the contralateral kidney and adequacy of flow. This modality has essentially replaced the utility of the on-table intravenous pyelogram (IVP). The presence of contrast will also allow visualization of a pseudoaneurysm of the renal artery. In the event that patient instability determine that exploratory laparotomy is paramount then determination of a viable functional contralateral kidney is important prior to exploration of any zone II hematomas. This is as easy as palpation of the size of the opposite kidney (10-12 cm optimal) and placement of a Doppler on the renal parenchyma to document arterial flow. In 10-15% of cases of renal artery injury both kidneys are involved.

Operative Technique: (Please see video clips)

- Preoperative Planning:
    - Wide trauma prep should be performed from the patient's chin to their knees.
    - Most patients are positioned supine with arms extended.
    - Thoracotomy and major vascular equipment should be available.
    - A wide variety of vascular suture and aortic clamps should be selected.
    - The blood bank should be notified and appropriate blood products should be on hold, or the massive transfusion protocol should be activated.
    - Cell saver techniques should be considered if there is no associated bowel injury.
- Exposure:
    - Supramesocolic region of Zone I:
        - Zone I is widely exposed using a left medial visceral rotation which involves midline mobilization of the left and sigmoid colon, the spleen, tail of the pancreas and potentially the left kidney.
        - Exposure includes the entire left side of the abdominal aorta from the diaphragmatic hiatus to the bifurcation and allows access to the origin of the celiac axis, the superior and inferior mesenteric arteries. The origin of the celiac and superior mesenteric artery may be merged in a "V" shape on the anterior aorta.
        - The celiac axis is buried deep in the retroperitoneum within centimeters of the aortic hiatus; proximal control may require thoracic aortic control and distal control is through the left medial visceral rotation.
        - If more space is required for proximal control, the aortic hiatus of the diaphragm may be divided in the 2 o-clock position to expose the distal thoracic aorta.
        - Performing a left medial visceral rotation may take 5-10 minutes, but this is the preferred exposure to the origins of the foregut and midgut vasculature.
        - For those patients who are exsanguinating, aortic occlusion at the hiatus may be obtained with initial limited exposure of the aorta. The aorta is exposed in the midline by retracting the stomach and esophagus (with the NG tube in place) to the patient's left and digitally separating the lesser omentum to identify the aorta at the diaphragm. If visual identification of the aorta for placement of a vascular clamp proves difficult, digital occlusion of the aorta at the hiatus may temporize the patient.
    - Inframesocolic region of Zone I:
        - Exposure is obtained by retracting the transverse colon cephalad and rotating the entirety of the small bowel to the patient's right side; this approach is similar to the exposure for an elective abdominal aortic aneurysm repair.
        - The root of the transverse colon mesentery can be inspected for a distal injury to the superior mesenteric artery.
        - The inferior mesenteric artery (IMA) is approached via the midline. It is located midway between the renal arteries and the aortic bifurcation.
        - Proximal control of the IMA is best obtained about 1 cm from the origin at the infrarenal aorta.
        - The inferior mesenteric vein (IMV) is located within the retroperitoneum to the left of and more superficial to the aorta. The IMV travels parallel to the

infrarenal aorta, moves medially just to the left of the ligament of Treitz, and dives beneath the inferior margin of the pancreas to merge with the splenic vein within a few centimeters of the SMV confluence.

