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Intra-abdominal vascular injuries in severe multiple injured patients: repair, shunt, ligate?

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Abstract

The major vascular structures within the abdomen are complex and vital for survival. When injured, there is high mortality and morbidity. The current review focusses on decision making and techniques in the operating room with a patient that has suffered multiple injuries including major abdominal vascular injury.

Key words: trauma; abdomen; vascular

Introduction

Intra-abdominal vascular injuries can be extremely challenging to manage for multiple reasons: 1) large volumes of flow can rapidly exsanguinate a patient; 2) surgical access can be technically challenging; and 3) most surgeons, except those in inner-city environments, lack the experience in managing the injuries. A simple logical approach, adequate preparation and rapid execution of a plan are essential for optimal outcomes.[1] The major considerations that come into play are 1) mechanism of injury – blunt or penetrating; 2) anatomy of the injury – which zone (see below) and/or vessel is injured; and 3) physiologic status of the patient – pH, core temperature, and coagulation status. Prior to addressing the vascular injury itself, preparation is key. The patient should be in a room that is warm, have adequate large bore vascular access and rapid infuser for massive resuscitation, and have blood products and/or whole blood available in large quantities. In addition to an experienced surgeon, trained/experienced personnel who can manage massive resuscitation are critical for success (Table I).[2]

Table I: Critical preparation for patient with possible abdominal vascular injury

Environment
Warm room
Equipment
Patient warming system
Rapid infuser/warmer
Vascular instruments
Appropriate self-retaining retractors
Personnel
Most experienced surgeon with adequate help
Most experienced anesthesiologist with adequate help for massive resuscitation
Appropriate blood products
Components/whole blood for massive resuscitation

Mechanism of injury

In general, all penetrating injuries need exploration to define the entire tract of the penetration and to diagnose and manage any injury or rule out injury within the tract. This applies to vascular and non-vascular structures that maybe in the tract of the injury. In patients with blunt mechanism of injury, a more selective approach to 'looking for' injury is advisable that is based on anatomical zones of the retroperitoneum.

Anatomy of injury

For descriptive and management purposes, the retroperitoneum is defined as having three zones.[3] It is important to understand that these zones, while useful in terms of understanding what vessels maybe injured and for defining management strategy, are arbitrary and not based on specific anatomical boundaries. Zone I, or central zone is the quadrangular area bounded laterally by the medial borders of the two kidneys, superiorly by the diaphragm and inferiorly by an imaginary horizontal line at the level of inferior vena cava (IVC) bifurcation. Zone II, or lateral zone is the retroperitoneal area lateral to the medial borders of the two kidneys, hence there are two lateral zone, one on each side. Zone III or pelvic zone is the retroperitoneum that extends into the pelvis inferior to an imaginary horizontal line at the level of IVC bifurcation. The major vascular structures in these three zones are shown in Table II.

Table II: Major vascular structures in retroperitoneal zones

Zone I
Aorta
Inferior vena cava
Portal vein
Visceral vessels – Celiac trunk; Superior and Inferior Mesenteric arteries and veins
Zone II
Renal arteries and veins
Zone III
Common iliac arteries and veins
External iliac arteries and veins
Internal iliac arteries and veins

In an injured patient who is undergoing laparotomy for possible bleeding in the abdomen, the bleeding will present either as active hemorrhage or as a retroperitoneal hematoma. If there is active hemorrhage that area should immediately be packed and pressure applied to temporarily control the hemorrhage. If the hemorrhage can be controlled by packing and pressure, even for a few minutes, that time should be utilized to ensure that 1) all equipment needed for exposure (self-retaining retractors etc.) and instruments (vascular) are available; and 2) appropriate personnel (anesthesia), equipment (rapid infuser/warmer), and large volume of blood products (components and/or whole blood) are available. Once this has been assured, the packs are removed and bleeding vessel exposed. It is preferable to place vascular clamps on the bleeding vessel to control the bleeding and determine the best course of action – ligate, repair or shunt (see below). In situations where packing and pressure do not control bleeding, the aorta can be pinched or clamped in the supra-celiac location to reduce infra-diaphragmatic blood flow allowing for quick identification of the source of bleeding and placement of vascular clamps. Once the actual bleeding vessel has been successfully clamped, the aortic control can be released. In situations where the hemorrhage is semi-contained in a retroperitoneal hematoma, since there is no immediate hemorrhage, prior to exploring the hematoma, the same preparations in terms of environment, equipment, personnel and products should occur as described above should occur (Table I). As a general rule, as mentioned above, patients with penetrating injuries, irrespective of the zones involved, should undergo exploration of the hematoma to identify and manage or rule out major vascular injury. However, even with a penetrating mechanism, patients with injuries isolated to zone II with stable non-expanding hematoma, maybe observed and/or plans made for later return with a physiologically resuscitated patient and possible specialist assistance for renal injury. In patients with blunt mechanisms, zone I hematomas should always be explored, zone II selectively explored (similar to penetrating injuries), and zone III not explored if the hematoma is non-expanding and no concern for external iliac artery injury (Table III).

