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Abdominal vascular injuries- What general/ trauma surgeons should know?

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NARRATIVE REVIEW

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Abstract

Abdominal vascular injuries are the common cause of death post-trauma. These are challenging injuries to manage due to severe haemodynamic instability, other associated injuries and difficulty in accessing and controlling these deep-seated vessels. Early control of bleeding can decrease mortality in these patients. Abdominal vasculature is divided into three zones, each requiring different operative strategy for exposure. Standard vascular surgery principles of achieving proximal and distal control before exploring any haematoma are followed when managing these injuries. Resuscitative endovascular balloon occlusion of aorta is a minimally invasive method of achieving proximal aortic occlusion. This also acts as bridge for definitive intervention or surgery. Endovascular interventions, including angioembolisation and stent-graft, have shown to improve outcomes, especially in patients with blunt abdominal trauma. Updated knowledge is necessary for all those directly involved in managing these patients. The current narrative review was planned to discusses relevant anatomy, principles, different surgical approaches and endovascular techniques to deal with these injuries.

Keywords: Abdominal traumaI, Injury, Aortal, Inferior vena cava.

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Introduction

Abdominal vascular injuries (AVIs) include injuries to abdominal aorta, inferior vena cava (IVC), iliac vessels and portal venous system. Each of these vascular territories needs a different operative strategy for controlling bleeding.

Injuries to these vessels are lethal as the abdominal wall does not provide tamponade to active bleeding till patient's death. There is bimodal pattern of death in patients with AVIs. Initial peak is due to uncontrolled bleeding and the second peak is due to multi-organ failure. These injuries can be due to penetrating trauma, like gunshot, stab wound, bomb blast etc., and due to blunt trauma, like road traffic accident (RTA). Their presentations vary depending whether bleeding is active or not. Patients with active bleeding present with haemodynamic instability and usually in extremes. Retroperitoneal tissue provides tamponade to some of these patients who may present in a stable condition with contained haematomas. These injuries can also cause arterial thrombosis and patients can present with end-organ ischaemia, such as limb or bowel ischaemia. In a patient with multiple injuries, an organised approach can identify abdomen as the source of haemodynamic instability. One out of every four patients with penetrating abdominal trauma may have AVI. Most of the patients die at the scene and never reach a hospital. Out of those brought to hospital alive, half of the patients die within a few hours of presentation. The peri-operative mortality is also higher for those who are brought alive to the operative table.[1-3] This mortality pattern has remained unchanged over the last two decades despite improvements in pre-hospital transfer services, perioperative care and in surgical and endovascular techniques. It may be that case that most patients brought to emergency rooms today would have died at the site previously before getting any medical attention. Although the concept of restricted resuscitation, permissive hypotension and damage control strategies are well established and practised, the most effective way to improve outcomes of these patients is still the "early and effective control of bleeding".

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Different zones of abdominal vascular structures

Three retroperitoneal zones have been described in literature for AVI management: one midline, two lateral and one pelvic.[4] The central zone (Zone I) extends from aortic hiatus to the sacral promontory. It contains aorta and IVC. Lateral zones (Zone II) are the right and left, and include kidneys, renal vessels and paracolic gutter, while the pelvic retroperitoneal zone (Zone III) contains iliac vessels. Perihepatic zone, containing portal and hepatic veins, is a separate zone.

Investigations

Early identification of injuries, by focussed abdominal sonography for trauma (FAST) examination and computed tomography (CT) is a significant priority in patients with abdominal trauma. In major abdominal vascular injuries, most patients present with severe hypotension, leaving very little time for diagnostic tests.[5] Quick bed-side ultrasound is useful as it can show intra-abdominal fluid.

CT scan of abdomen can be obtained in haemodynamically stable patients with blunt trauma. This can show any retroperitoneal haematoma, pseudo-aneurysm or arterial thrombosis, and help in the treatment plan.

Principles of treating AVIs

Patients with AVIs need not be over-resuscitated and managed with 'permissive hypotension'. Studies have shown that patients with penetrating injures, particularly to the thoraco-abdominal region, have better outcomes with restrictive clear fluid resuscitation policies, permitting a systolic blood pressure (SBP) 60-70mmHg until the patient is taken to the operating room (OR).[6] Once haemorrhage has been controlled in OR and blood products are available, higher blood pressure (BP) may be targeted. The same policy of restrictive fluid therapy is recommended for blunt trauma patients. This restrictive fluid policy is thought to minimise intra-abdominal bleeding while maintaining adequate oxygen perfusion and reducing the risk of intra-abdominal hypertension and complications. Every effort is made to keep these patients warm and prevent them from hypothermia as this can lead to poor platelet adherence and exaggerates coagulopathy. Whenever possible, patients are covered with warm blankets, OR temperature is increased and warm fluids are infused. Effective communication with other team members, including anaesthesia and blood bank members, is key in the successful management of such patients. Major haemorrhage protocol needs to be activated.[7] Patients with major abdominal injury are prepared before induction of anaesthesia and prepared from neck to knee in anticipation of need of thoracotomy and great saphenous vein harvesting. Whenever possible, rapid infusion devices are used, and the basic idea is to think ahead of possible injuries and possible approaches to deal with them. Leadership and team management skills of the operating surgeon are as important as the operative skills. One needs to be organised and not to hesitate in seeking help from senior or even from a junior colleague. Two assisting hands are always better than none. Staying calm and keeping nerves intact in these stressful situations is essential as hasty movements and decisions can cause more damage to the patient than the primary injury itself. Immediate midline laparotomy is performed from xiphoid to pubic symphysis to achieve temporary control of bleeding. In most cases, bleeding is controllable by four-quadrant packing by direct pressure. Rarely, when bleeding is not controllable by direct pressure, aortic cross-clamping is performed at the aortic hiatus level. Major vascular injuries are managed by sticking to basic principles of vascular surgery. Proximal and distal control is achieved before exploring any haematoma. All haematomas due to penetrating injuries need to be explored except a stable retrohepatic haematoma.

