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BLUNT ABDOMINAL TRAUMA (K SØREIDE, SECTION EDITOR)

Intraabdominal Vascular Injuries in Blunt Trauma: Spectrum of Presentation, Severity and Management Options

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Abstract
Purpose of Review Blunt abdominal vascular injury is rare, hard to diagnose and there is little consensus as to what constitutes best management. This review was undertaken to assess how blunt abdominal vascular trauma management has changed over last few years and what new therapies have been reported.
Recent Findings Increasing diagnostic accuracy through the ubiquitous use of CT angiography has identified a greater range of injuries than clinicians were previously aware of. Most of these injuries can be managed non-interventionally but where intervention is required an increasing range of non-surgical options are available. Hemorrhage control with resuscitative balloon occlusion of the aorta has become popular and both covered and uncovered stents are available in situations where simple embolization is not feasible.
Summary Patients with suspected blunt abdominal vascular injury need CT angiography to diagnose injuries and plan further management. Recently published literature suggests an increasing role of non-operative and endovascular treatment of these injuries. The role of open surgery is limited to a few situations and is more often a backup in the event of a failed endovascular intervention.

This article is part of the Topical Collection on *Blunt Abdominal Trauma*

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Introduction

Vascular injury is an uncommon consequence of trauma and this is particularly so in relation to blunt abdominal vascular injury (injury to intraperitoneal or retroperitoneal named arteries or veins) [1]. Blunt abdominal vascular injury (BAVI) is rarely isolated and has significant mortality (17%), not only because of the vascular injury itself but also because of the associated injuries [2•]. Motor vehicle crash, fall from height, and direct blows are some of the more common causes. Generally, deceleration forces lead to avulsion of small branches from major vessels or initiate a partial intimal and medial tear with a secondary thrombosis of the lumen. A full-thickness tear will produce frank bleeding or a secondary pseudoaneurysm. A direct anterior crush (seat belt) or blow (handlebar) can also disrupt vessels leading to hemorrhage. Where major bleeding is the consequence of a vascular injury, the diagnosis and treatment strategy is usually obvious. Where less serious consequences ensue, a greater range of options are available and the decision-making is more complex.

We reviewed a selection of studies on management of blunt abdominal vascular injuries, which are listed in Table 1.

Clinical Presentation

Where thrombosis rather than hemorrhage results from an injury, the deep location of the vascular structures along with distracting abdominal visceral or spinal injuries may make a timely diagnosis difficult. Examination findings can include a seat belt sign, abdominal wall contusions (and associated

Table 1 Summary of selected studies on new developments in management of blunt abdominal vascular injuries used for this review