- Superior mesenteric vein and the portal triad:
  - Adequate exposure requires a partial or complete right medial visceral rotation. The right colon and duodenum are mobilized completely with the right kidney left in its bed. This exposes the entire length of the infrahepatic inferior vena cava, the right kidney and allows access to the porta hepatis as well.
  - Exposure of the injured portal vein can be a challenge because the patients are often bleeding and hypotensive and the injury is covered by hematoma. Once the hepatic flexure is taken down and the Kocher maneuver of the duodenum is complete one might have access to the site of injury. Often adequate exposure of the portal vein requires additional exposure of the SMV and the splenic vein. Occasionally this requires mobilization of the superior and inferior surface of the pancreas and if this is insufficient then the neck of the pancreas is divided with the stapler.
  - Injuries within the porta above the edge of the pancreas can generally be visualized with this mobilization and cephalad retraction of the liver.
  - Most patients have a relatively consistent relationship of the portal structures with the common bile duct lateral, the hepatic artery medial and the portal vein posterior.
  - The most common anomaly, a duplicate or replaced right hepatic artery, is generally found coursing posterior and lateral to the portal vein.
  - Due to the proximity of the biliary structures, clearly defining vascular injuries within the porta is necessary.
  - Proximal control is generally adequately achieved with a standard Pringle maneuver. Formal distal control may be difficult and space is often limited. Forceps or sponge stick occlusion may be helpful until the injury is clearly identified.
  - SMV injuries may occur behind the pancreas at the portal venous confluence. Pancreatic parenchyma can be divided to fully visualize the portal venous confluence. The author divides the pancreas between non-crushing bowel clamps using cautery and sutures placed at the 4 corners; alternatively a stapling device may be used. Management of the pancreas (distal pancreatectomy, roux-en-y pancreaticojejunostomy, or pancreaticogastrostomy) is subsequently necessary either at the same setting or, in damage control situations, a delayed setting.
  - An extensive Kocher maneuver to move medially the duodenal will help mobilize the head of the pancreas and allow digital compression of the injured portal, mesenteric and splenic veins until better visualization and direct clamping is achieved.
- Zone II:
  - The renal vessels or renal parenchyma is generally approached directly after a left or right medial visceral rotation. Authors have described pre-exploration midline control of the renal vasculature but it is generally accepted that proximal control at the aorta/vena cava does not impact nephrectomy rates. Moreover, the renal vessels are deep in the retroperitoneum and often diminutive. Therefore, the direct approach into a zone II hematoma with lateral mobilization of overlying

viscera followed by rapid opening of Gerota's fascia with elevation of the kidney is generally the best option.

- If initial vascular control in the midline is selected, vertical elevation of the transverse mesocolon, exposes of the left renal vein overlying the infrarenal aorta. Cephalad retraction of the completely mobilized left renal vein will allow visualization of the left and right renal arteries that will most likely lay deep to and superior to the left renal vein. The proximal take-off of the right renal artery may be identified before it dives deep to the inferior vena cava.
- Renal vascular injuries may be managed with endovascular techniques in stable patients.
- Non-expanding hematomas in Zone II after blunt trauma may be observed rather than explored if it is felt that a main renal artery or venous injury is unlikely.

- Video Clip 1: Left medial visceral rotation and midline control of supraceliac aorta
- Video Clip 2: Midline control of infrarenal aorta and right medial visceral rotation
- Video Clip 3: Control of kidney and renal vasculature (midline and lateral)

Management and Outcomes:

- Supramesocolic region of Zone I:
    - Injury to the celiac axis is an uncommon injury, seen predominately with penetrating trauma.
    - Following traumatic injury, the celiac axis and each of the branches (left gastric, the common hepatic and the splenic artery) may be ligated with relative impunity.
    - The high mortality of 40-80% is usually related to other injured vessels; damage control techniques may need to be employed.
    - The liver receives its oxygenation from the hepatic artery and the portal vein, so only one of these should be ligated if required. Ligation of the hepatic artery may result in perfusion to the proper hepatic via the gastroduodenal artery.
    - Injury to the superior mesenteric artery is characterized by the classic Fullen zones, described in the early 1970s:
        - Fullen Zone I: Origin and retropancreatic segment
        - Fullen Zone II: Edge of pancreas to base of transverse mesocolon (between pancreaticoduodenal and middle colic arteries)
        - Fullen Zone III: Beyond middle colic artery
        - Fullen Zone IV: Level of enteric branches
    - Proximal SMA injuries (Zone I and II) may be managed with primary repair if amenable but generally require interposition grafting with autologous tissue or prosthetic.
    - If there is a concomitant pancreatic injury (either from the primary mechanism or during exposure of the vascular injury), the interposition vascular graft should be separated from the pancreatic parenchyma by using a more distal portion of infrarenal aorta as a takeoff point. Retroperitoneal tissue or an omental tongue can separate the vascular repair from the pancreas, and the native origin of the superior mesenteric artery can be divided in this case. In rare cases, endovascular options may exist.
    - Patients requiring damage control surgery can have a temporary intravascular shunt placed in the SMA if necessary. These shunts may be difficult to place and have a higher thrombosis rate than temporary shunts placed in extremity vessels. These patients should