Patient physiology

Severe multiple injury patient with intra-abdominal bleeding is likely to be physiologically compromised and quite possibly near physiologic exhaustion. In this state any prolonged surgery is hazardous and risks death. The three major objective components of measuring the physiologic state are 1) degree of acidosis; 2) degree of coagulopathy;

Table III: Operative recommendation based on mechanism and zone for retroperitoneal hematoma

Mechanism	Zone I	Zone II	Zone III
Penetrating	Explore	Selective*	Explore
Blunt	Explore	No if not expanding	No if not expanding**

*If penetration is through and through the kidney and hematoma is stable

**If no concern for external iliac artery injury (no limb ischemia)

and 3) core body temperature. Any patient with core body temperature <35°C, pH <7.2 (or BE < –15), and PT/aPTT >50% of normal is close to physiologic exhaustion. Maintenance of body temperature (warm room and body warmers), active resuscitation with blood products with frequent blood gas analysis and coagulation assay (preferably utilizing visco-elastic assay) are critical components of intra-operative resuscitation. All three serve to define the status of the patient and the effectiveness of resuscitation. Additionally, frequent point of care coagulation profile assessment utilizing a visco-elastic assay can guide resuscitation by identifying optimal blood component needed at that point in time.

Injuries to specific vessels – Zone I

Aorta

Even in the most dire conditions, an aortic injury has to be repaired to stem bleeding and restore flow.[4] For simple injuries, lateral arteriorrhaphy is preferable since can be accomplished rapidly. If that is not possible or will lead to significant stenosis, patch angioplasty should be performed utilizing PTFE, Dacron or autologous vein patch depending on surgeon experience. In general, prosthetic patches are easier to manage than a vein patch and save time as are immediately available and not have to be harvested. To be able to repair the injury adequate exposure will be needed. This is best accomplished by a left sided medial visceral rotation that can expose the entire abdominal aorta from the diaphragm to the aortic bifurcation.

IVC

Injuries to the IVC should be repaired. This can be accomplished quickly with lateral venorrhaphy. Up to 50% narrowing of the vena cava is acceptable.[5] In dire situations if the injury is to the infra-renal IVC, it maybe ligated. This often leads to compartment syndrome involving both thighs and lower legs. Hence, strong consideration should be given to performing bilateral fasciotomies of the thighs and lower legs.[2] If fasciotomies are not performed, serial measurement of compartment pressures should be done to diagnose compartment syndrome early and treat expeditiously. Exposure of the infra-renal IVC is best accomplished by a right medial visceral rotation mobilizing the entire small bowel mesentery superiorly and to the left. Juxta-renal infra-hepatic IVC can be exposed by the Kocker maneuver by dividing the peritoneum lateral to the duodenum and rotating the duodenum along with the head of the pancreas to the left. Retro-hepatic IVC injuries are the most challenging. The entire right lobe of liver may need to be mobilized by dividing the triangular ligaments attaching the liver to the diaphragm. To accomplish this, the midline laparotomy incision may need to be extended in a 'T' fashion towards the right. If through the use of Pringle maneuver it is determined that there is likely injury to the retro-hepatic IVC, an alternative approach maybe to pack the area without mobilization. Being a low-pressure system, packing may stem the bleeding. Temporary abdominal closure can be performed. Patient is then resuscitated either in the operating room or in the Intensive Care Unit. During this time, preparations can be made for total hepatic isolation. Once the patient is physiologically resuscitated, the abdomen is opened and decision made to proceed with total hepatic isolation and hepatic mobilization to repair the retro-hepatic IVC injury. Total hepatic isolation is a highly specialized technique and ideally calling in surgeons with experience in that technique is highly recommended.

Portal vein

Portal vein is a low-pressure high-volume system, so injuries can result in significant bleeding but also self-containment. The hematoma itself often-times has dissected the planes making exposure relatively straightforward. Pringle maneuver helps with control while a decision is made to repair of ligate. Ideally portal venous injuries should be repaired either by direct suture or patch venoplasty. However, if patient is in extremis, and with an un-injured hepatic artery, the portal vein can be ligated.[6] Decision to ligate should be made early to avoid unnecessary bleeding. Portal venous ligation can result in significant edema of the

entire gastro-intestinal tract and loss of circulating blood volume – splanchnic hypovolemia. Volume resuscitation and pressor support will be required. Temporary abdominal closure and second look laparotomy is recommended to avoid abdominal compartment syndrome.[2]

Visceral vessels

Celiac artery/trunk: Celiac vessel can be safely ligated as the collateral circulation with superior mesenteric vessels is very well developed and ischemia rarely if ever develops. Among the branches of the Celiac trunk, the left gastric and splenic artery can be ligated. Hepatic artery can be ligated but almost always results in necrosis of the gall bladder, hence a cholecystectomy should be performed, and often ischemic/infectious sequalae to the liver.[7]