	Author	Journ al/title	Methods	Data collection time	Number of cases	Summary	Comments
Subject 1	Jong Soo Shin et al.[3•]	Diagn Interv Radiol (Transcatheter arterial for traumatic mesenteric bleeding: a 15-year, single-center experience)	Nonrandomized, retrospective study, all data were collected through a review of the medical records	15 years	10	100% technical success No complications	Non randomised retrospective study showing endovascular treatment of mesenteric bleeding is safe and effective
Subject 2	Kristofer M. Charlton- Ouw et al. [4••]	Annals of Vasc Surg (Observation may be safe in selected cases of blunt traumatic abdominal aortic injury)	Retrospective review	15 years	16	BTAAI rare, small pseudoaneurysm, intimal flaps can be observed,	Retrospective review over a 14 year period of blunt traumatic abdominal aortic injuries, concluding certain injury types can be safely managed conservatively
Subject 3	Anna Maria Ierardi et al. [5•]	Cardiovasc Intervent Radiol (Uncommon case of a post-traumatic portal vein pseudoaneurysm treated with percutaneous transhepatic stent grafting)	Case study	2016	1	Endovascular solution to a vexing surgical intervention	Description of an elegant endovascular solution to a very challenging open portal vein repair
Subject 4	Julien Ghelfi et al. [6•]	Cardiovasc Intervent Radiol (Arterial embolization in the management of mesenteric bleeding secondary to blunt abdominal trauma)	Retrospective review	7 years	7	Review, retrospective study	Study with a small sample size, showing laparotomy can be avoided with successful embolization
	Chih-Yuan Fu et al. [7•]	Injury (Hypotension does not always make computed tomography scans unfeasible in the management of blunt abdominal trauma patients)	Retrospective review	5 years	91	Shorted scanning times and shorter distance to scanner enable CT even in hypotensive patient	5-year retrospective review of blunt abdominal trauma patients at a major trauma center, reporting findings that challenge traditional concepts of not scanning hypotensive patients
	Joseph J. Du Bose et al. [8•]	J Trauma Acute Care Surg (The American Association for the Surgery of Trauma Prospective Observational Vascular Injury Treatment (PROOVIT) registry: multicenter data on modern vascular injury diagnosis, management, and outcomes)	PROOVIT registry review	1 year	542	Shows continued advancement of endovascular capabilities, emerging endovascular technologies might be superior to traditional open repair modalities in certain cases	A prospective database showing the change in management of vascular injuries along with evolving diagnosis and emergent new therapies
	B. O. Patterson et al. [9•]	British Journal of Surgery (Imaging vascular trauma)	Systematic review of literature	10 years	58	Suggest CTA as first line of investigation	Systematic review of the literature concerning radiological diagnosis of vascular trauma over a 10 year period and proposing CTA as the first line investigation for diagnosis
	Branco BC et al. [10•]	Journal of Vascular Surgery (Trends and outcomes of endovascular therapy in the management of civilian vascular injuries)	Retrospective review	9 years	23,105	A 9-year analysis of the National Trauma Data Bank	This is the largest study to date on management of civilian vascular injuries by endovascular means. It reports a major increase in the use of endovascular therapy with reduced mortality and lower rates of sepsis
	Michael J. Osgood et al. [11•]	J Vasc Surg (Natural history of grades I–II blunt traumatic aortic injury)	Retrospective review	10 years	204	Reports that 95% injuries need no intervention	Retrospective review over a 10 year period, reportedly the largest experience with Grade I and II aortic

Table 1 (continued)

Author	Journ al/title	Methods	Data collection time	Number of cases	Summary	Comments
						injuries and its findings endorse the safety of non-operative management
Donald G. Harris et al. [12]	Annals of Vasc Surg (Patterns and Management of blunt abdominal aortic Injury)	Retrospective review	10 years	17	MAI low risk of complications	Strengthens the case for non-operative management of MAI
M. Heuer et al. [2•]	Eur J Trauma Emerg Surg (Abdominal vascular trauma in 760 severely injured patients)	Retrospective review of Trauma Registry of the German Society of Trauma Surgery (TR DGU)	15 years	760	Low incidence of vascular injury in abdominal trauma, use of CTA and conservative treatment in stable patients	A retrospective review of abdominal vascular trauma patients over 16 years, which incorporates findings into current literature to suggest a treatment algorithm
Charles de Mestral et al. [13•]	J Vasc Surg (Associated injuries, management, and outcomes of blunt abdominal aortic injury)	Nested case-control design, patient cohort from 180 centers	2 years	436	Spine, hollow visceral, retroperitoneal injury can be associated with blunt aortic injury, conservative and endovascular are emerging therapies	Using nested case-control design, this study evaluated blunt abdominal aortic injury patients from 180 centers in the US, presenting the most rigorous characterization to date of injuries associated with BAAI and showed most conservatively managed patients left hospital alive
Sherene Shalhub et al. [14]	J Vasc Surg (Blunt abdominal aortic injury)	Retrospective review	5 years	28	Emerging role of non operative therapy 100% mortality with free rupture	15 year retrospective review of blunt abdominal aortic injuries with suggestions about optimal management
Koji Idoguchi et al. [15•]	Cardiovasc Intervent Radiol (Endovascular treatment of blunt traumatic abdominal aortic occlusion with kissing stent placement	Case report	2011	1	Endovascular stent placement is safe in traumatic aortic occlusion	Case report about the first time use of a kissing technique for stent placement to treat traumatic aortic and iliac occlusion
Fabian Springer et al. [16]	Cardiovasc Intervent Radiol (Delayed endovascular treatment of renal artery dissection and reno-vascular hypertension after blunt abdominal trauma)	Case report	2011	1	Endovascular renal artery recanalization	Suggests delayed renal revascularization can be attempted
Sandeep S. Vaidya et al. [17]	Emerg Radiol (Inferior vena cava dissection following blunt abdominal trauma)	Case report and literature review	2010	1	Rare form of blunt IVC injury and management	Describes IVC injury treatment