have temporary abdominal closures that allow bowel visualization and be taken back to the operating room for definitive management once more normal physiology is restored.
    - Ligation of the proximal SMA is not an option as it is usually poorly tolerated and small bowel ischemia ensues.
    - Survival with injury to the SMA ranges from 29-61% in several series published in 2000-2001.
    - Injury to the SMV may be difficult to expose as detailed above. Once exposed, some injuries are amenable to primary venorrhaphy and this should be performed if possible. If the vein is transected, it often retracts due to the weight of the small bowel; repair often requires an assistant to support the bowel mass to allow end to end anastomosis without tension. Alternatively, if primary closure of the portal or superior mesenteric veins appears to leave a significant stenosis, patch angioplasty with saphenous vein (preferred) or pericardial patch may be appropriate. Interposition grafts with 12-14 mm externally-reinforced PTFE grafts have been employed as well. Shunts have been described in damage control situations with delayed reconstruction. Ligation may also be performed in extreme situations. Both portal venous and SMV ligation is associated with massive bowel edema
    - Survival with injury to the SMV was approximately 58% in three series published in 2000-2001.
- Inframesocolic region of Zone I:
    - Injuries to the IMA are uncommon and may occur from both blunt and penetrating mechanisms, the latter occurring more frequently. Bleeding may ensue from a tear within the retroperitoneal tissues or a central hematoma may develop if those retroperitoneal tissues remain intact.
    - Ligation of the IMA is an acceptable treatment in the majority of cases.
    - Ligation of the IMA is often well tolerated, especially in an otherwise young previously healthy trauma patient without other visceral arterial injuries or large bowel resections that would disrupt arterial collaterals.
    - Injuries to the IMV may occur anywhere along the course of the vein within the base of the large bowel mesentery. Blunt avulsion may occur with aggressive exposure of the retroperitoneal aorta and penetrating wounds may result in transection. On occasion the IMV is avulsed off of the insertion into the splenic vein.
    - Ligation of the IMV is an accepted maneuver without further compromise as there is sufficient venous collateral drainage.
- Zone II:
    - Management options for renal artery injury include doing nothing, open surgical revascularization, endovascular repair, and nephrectomy. Time from injury to revascularization is thought to be critical in terms of preserving renal parenchyma. The historical standard has been that if time from injury to revascularization is less than 4-6 hours, intervention is warranted. This has been challenged in situations where complete warm ischemia over 1.5 hours is thought to render the kidney dysfunctional. In situations where there is a solitary kidney or both kidneys are injured, one could make a case for aggressive intervention outside the 1.5-6 hour limit.
    - Open surgical repair of renal artery injuries is dependent upon the location of the injury along the course of the artery; the left renal artery is shorter than the right, and the vessels begin rapid branching into the renal parenchyma.