In case of blunt trauma, stable, non-expanding haematoma can be left in place, while only expanding or leaking haematomas need exploration. Damage control strategies are followed when managing these patients. All complex venous injuries can be ligated, intravascular shunts can be placed for arterial injuries which can be dealt when patient is stable, an diffuse oozing can be packed. The abdomen is left open with temporary abdominal closure[8] and the patient is shifted to intensive care unit (ICU) for the correction of coagulopathy, acidosis and hypothermia.

Specific abdominal vascular injuries

Abdominal aorta

The abdominal aorta starts from the aortic hiatus and run in the retroperitoneum in midline up to sacral promontory where it divides into iliac arteries. It can be divided for injury management point of view into supra-renal, juxta-renal and infra-renal segments, with each requiring a different operative strategy.

a. **Supra-renal and juxta-renal aorta:** Supra-renal and juxta-renal aortic injuries carry the highest mortality. These can be approached by left medial visceral mobilisation. For this extensive manoeuvre, initially peritoneal reflection along the line of the Todt is dissected and the descending colon along with splenic flexure, spleen, fundus of stomach and tail of pancreas is mobilised towards the midline. This dissection is carried out either anterior or posterior to the kidney, and the kidney can be dissected along these structures. This provides good exposure to the supra renal aorta and origin to its branches: the coeliac and superior mesenteric artery (SMA) and the left renal artery. There is dense peri-aortic tissue which also needs dissection to get proper aortic exposure and control. Before exploring this area, proximal aortic control can be achieved at the level of descending aorta by either left anterolateral thoracotomy or at the aortic hiatus.

b. **Infra-renal aorta:** The operative approach is the same as the one performed for elective infra-renal abdominal aortic aneurysm repair, which is trans-peritoneal exposure of aorta. The small bowel is eviscerated and packed to the right side of abdominal cavity, the transverse colon is lifted cranially, and the descending colon is retracted to the left. Simple aortic defects are repaired primarily. Larger defects <50% of circumference can be managed with patch repair. Defects >50% need interposition grafting using either prosthetic or vein grafts.

c. **Coeliac artery:** Injuries to the coeliac artery are rare. Because of extensive fibrous, ganglionic and lymphatic tissues that surround the trunk, surgical dissection may be tedious. It can be exposed by left lateral visceral mobilisation and most of the times it is ligated, provided other visceral arteries, like SMA and inferior mesenteric artery (IMA), are patent. There is a rich network of collaterals around the coeliac artery and ligation of the coeliac branches, including the common hepatic artery, that can also be performed with negligible risk of visceral ischaemia.[9]

Superior Mesenteric Artery

Injury to SMA is rare and highly lethal. It is due to deep location of SMA, associated injuries and severe bowel ischaemia. SMA is divided in four zones (Table). Mortality directly correlates with the injury level. Retro-pancreatic zone (Zone I) either needs left medial visceral rotation or direct exposure by division of pancreatic head. Zone II can be exposed on the left side by division of ligament of Trietz and the right side by mobilisation of the duodenum. Zones III and IV injuries can be exposed directly. Proximal injuries either need primary repair or interposition grafting, while distal zone injuries can be ligated. Given the high likelihood of associated pancreatic injury, it is important to isolate vascular anastomosis from pancreatic leak using omentum or other surrounding soft tissues.

d. **Inferior Mesenteric Artery:** This can be approached by the exposure described to manage infra-renal abdominal aortic injuries. Most of the times, it can be ligated.

Iliac artery injuries

Aorta divides into two common iliac arteries joining at level of fourth lumbar vertebra (L4). These further divide into external and internal iliac arteries. Both right and left iliac arteries are approached differently. For both-side injuries, proximal control is achieved at the infra-renal abdominal aorta and distal control by dissecting the femoral arteries at the groin level by a separate incision. Common iliac and external iliac arteries are approached directly by dividing the overlying retroperitoneum. Right common iliac artery exposure can be facilitated by mobilising ascending colon mobilising medially. For the left common iliac artery and its branches, this exposure can be facilitated by mobilising the sigmoid mesentery medially. Small defects can be repaired primarily, while large defects are repaired with interposition prosthetic grafts, provided there is minimal contamination. Ipsilateral internal iliac artery interposition can also be considered in case of external iliac artery transection and in contaminated field. In this case, both external and internal iliac arteries are mobilised to the maximum length, and internal iliac artery is usually divided into middle haemorrhoidal vessels. In case of common iliac injury with severe contamination, ligation of artery followed by extra-anatomical bypasses (fem-fem cross over / axillo-femoral bypasses) can also be considered.