hollow viscus injury), or spinal injury [18••]. Blunt abdominal vascular trauma can be silent, result in hemodynamic instability, or acute lower body arterial ischemia.

Diagnosis

If laparotomy is not immediately necessary, the main diagnostic test is multi slice CT [9•, 19]. Focussed abdominal sonography for trauma (FAST) is not accurate and cannot morphologically detail the extent of blunt vascular injury. Magnetic resonance angiography (MRA), though accurate, has availability and logistic issues that largely preclude its use in acute trauma. CT angiography (CTA) localises injury and allows planning for endovascular therapy. Studies have shown that now even patients in a relatively hypotensive state can be safely scanned using multi-slice scanners to shorten acquisition time [7•].

Imaging for diagnosis of blunt vascular trauma
• FAST misses many vascular injuries
• MRA has technical limitations (timing, availability)
• CTA is investigation of choice
• High specificity reported (82–100%)
• Identifies and helps in planning endovascular treatment

Treatment of Blunt Abdominal Vascular Injury

Traditional treatment has always been open surgery but this may involve challenging access, visceral injury, a potentially contaminated operative field, hypothermia, poor results and a low injury incidence, which compromises accumulation of any meaningful experience. However, with the increasing use of endovascular therapies throughout vascular surgery, there has also been a distinct shift towards endovascular treatment for blunt vascular trauma over the last 5 years. Endovascular treatment has been progressively moving from elective to hemodynamically compromised and life threatening situations, with good technical and therapeutic success. This has increased the endovascular options in blunt abdominal vascular injuries. There is now a documented increase in the number of endovascular procedures with reported good technical success and reduced morbidity and mortality [20]. Minimal invasiveness along with ease of use of new technologies and devices, its application even in contaminated fields, and precise delivery systems which minimise collateral damage are distinct advantages. Further, its use does not burn bridges to open surgery. Endovascular therapy can also be used as a bridge to further definitive treatment in more controlled settings.

Specific Blunt Abdominal Vascular Injuries

Abdominal Aortic Injury

The reported incidence of blunt abdominal aortic injury is 0.2% of all trauma admissions [12]. It is commonly caused by seat belt, steering wheel or cycle handle bar impact. It can be associated with retroperitoneal visceral or lumbar spine injury. Impact forces disrupt the aortic intima and depending on the magnitude of injury, this intimal injury could be minimal or progressive [14, 21••]. Partial thickness injury with intact adventitia will present as a pseudoaneurysm. If there is adventitial injury along with intimal and medial injury, it will present as complete aortic disruption or vessel avulsion. The majority of blunt abdominal aortic injuries are infra renal in location [22]. Intimal injury is generally silent, but thrombosis can develop over time; hence, a robust initial physical exam followed by repeat serial exams is useful.