- Small arterial injuries may be treated by simple suture repair or patch angioplasty to prevent stenosis of the repair. Larger defects in the renal artery from penetrating wounds might require debridement, mobilization, primary repair or revascularization with a vein graft or synthetic graft from the infrarenal aorta.
- Nationally, approximately 10% of renal artery injuries undergo attempted repair. Overall success rate for renal salvage is about 28%. Unfortunately, 12-60% of patients undergoing revascularization of the injured renal artery will develop hypertension.
- In hemodynamically unstable patients who present with active bleeding from renal artery injuries, the surgeon should consider damage control surgery and ligate the injured renal artery flush with the aorta and ligate the vein as well. Re-exploration and nephrectomy could be done at a later date.
- Renal vein injuries are often from penetrating wounds and rarely from blunt trauma. The latter results from the same mechanism of avulsion type injury as the artery. Direct suture repair is most desirable with the option for a patch if high-grade stenosis would result from lateral venorrhaphy. Ligation of the left renal vein as close as possible to the inferior vena cava is perfectly acceptable as the venous outflow will continue to occur through robust collaterals from the adrenal, gonadal, and lumbar veins. Ligation of the right renal vein will result in venous engorgement and renal infarction secondary to minimal collateral drainage hence repair is most desirable.

- Porta Hepatis:
  - The portal vein originates at the confluence of the SMV and the splenic vein at the top of the pancreas. The portal vein measures 6-10 cm long and comprises a large portion of the hepatoduodenal ligament. The portal vein divides into the left and right branches at the hilum of the liver and provides about 75% of blood flow to the liver but only 40-50% of the oxygen supply.
  - Injury to the portal vein is overwhelmingly from penetrating trauma and is often associated with other major organ and vascular injury.
  - Lateral venorrhaphy of the portal vein is the optimal approach.
  - Other options for portal vein repair include patch venoplasty using saphenous vein or interposition grafting with a 12-14 mm PTFE graft.
  - Ligation of both sources of blood flow into the liver; the portal vein and hepatic artery is uniformly fatal. Ligation of the portal vein alone with preserved hepatic arterial inflow is reasonably well tolerated with survival rates as high as 55-85%. Portal vein ligation, much like SMV ligation leads to massive bowel edema and third-spacing of fluid. Open abdomen and mandatory delayed re-exploration is the norm.
  - The hepatic artery provides 50-60% of the oxygen to the liver and all of the oxygen to the bile ducts. Ligation of the common hepatic artery is tolerated through rich collateral flow through the gastroduodenal artery. Ligation of the more distal proper hepatic artery (distal to the GDA) may result in hepatic necrosis or bilomas but has been reported as safe in numerous publications. Vein graft reconstruction in select patients may be wise to maintain prograde arterial flow at this level.
  - Selective ligation of an injured right or left hepatic artery is usually well tolerated as there is the potential for collateral circulation within the liver parenchyma, the phrenic arteries, and the left gastric artery. Ligation of either the right or left hepatic artery may result partial hepatic necrosis.
  - Ligation of the right hepatic artery requires cholecystectomy.

  - Overall mortality rates of 42% have been reported for patients with hepatic artery injuries.

Special Considerations Including Endovascular Techniques:

- Outside of the established roles elucidated below, the vast majority of literature concerning endovascular techniques after traumatic injury to the visceral vasculature consists of case presentations and small case series. Long term follow-up in many of these series is non-existent.
- Non-operative therapy for late presentations of renal artery injuries with thrombosis is common.
- Superior mesenteric artery dissections from trauma are uncommon. Spontaneous SMA dissections and those arising from aortic dissections lend themselves to endovascular interventions in certain cases. This experience may translate to traumatic injuries but the overall reporting is limited. Superior mesenteric artery traumatic pseudoaneurysms may occur at any level of the SMA but those within the mesentery (Fullen Zones III and IV) are usually treated with open surgery.
- Splenic artery injuries from blunt or penetrating trauma that are contained pseudoaneurysms lend themselves to endovascular embolization with coils and/or intravascular hemostatics that essentially disrupt perfusion and occlude the vessel.
- Renal artery injuries should be considered for endovascular repair in stable patients with intimal disruptions, pseudoaneurysms and arterio-venous fistulas during the early period after injury. Complete occlusions have also been considered but care must be exercised in the choice of patients in an effort to avoid manipulation of a completely disrupted vessel.
- Several case reports documenting successful delayed endovascular management of abdominal vascular injury in hostile abdomens (e.g. delayed diagnosis in patients 1-3 weeks after extensive laparotomy for trauma) have been reported.