Superior mesenteric artery (SMA)/vein (SMV): Blood flow through the proximal SMA (prior to middle colic) is critical for intestinal survival. Proximal injuries should be repaired or blood flow restored via vein grafts.[8] In damage control situations, stenting can be used to preserve intestinal viability while the patient is resuscitated and definitive repair performed.[9] More distal SMA (distal to middle colic) injuries maybe ligated. However, there is some risk for intestinal ischemia and necrosis and hence temporary abdominal closure with second look laparotomy is recommended. SMV injuries can be ligated. Ligation of the vein will result in some splanchnic edema similar to what is observed with portal vein ligation, but to a much smaller degree.[10] Exposure of the proximal SMA is by left sided medial visceral rotation. More distal SMA can be directly approached through the small bowel mesentery. Proximal SMV can be approached through the base of the transverse mesocolon to expose the third part of the duodenum and the pancreatic neck.

Inferior mesenteric artery (IMA)/vein (SMV): Both these vessels can be approached directly and if needed ligated. Colonic ischemia can occur presenting with blood per rectum. In which case a diagnostic sigmoidoscopy maybe needed and if confirmed colectomy.

Injury to specific vessels – Zone II

The only vessels of importance in Zone II are the renal vessels. As with other major abdominal vessels, as a general rule, renal vessels should be repaired. However, for any patient in extremis, after confirming the presence of a contralateral uninjured kidney by palpation, the injured kidney can be removed. Exposure of the renal vessels is obtained by left or right medial visceral rotation essentially retracting all structures anterior to the kidney and exposing the Gerota's fascia. Some surgeons prefer to obtain proximal control of the renal vessels prior to entering the peri-nephric hematoma believing that the incidence of nephrectomy is lowered with such control.[11] Others feel that obtaining proximal control takes up time and an experienced surgeon can enter the hematoma and obtain rapid control using his/her fingers and the incidence of nephrectomy is no higher.[2]

Injury to specific vessels – Zone III

The iliacs – common, internal and external arteries and veins – are the major vessels within the pelvis or zone III. The common and external iliac arteries are critical for lower extremity perfusion and the incidence of amputation is very high if these vessels are ligated. The arteries should be repaired utilizing standard vascular techniques of proximal and distal control, simple repair, plasty or interposition grafting depending on degree of injury.[2] In patients who are in extremis, intra-vascular shunts have been used very successfully to reduce the incidence of limb loss.[12,13] Internal iliac artery can be ligated with little consequence, but if both the internal iliac arteries are ligated, there is a high incidence of impotence in male patients.[14] Common and external iliac veins should be repaired, if possible, but maybe ligated.[15] With ligation there is a significant incidence of ipsilateral lower limb compartment syndrome and hence either prophylactic fasciotomies should be performed or compartment pressures closely monitored. Exposure of all iliac vessels is usually obtained by retracting the small bowel along with cecum superiorly and the sigmoid colon laterally. The retroperitoneum over the aortic and IVC bifurcation is opened to expose all the vessels. In patients with distal external iliac artery injury, a separate thigh incision maybe required for distal control. Care should be exercised near the iliac bifurcation so as not to damage the ureter.

Conclusions

Abdominal vascular injuries can be challenging to approach and repair. Good preparation (environment/equipment/personnel), rapid formulation of plans (repair/ligate/shunt) and expert execution are key for optimal results. The surgeons should not only be familiar with repair techniques, but also with damage control and intra-vascular shunt use. Even in the best of hands, and in major centers, mortality of multiply injured patients with major abdominal vascular trauma remains high.

Table IV: Summary of exposure and management of abdominal vascular injuries

Vessel	Exposure	Management		Notes
		Optimal	Acceptable	
Aorta	Left medial visceral rotation	Repair	-	-
Inferior vena cava				
Infra-renal	Right medial visceral rotation	Repair	Ligate	Lower extremity compartment syndrome
Supra-renal	Right medial visceral rotation	Repair	-	-
Retro-hepatic	Right hepatic lobe mobilization	Repair	-	May require total hepatic isolation
Portal vein	Open hepato-duodenal ligament	Repair	Ligate	Splanchnic hypovolemia
Celiac trunk	Left medial visceral rotation	Ligate	-	-
SMA				
Proximal	Left medial visceral rotation	Repair	Shunt*	-
Distal	Root of mesentery/transverse mesocolon	Repair	Ligate	Consider second look for ischemia
SMV	Root of mesentery/transverse mesocolon	Repair	Ligate	Bowel edema/venous gangrene
IMA	Direct access	Ligate	-	Possible left colon ischemia
IMV	Direct access	Ligate	-	-
Comm. iliac artery	Direct access	Repair	Shunt*	-
Ext. iliac artery	Direct access/possible thigh incision	Repair	Shunt*	-
Int. iliac artery	Direct access	Repair	Ligate	Impotence with bilateral ligation
Comm. Iliac vein	Direct access	Repair	Ligate	Lower extremity compartment syndrome
Ext. iliac vein	Direct access	Repair	Ligate	Lower extremity compartment syndrome
Int. iliac vein	Direct access	Ligate	-	-

*Temporary

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