Patients with minimal aortic injuries (MAI) can be safely observed, with follow-up surveillance studies [4••]. The natural history suggests that more than 95% settle with aspirin, and beta blockers [11•]. Large intimal flaps should be initially observed and if repeat CT within 72 h shows a progression, then intervention is needed. Focal traumatic dissections should be observed initially. These are generally short in length. Aortic pseudoaneurysm should be treated as the natural history is still not well defined, though it lends itself to semi elective treatment [23]. Generally patients with frank rupture do not make it to hospital alive and the outcome is poor even in those who have open surgery. Partial or complete circumferential aortic transection (contained disruption) is amenable to stent grafting. Avulsion of branch vessels from the aorta or complete aortic disruption will need open repair, though temporary balloon occlusion can be useful. Vascular control of rapid abdominal or pelvic bleeding using REBOA (resuscitative balloon occlusion of the aorta) [24] has been increasing in popularity with the use of a partial REBOA technique [25] and smaller sheaths [26] possibly providing even greater utility [27•].

Blunt abdominal aortic injury in adults
• CTA as diagnostic modality
• More endovascular treatment options
• Increase in MAI as imaging improves
• Conservative treatment for MAI
• Suprarenal pseudoaneurysm needs embolization or open repair
• Infrarenal pseudoaneurysm can be treated with stent graft
• Open repair for aortic disruption or branch vessel avulsion
• Axillobifemoral graft for thrombosed infra renal aorta
• Rule out IVC injury

Abdominal aortic injury with open visceral injury should be preferentially treated endovascularly if possible to

minimise the risk of contamination and circumvent compromised patient physiology [28].

A review has shown that 90% of blunt abdominal aortic injuries were managed conservatively. Of the rest, the majority underwent endovascular treatment and only a small group needed open repair [13•].

The Society for Vascular Surgery guidelines also recommend endovascular treatment for grades II–IV thoracic aortic injuries [29]. Free rupture, acute ischemia (limb/visceral) and thrombosis however still need acute open intervention.

What is new in blunt abdominal aortic injury management

- Observation and conservative management
- Observe large intimal flaps, but may need intervention
- Use uncovered stent for large flaps to maximise collateral perfusion
- Stent graft for contained disruption/compromised aortic wall
- Open surgery for aortic pseudoaneurysm replaced by stent graft in infra-renal aorta and coil embolization in supra renal aorta
- Use REBOA for endovascular control prior to open repair
- Treat aortic injury associated with visceral injury by endovascular means
- Avoid complex endovascular procedures in trauma
- Limited role for open repair
- Endovascular damage control (REBOA)
- Endovascular IVUS
- Hybrid theatres

In blunt trauma induced aortic dissection complicated by aortic occlusion, one patient out of three has a delayed diagnosis. However, the limited dissection length generally lends itself to endovascular treatment. If the dissection extends to the common iliac arteries, kissing stents will be required. If there is focal dilatation of aorta, an aortic stent graft will be necessary. Intervention can be delayed by 72 h and use of a self-expanding stent graft is advocated for the abdominal aortic wall weakened by dissection [15•].

Aortic injuries near the renal arteries and in the visceral abdominal aorta are generally not amendable to stenting [30]. There have been reports of using a chimney graft technique for these injuries. However, it has been shown that increasing complexity of endovascular intervention has been associated with failure and mortality.

Resuscitative endovascular balloon occlusion of the aorta (REBOA)

- Proximal control at level of diaphragm or at aortic bifurcation
- Standard 5 F common femoral cannulation
- Advance Amplatz up to 2nd rib space
- Mark end of wire on table drape to ensure it stays in position
- Advance 32 mm CODA balloon up to xiphoid
- Use 10 ml contrast mixed with 20 ml saline to inflate balloon
- Immediate rise in SBP
- Transport to definite Rx place
- Modifications using partial REBOA and smaller sheaths
- More than 90 min of REBOA linked with liver & kidney damage
- Systematic review found weak evidence to support REBOA

The role of endovascular US has been investigated and has been shown to have some distinct advantages in blunt thoracic aortic injury [31].