Pearls from the Experts: Drs. David V. Feliciano and John A. Weigelt

- On admission, signs suggestive of a penetrating abdominal vascular injury include persistent hypotension despite resuscitation (arterial injury) and a distended abdomen during resuscitation.
- More specific signs of a visceral vascular injury would be gross hematuria with a renal hilar injury and "black bowel" at laparotomy with injury to the proximal superior mesenteric artery.
- "Tucking" the upper extremities on all laparotomies for trauma allows for insertion of retractors fixed to the operating room table, for enhanced exposure of injuries to the midline vessels above the mesocolon (supramesocolic) and to the superior and posterior hepatic segments, and for ease of performing an anterolateral thoracotomy or median sternotomy if needed.
- Once the abdomen is opened and blood and gastrointestinal contents are evacuated, an area of exsanguinating hemorrhage not involving the liver, spleen or mesentery is approached directly without 4-quadrant packing or application of clamps to gastrointestinal perforations.
- Hemorrhage that can be controlled by compression or clamps will then allow for clamping or stapling of gastrointestinal perforations.
- If necessary because of the lack of a massive transfusion protocol or logistic problems in the blood bank, autotransfusion of contaminated blood is acceptable with concomitant administration of intravenous antibiotics.
- Profoundly hypotensive patients (systolic blood pressure <70 mmHg with patient in supine position) after abdominal trauma in a hospital in which the operating room is geographically

distant may benefit from emergency center thoracotomy with cross-clamping of the descending thoracic aorta or transfemoral insertion of an occluding intra-aortic balloon (REBOA).

- Options for control of visceral arterial hemorrhage at laparotomy include cross-clamping of the supraceliac aorta in the aortic hiatus, manual compression till proximal and distal arterial control is obtained, or insertion of a Fogarty or Foley balloon catheter into the area of injury.
- Novice surgeons often try to cross-clamp the supraceliac aorta without first passing the left index and middle fingers *inside* the diaphragmatic muscle filers of the aortic hiatus.
- This maneuver is made much easier by the division of the muscle fibers of the diaphragmatic aortic hiatus at the 2 o'clock position as mentioned in the text as it allows for exposure of the distal descending thoracic aorta superior to the celiac ganglia and lymphatics in the abdomen.
- Ligation and division of the celiac axis significantly improve exposure of the supraceliac aorta and origin of the superior mesenteric artery.
- Significant loss of tissue from the suprarenal and infrarenal aorta can be managed by insertion of a thin walled-PTFE patch if the surgeon wishes to avoid insertion of an interposition graft.
- Profoundly hypotensive patients do *NOT* tolerate ligation of Fullen zones I-III of the superior mesenteric artery. A surgeon who is uncomfortable inserting a temporary intra-arterial shunt (the ideal choice in a damage control situation) should call for a colleague or vascular surgeon.
- Penetrating injuries to the renal artery discovered at laparotomy are fixed or ligated depending on location, extent, hemodynamics, and confirmation of a contralateral normal kidney. Ligation mandates a nephrectomy at the first reoperation after a "damage control" laparotomy.
- A blunt intimal tear or thrombosis of a renal artery diagnosed on admission CT is managed with endovascular techniques.
- Ligation of the left renal vein for exposure of the juxtarenal aorta led to short and long-term problems with the left kidney in 30% of patients in one elective vascular series.
- An anterior suture repair, patch, or prosthetic graft in the infrarenal aorta should *ALWAYS* be separated from the overlying duodenum with a viable pedicle of omentum.
- Ligation of the portal or superior mesenteric vein results in splanchnic hypervolemia and systemic hypovolemia as described by Harlan Stone and mandates vigorous infusion of crystalloid solutions postoperatively.
- Endovascular approaches are indicated for intimal defects or proximal blunt thrombosis of the superior mesenteric artery or renal artery, a late (postoperative) diagnosis, a hostile abdomen precluding operation, and the presence of a complex acute or chronic arteriovenous fistula.
- One reason survival after abdominal vascular injuries has decreased is faster transport times from scene to trauma center.
- While blunt injury to major visceral vascular structures is uncommon, injury to mesenteric vessels associated with bowel/mesentery injuries is common after blunt abdominal injury. These injuries can be occult from a bleeding standpoint, but can lead to bowel necrosis if not identified during initial evaluation.
- Patients arriving with a penetrating wound, especially GSW, below the umbilicus who are in shock, think about an iliac vessel injury and a trip to the operating room should not be delayed.
- An overlooked equipment need is intravascular shunts. Knowing what shunts are available in the operating room and where they are located should be a part preoperative planning.
- In the exsanguinating patient, do not forget simple digital occlusion of the aorta at the hiatus or the use of an aortic occlude. This obviously requires a set of hands that will not be able to help with further dissection, but can be a great help in facilitating the dissection in a less bloody field.

