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Mini-Review

Review on Inferior Vena Cava (IVC) Injuries and Current Management Strategies

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ABSTRACT

IVC injuries are rare but are associated with high morbidity and mortality. Most are traumatic (blunt versus penetrating), which often require surgical management, either repair or ligation, as first-line depending on clinical stability. Unlike advancements in endovascular approach for arterial disease, the role for endovascular therapy such as balloon occlusion or stent graft remains unclear. In this review, we discuss management of IVC injuries based on anatomic and clinical considerations and various treatment options including traditional, standard-of-care surgical approach versus novel, off-label endovascular repair. In the trauma setting, up to half of patients will die before even reaching the hospital, and of those who arrive to the hospital, roughly half will not survive to discharge.

Keywords: IVC injury; Endovascular repair; Stent graft

INTRODUCTION

Injuries to the Inferior Vena Cava (IVC) are rare but are associated with significant morbidity and mortality. Majority of cases are due to traumatic insult with overall incidence of 0.5-5% in penetrating trauma and 0.6-1% in blunt trauma whereas reported incidence of iatrogenic injury during intraabdominal surgery is 0.01-1.9% [1,2]. In the trauma setting, up to half of patients will die before even reaching the hospital, and of those who arrive to the hospital, roughly half will not survive to discharge [3,4]. Despite improvements in pre-hospital care and advances in management of vascular trauma, mortality remains high and unchanged over the past several decades [1].

In this review, we first delve into anatomic and clinical considerations when managing IVC injuries and then discuss various treatment options including traditional, standard-of-care surgical approach versus novel, off-label endovascular repair. We also propose a workflow scheme for how to approach these injuries depending on variables like anatomic and clinical factors discussed in great detail below (Figure 1).

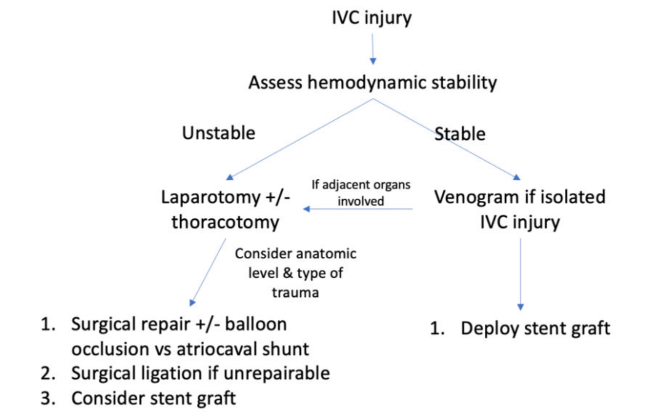

Figure 1: Schematic of workflow for management of IVC injury.

LITERATURE REVIEW

Anatomic and clinical factors

The IVC is a large retroperitoneal vein that drains venous return from the lower extremities, pelvis, and abdominal viscera to the

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right atrium of the heart. It is formed by the confluence of the iliac veins at L5 and receives numerous tributaries such as lumbar, gonadal, renal, and hepatic veins as it ascends into the thoracic cavity through the diaphragmatic hiatus at T8. Anatomically, the IVC can be divided into four segments in terms of location of injury for management considerations including infrarenal, juxta-renal, retrohepatic, and suprahepatic.

Typically, infrarenal IVC injuries have the best survival due to the relative ease of access and ability to tamponade bleeding whether surgically or endovascularly [5]. Suprarenal IVC, while still accessible, tends to have more adjacent structures to dissect apart and tend to have associated renal and liver injuries. For instance, retrohepatic IVC injury commonly also involves liver parenchyma damage, which requires mobilization of the liver and exposure of hepatic vasculature, leading to increased complexity. Morality for such cases may range from 50% to 80% [6]. Suprahepatic IVC presents even more difficulty controlling bleeding and is near universally fatal with rare case reports of survival [1,7,8]. Patients can present with cardiac tamponade, and clamping and draining of IVC for emergent cardiopulmonary bypass can be technically challenging, especially if the IVC is torn. In the largest available prospective registry (PROOVIT), overall mortality was 42% (infrarenal 33% versus suprarenal 66%, $p<0.001$) [9].