Endovascular US

- Most accurate in diagnosis of vascular injuries
- Unmatched 100% specificity and sensitivity compared to other diagnostic modalities
- Can differentiate between acute and chronic injuries
- Can rule out indeterminate injuries
- Can be used as follow-up tool e.g. when CTA is contraindicated

Pediatric Abdominal Aortic Injuries

The incidence of blunt abdominal aortic injuries is low, involving just over 2% of pediatric blunt abdominal trauma patients in the US National Trauma Data Bank [32•]. Most injuries are due to lap seat belts. Conservative management is appropriate for stable patients with lower grade injuries. Unstable patients or those with frank rupture need intervention [33]. Open aortic surgery is challenging and primary repair, debridement, thrombectomy, and repair using autogenous patch/artery are the various options. Use of intraoperative ultrasound to minimise aortic wall debridement and obtain primary repair has been reported [34•]. Synthetic grafts can be used; however, these will need future revision and there is a risk of infection if there is visceral injury/contamination. An endovascular approach using a stent has been reported [35]. An open femoral artery cut down is recommended for precise puncture and a bare metal stent graft (low profile, can fix dissection flap) should be used. This will preserve important collaterals and is better suited to a contaminated field. If the patient has a frank aortic rupture, then a standard stent graft should be used. However, size mismatch is an issue due to the initial small size of aorta and iliac arteries, and the potential future growth of the native vessels. Using a balloon mounted stent, with a view to oversize this later on, will minimise this size mismatch [35].

Blunt pediatric abdominal aortic injury

- Conservative treatment has a role
- Open surgery is challenging
- Thrombectomy and primary repair in aortic thrombosis
- Use of intraop US as adjunct to facilitate open repair
- Bare metal stent is the new treatment option
- Do open femoral cut down to facilitate access

Renal Artery Injury

What is new in renal artery blunt trauma

- Delayed endovascular recanalization
- Coil embolization of narrow neck renal artery pseudoaneurysm
- Use of bare stent and coil embolization through interstices for wide necked pseudoaneurysm
- Use of covered stent for renal artery pseudoaneurysm
- Avoid covered stent graft in younger age patient
- Rule out renal vein injury in renal artery avulsion injury
- Renal vein injury not amenable to endovascular options

The reported incidence of blunt renal artery injury (Fig. 1) is 0.05% of all blunt trauma admissions [36]. The injury pattern is dissection, thrombosis, avulsion and pseudoaneurysm. US is user dependent and has decreased sensitivity compared with CTA which is the diagnostic modality of choice [37]. New ways to treat renal artery pseudoaneurysm have been the use of coil embolization, uncovered stents with coil embolization though the stent interstices, and covered stent grafts.

Embolisation: factors to consider

- Size of vessel
- Duration of occlusion
- Coils and plugs in larger vessels
- Coils need functional coagulation system
- Micro coil or gelatin sponges in smaller vessel
- Proximal embolization for multiple bleeding points/extravasation and unstable patient
- End arterial organ as kidney or non-expendable arteries not suitable for proximal embolization
- Super selective catheterisation to preserve organ function
- Hypotension, blush diameter more than 1.5 cm predict need for intervention to stabilise
- Look for another source of bleeding if no hemodynamic stability after successful embolization

Use of a covered stent should be avoided in the younger age group due to stenosis risk [38]. Endovascular revascularisation has a generally successful outcome [39]. Angioembolisation has been shown to maximise renal glomeruli preservation [40] and successfully stops bleeding [41].

The previously held view about vascularising the kidney within hours has been challenged with the report of a successful endovascular recanalization after 25 days [16]. Minimising warm ischemia time is important; however, there is no absolute cut off point as results reported above would suggest. Endovascular recanalization of the thrombosed renal artery could be attempted, even after 24 h, if it is safe to do so but our practice is not to intervene if more than 6 h after injury.

SMA (Superior Mesenteric Artery) Injury

Mesenteric bleeding causes hemorrhage and a hematoma, which further compromises bowel blood flow by pressure, and can cause ischemic gut. Open surgery is the established treatment option. However, endovascular treatment options have been reported. Embolization stops bleeding and limits hematoma formation which makes surgery easier if required later on. Embolization techniques are either proximal embolization (limits distal gut ischemia) or back and front door embolization (limits reperfusion via collaterals).