Table: Showing different zones of superior mesenteric artery injuries.

Zone	Segment of superior mesenteric artery
I	Trunk proximal to inferior pancreaticoduodenal artery
II	Trunk between inferior pancreaticoduodenal and middle colic artery
III	Trunk distal to middle colic artery
IV	Segmental branches, jejunal, ileal or colic

Most of the times, the patient is so unstable that damage control strategy of placing the arterial shunt is the best one, and arterial reconstruction is done when patient is haemodynamically much better.

Inferior vena cava (IVC) injuries

From the injury management point of view, the IVC can be divided into infra-renal, juxta-renal, supra-renal and retro-hepatic anatomical areas. Each of this territory needs a different operative strategy for vessel exposure.[10]

a. **Exposure of supra- and juxta-renal IVC:** Exposure of supra-mesocolic IVC can be achieved by right visceral mobilisation. Initially, medial rotation of the right colon and the hepatic flexure is done. Then, Kocker's mobilisation of duodenum and head of the pancreas is performed to expose juxta-renal and supra-renal IVC. Both renal veins are controlled.

b. **Exposure of infra-renal IVC injuries:** Infra-renal IVC is explored by lateral mobilisation of colon. The ascending colon is mobilised to the left to expose right pararenal region and the descending colon is mobilised to the right to expose the left pararenal region.

For IVC injuries, even with proximal and distal control, there is troublesome bleeding, mostly coming from lumbar and renal veins. This can be controlled by using side-biting Satinsky clamp.

Dealing with IVC defects

Simple IVC injuries can be repaired primarily.[11] Complex injuries in a haemodynamic unstable patient mandates ligation. Usually ligation is well tolerated with low incidence of compartment syndrome and need for fasciotomy. The post-operative leg swelling can be managed by limb elevation and compression dressing.

Retro-hepatic injuries

The mortality is higher for more proximal IVC, like retro-hepatic and supra-renal IVC injuries, compared to infra-renal IVC injuries. Stable retroperitoneal haematomas

are not explored both in case of penetrating and blunt trauma.

Damage control strategy for AVIs

Damage control principles are applied for these haemodynamically unstable patients[12] and has been associated with decreased mortality rates.[13]

Endovascular treatment and mortality

Recent increase for endovascular interventions, especially for blunt injuries, have shown survival benefit and less need for blood transfusion[14] but this benefit has not been shown in penetrating abdominal trauma.[15]

A hybrid OR can help smoothen work flow and facilitate in controlling bleeding both by endovascular means, like temporary intravascular balloon placement/ angioembolisation/ stenting, and surgical means.[16,17]

Resuscitative endovascular balloon occlusion of aorta (REBOA)

REBOA is a minimal invasive way of proximal aortic control and probably indicated in patients who are a candidate for resuscitative thoracotomy.[18] The catheter is mostly placed from one of the femoral arteries. The idea is to achieve temporary control until definitive repair or further investigations can be done.

For the placement of REBOA, the aorta is divided into three zones. The upper zone starts from the left subclavian artery up to the coeliac artery and is recommended for catheter placement when the patient is bleeding from one of the major intra-abdominal arteries. The mid/para visceral zone contains origin of celiac, superior mesenteric and renal arteries, and lies between the coeliac and the lowest renal artery. Balloon tamponade is not recommended in this zone due to the risk of severe bowel and renal ischaemia. Lower zone is the infra-renal zone and extends from the lowest renal to aortic bifurcation. For uncontrollable pelvic bleeding, the balloon is placed in this zone. Despite its potential benefits, REBOA has not been shown to decrease mortality in penetrating injuries.[19]

Potential areas to work on to improve AVI outcomes

To improve the outcomes of patients with AVIs, the first and foremost step is improving expertise of surgeons dealing with these injuries. This can be done by simulated workshops or cadaveric workshops to make the participants more conversant with abdominal vasculature and different operative approaches. In low and middle-income countries (LMICs), there is a need to develop dedicated trauma centres where these patients can be managed efficiently. This must be coupled with early transportation by improved ambulance services. Dealing with these injuries needs a mindset of high clinical suspicion and early exploration whenever indicated. Organised team approach with the right mindset and with improved perioperative care can make a difference in the outcomes of these patients.

Simultaneously, preventive strategies, such as improving law and order and weapon control conditions and strict implementation of traffic and road safety laws, can decrease the burden of these injuries.

Conclusion

AVIs carry high mortality. Early control of bleeding can make a difference in these patients. Updated knowledge of relevant anatomy and various surgical approaches is important for anyone dealing with such injuries.

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