- When doing you left medial rotation, do not worry about splenic injuries. If they do occur, you will be able to remove the spleen later.
- A hematoma at the base of the transverse mesocolon can sometimes be quickly explored and controlled before bowel mesentery rotation.
- Extending your Kocher maneuver into a Cattel-Brasch mobilization will increase your exposure in the area of the superior mesenteric vein and portal triad and does not take much more time.
- A Pringle maneuver with control of the portal hepatis is valuable and helpful, but often a clamp is mentioned as the instrument of choice. A Rommel tourniquet with umbilical tape is just fine or a vascular loop will be less cumbersome and not get in the way of future efforts at exposure of injuries.
- If pancreatic division is necessary and successful for vascular control, a distal pancreatectomy is probably the best option instead of any type of pancreatic repair that requires a bowel anastomosis which can then have future complications.
- Careful assessment of outcomes of SMA injuries is necessary to understand our ability to manage these injuries. Zone I and II injuries are very difficult to manage and are always associated with other injuries. Many recent articles have more Zone III and IV injuries included making outcomes better.
- An actively bleeding renal hematoma in a hypotensive patient is best treated by nephrectomy using a lateral to medial exposure. Only exception might be if only one kidney is present.
- An expanding renal hematoma in a patient who is not in shock is best explored directly at the renal hilum to control renal arteries and veins. Medial exposure is neither easy nor quick.
- Unless primary repair of a visceral vascular injury is possible, all other options are not easy. Once vascular control is obtained, take a deep breath, review the injury anatomy, and develop a potential plan for repair. If extra help is needed, now is the time to ask for it.
- Shunts can and should be used while decisions are being made regarding definitive repair.
- These injuries are commonly associated with other intra-abdominal injuries and possibly extra-abdominal injuries. Be honest in your assessment of potential outcomes, so resource consumption is not excessive for a non-survivable complex of injuries.
- The best case scenario for a blunt renal artery injury is a grade I injury, intimal lesion, normal blood pressure and no other injuries requiring abdominal operative intervention. These patients should be evaluated for endovascular repair as soon as possible.
- Revascularization of a renal artery injury with a long, > 2 hours, ischemic time is a long run for a short slide and not worth it.
- If lateral venorrhaphy is not possible, I would use a vein patch or interposition vein graft and not a prosthetic material. Portal vein is too delicate at the porta and the stiffer prosthetic graft material is difficult to work with in the area. Prosthetic material is better for IVC repair.
- Arterial reconstruction is possible if the hepatic artery is injured distally to its collateral circulation and vein graft is preferable.
- A cholecystectomy done as part of any revascularization in the area of the porta hepatis is prudent.
- Splenic artery injuries can be treated with endovascular repair, but if occlusion of the splenic artery is the result, open treatment with ligation of the splenic artery and splenectomy is best in most patients.

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Adjuncts

• Videos: Various exposures of the abdominal vasculature. (See above)