Mesenteric arterial bleed: what is new

- Embolization (proximal or back and front door technique)
- Use bioresorbable material
- Indicated in isolated mesenteric bleeding
- Successful embolization can make subsequent laparotomy unnecessary
- Stents can be used in more proximal SMA but sizing issues are relevant

In proximal embolization, the embolization is done as close as possible to the bleeding source. In front and back door embolization, the proximal and distal vessels leading to the bleeding source are embolized to prevent bleeding from either end or recruitment of collaterals (Fig. 2).

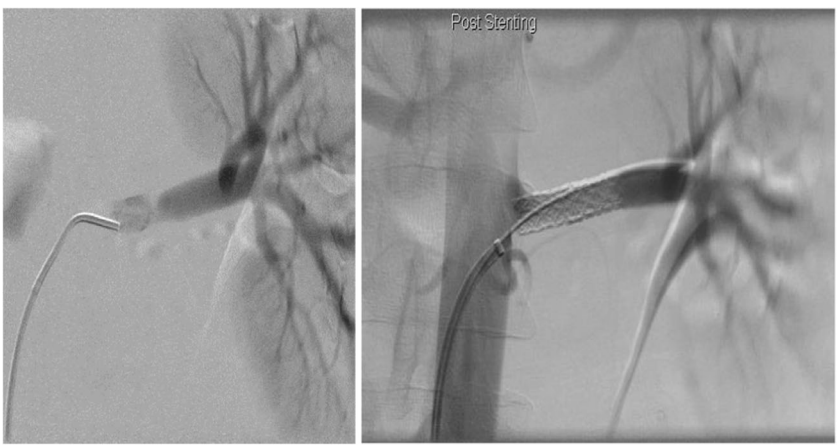

Fig. 1 CT (male; crush injury) shows dissection in left renal artery. Catheter angiogram confirms those findings and shows stent placement

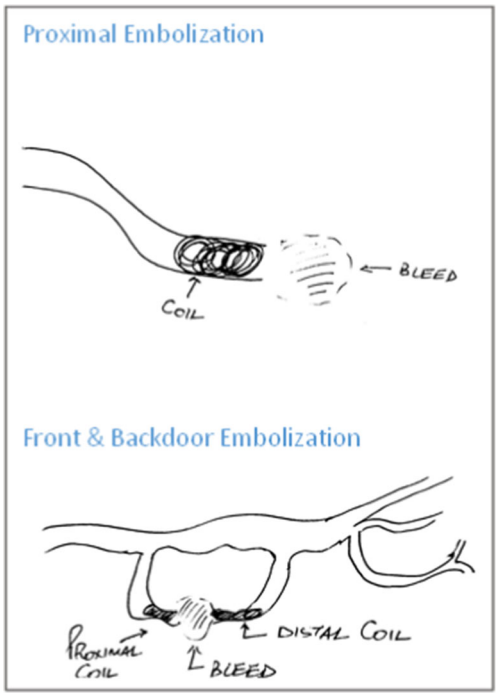

Fig. 2 In proximal embolization, the embolization is done as close as possible to the bleeding source. In front and back door embolization, the proximal and distal vessels leading to bleeding source are embolized to prevent bleeding from either end or recruitment of collaterals

Successful embolization attempts in mesenteric arterial bleeding, with the advantages of safety and efficacy, have been reported [3•, 6•]. Superselective catheterisation is a vital access technique. A catheter angiogram should be used to localise the bleeding and deliver microcoils, gelatin sponge or n-butyl cyanoacrylate application (NCBA). Embolization should be attempted in those with active bleeding but no ischemic gut. It can also be attempted in hemodynamically stable patients or even in those unstable patients in whom FAST/CT shows no intraperitoneal bleed. Superior mesenteric venous bleeds are not controllable with endovascular means.

Celiac Artery Injury

Celiac artery injury is the least common among all blunt abdominal vascular injuries [42]. The most common presentation is with dissection or avulsion. There has been no described interventional treatment, with open surgery the default intervention.

What is new in celiac artery blunt trauma

- Least common among all blunt abdominal vascular injuries
- Endovascular treatment (plug the celiac origin abdominal aorta)
- Access can be an issue
- Primary repair of celiac artery if small injury, tangential injury and experienced surgeon
- If complete celiac disruption, ligate celiac and reconstruct using autogenous or prosthetic graft
- Take graft from infra renal aorta and anastomose to common hepatic artery

New therapeutic strategies, such as conservative treatment using aspirin [43], have been described. Further, endovascular treatment involving a stent in the aorta and retrograde access to plug the celiac origin has been reported [44]. Primary repair should be considered if there are small tangential lacerations, but if there is total disruption of celiac trunk, then ligation and possible bypass to the common hepatic artery will be needed. Use of autogenous vein graft or prosthetic graft have both been reported [45–47].

The endovascular treatments for celiac artery injury are not simple procedures. Endovascular treatment stops bleeding, but does not revascularise the celiac axis. If visceral ischemia develops, then an open procedure to revascularise the celiac axis via the common hepatic or splenic artery needs to be undertaken.

IMA (Inferior Mesenteric Artery) Injury

These are uncommon injuries and may be partial lacerations or avulsions. Open surgery remains a valid treatment option; however, endovascular treatments have been reported, such as embolization of the IMA via a lacerated origin [48] and stent graft placement in the aorta and embolization of IMA stump via SMA collaterals [49].

There has been a shift towards endovascular options, yet some of these endovascular options are not simple to perform.

Inferior mesenteric artery injuries

- Open surgery (ligation)
- Embolise via origin, if partial laceration
- Stent aorta and retrograde embolization of IMA stump through SMA branch

Open surgery is generally straight forward with ligation of IMA, easily combined with laparotomy for other visceral injuries. However, in isolated IMA injuries, with stable patients and a properly trained surgeon/interventionist, endovascular treatment could be attempted

Iliac Artery Injury

There is a 20% incidence of arterial injury in pelvic fractures. Blunt iliac artery injury mortality can reach 50% [50•]. Bleeding, dissection or AV fistula are modes of presentation. Blunt intimal injuries in the common or external iliac artery can progress to

thrombosis and acute ischemia. Endovascular repair of common/external and internal iliac artery is not uncommon [51••].

Iliac artery blunt trauma: what is new
• Endovascular treatment is the preferred option
• Stent for common/external Iliac injury
• Embolize branches/smaller vessels
• If arterial lesion can be crossed, embolize proximal and distal to lesion
• Embolization is more effective than external fixation to stop arterial bleed
• Leave access sheath in for 24 h, in case of rebleed

Iliac Vein Injuries

In many situations pelvic packing is the appropriate damage control technique for pelvic venous hemorrhage, but occasionally open intervention can be effective either by ligation or repair of small lacerations. Generally, it is not possible to obtain effective hemostasis of diffuse venous bleeds endovascularly because of anatomical issues affecting access, and multiple branches. Insufflating the urinary bladder to obtain pelvic tamponade has been reported [52•]. However, major veins, such as the iliac veins and IVC, do lend themselves to endovascular control. Recently use of a covered stent [53•, 54] and even an uncovered stent has been reported [55•]. It is felt that an uncovered stent could be effective by improving axial flow in the vein and relieving the pressure of overlying hematoma on the vein wall.

What is new in iliac vein injuries
• Use of covered stent graft
• Use of uncovered wall stent
• Use of venous balloon occlusion
• Clamp urinary bladder catheter to increase intrapelvic pressure for better hemostasis
• Only major axial veins suitable for endovascular treatment
• Avulsed veins can't be treated endovascularly, need open repair

IVC Injury

Blunt IVC injuries are difficult to treat surgically and carry more than 60% in-hospital mortality [56]. The retrohepatic segment of the IVC is the most commonly segment injured in blunt trauma [17] and has the worst prognosis. Conventional treatment has been primary repair, end to end anastomosis, use of synthetic/autogenous graft and ligation. Damage control, packing, temporary shunting of the IVC and ligation of the IVC are contemporary manoeuvres.

Some IVC bleeding will stop and become contained; hence, there is a role for non-operative treatment, which involves keeping CVP low, bed rest, intensive monitoring and avoiding excessive crystalloid infusion (to prevent dilution of clotting factors and destabilising of clot). It has been shown that low venous pressures may be associated with a good clinical outcome with conservative management.

Percutaneous venous balloon occlusion [57•] and stent graft repair have been reported [58, 59•]; however, potential risks of inserting a device designed for intra-arterial use to treat a venous injury include erosion into the cava, migration, and branch occlusion.

What is current in inferior vena cava injuries
• Laceration is the most common injury type
• Retrohepatic IVC is commonly injured
• Conservative treatment
• Intravenous balloon occlusion
• Stent graft
• Use IVC filter in IVC dissection
• Prophylactic fasciotomy while doing IVC or iliac vein ligation
• Survivors prone to VTE, edema, venous insufficiency symptoms

Aortic endograft extension cuffs are useful, specifically in retrohepatic IVC injuries [60]. If the IVC is large, then the use of the Cook graft is recommended. Sizing the IVC graft should be 10–15% more than the IVC diameter obtained through valsalva. Post procedural anticoagulation is recommended.

Portal Vein Injury

Portal vein injuries can be very difficult to treat. Hemodynamic instability or hematoma around the portal vein are indications for intervention. The surgical approach carries considerable risk [61] due to oedematous peripancreatic fat, problems in handling the superior mesenteric vein/portal vein confluence and mortality rates of 50–70% have been reported. Successful endovascular treatment has been reported using a self-expanding stent with access via percutaneous transhepatic puncture of the right portal vein [5•].

Blunt traumatic portal vein injury
• Unstable patient or expanding hematoma need intervention
• Open repair difficult, 60–70% mortality
• Endovascular repair reported
• Access: intrahepatic via right portal vein
• Use self-expanding stent

Outcome

Endovascular treatment has been reported in almost every type of blunt abdominal vascular injury. There is an

increase in use of endovascular devices with a mortality reported to be 35% less than open intervention [62]. Most are being done within hours of admission and even hypotensive patients are being endovascularly treated [63•]. A better understanding of the natural history has enabled conservative and delayed endovascular interventions. However, specific skill set acquisition is needed to realise these benefits [64•, 65••]. Since the incidence of blunt abdominal vascular trauma is low, its management should be confined to centers, where the gains of accumulating experience and maintaining improved survival outcomes can occur.

Issues such as use of large caliber devices in younger patients, endoleaks, stent migration and long-term up follow-up do remain. However, technical success, good results, use of simple devices, and still having open surgery as bail out option might be the reasons behind the increasing use reported in literature. We note a paradigm shift in management of blunt abdominal vascular trauma with more being either managed conservatively or with endovascular means [8•, 10•].

Conclusion

Blunt abdominal vascular injuries are rare. There is no consensus on best management options. The trauma severity is generally high. Thrombosis or intimal injuries are the common mode of presentation. Use of multi slice CT scanners has enhanced diagnostic ability and allowed planning of endovascular treatment. There is a better understanding of the natural history. Open surgery still has a role, though it is diminishing. Conservative management and endovascular interventions are being increasingly used to successfully manage these injuries. Endovascular treatment options have proven to be less invasive, with greater technical and therapeutic success and reportedly better survival rates. Despite lack of medium to long-term survival data, more and more blunt abdominal vascular trauma cases are being treated endovascularly. Specific skill sets need to be acquired and multidisciplinary team input is a must.

Compliance with Ethical Standards

Conflict of Interest Drs. Chandhok and Civil declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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