Not surprisingly, commonly reported clinical predictors of mortality include factors such as hypotension, higher injury severity score, lower Glasgow coma score, and need for thoracotomies [5,10,11].

DISCUSSION

Surgical approach

Primary ligation *vs* repair: There is currently a lack of expert consensus in terms of best approach for managing IVC injuries, in part due to rare incidence limiting outcomes data to small single center studies without standardized details for reporting across institutions.

Factors such as patient's clinical status, type of trauma, and IVC level of injuries, surgeon experience, and patient anatomy all contributed to the decision for ligation versus repair. Time is of the essence when it comes to the management of IVC injuries. In a stable patient with a simple injury, repair, if feasible, is generally favored. However, in an acute unstable patient who is in hemorrhagic shock, damage control with IVC ligation may be a reasonable option, particularly for complex injuries [12]. Previously in a propensity score matching analysis using the National Trauma Data Bank (NTDB) from 2007-2014, there was no difference in mortality between IVC ligation and IVC repair (41.3% *vs* 39.0%; OR 1.10; 95% CI 0.80 to 1.52), but ligation was associated with higher complication rates such as extremity compartment syndrome (OR 5.23; 95% CI 1.50 to 18.24) and hospital length of stay (17.0 days (interquartile range 1.0 to 35.0 days) *vs* 9.0 days (interquartile range 1.0 to 22.0 days); $p=0.002$) [13,14]. One major limitation is the lack of data granularity such as reporting of IVC anatomic level of injury and type of trauma. For instance, suprarenal IVC injury has been reported as an independent predictor of mortality [12,15]. Similarly, blunt trauma is associated with higher mortality than penetrating trauma since the nature of the injury requires significant energy which leads to numerous other injuries.

In a more recent comprehensive meta-analysis of 14 studies, IVC ligation was associated with higher mortality than IVC repair (OR 3.12; 95% CI 1.58 to 6.15; $p<0.01$, $I2=49\%$) in all-comers [12]. However, in a subset analysis on the impact of ligation versus repair specific to infrarenal IVC injury, there was again no statistical difference on mortality (OR 3.13; 95% CI 0.83 to 11.75, $p=0.0917$, $I2=61\%$), which would be consistent with prior studies using NTDB [13,14]. Alternatively, this also raises concern for a type II error due to smaller sample size of 193 patients. In a large single center series of IVC injury outcomes involving 100 patients, 25 underwent ligation of the IVC, including 22 infrarenal IVC and 3 suprarenal, versus 29 who underwent IVC repair [16]. Infrarenal IVC ligation resulted in early mortality of 41% compared to 21% for repair ($p=0.11$), albeit statistically insignificant, and was associated with increased length of stay. For juxtarenal injuries, 3 were ligated and 18 repaired. Notably, all 3 ligations were performed as salvage after repair failed (2 died on the table). Overall, 10 patients with IVC ligation (9 infrarenal, 1 suprarenal) survived to hospital discharge, and at an average of 42 months (11-117 months), no patients have significant complications such as lower extremity edema.

Atriocaval shunt: Also known as the Schrock shunt, the Atriocaval Shunt (ACS) was first described in 1968 as a last-ditch effort in trauma patients with suprarenal IVC injury to control hemorrhage by placing a tube inserted through the right atrium into the suprarenal IVC to create a shunt bypassing the defect. Survival in patients with ACS is abysmal, roughly 19%-22% [17,18]. In the era of endovascular therapies, ACS is becoming more obsolete.

Endovascular approach

Despite advances in endovascular technique for arterial disease, there has been limited adoption of endovascular approach for IVC injury, used in 2% of cases in the largest prospective registry (PROOVIT) [9]. The main advantage of endovascular approach (balloon occlusion and stent graft) is potentially the relative ease and speed for controlling active hemorrhage, leading to decreased subsequent coagulopathy and reduced procedure time. In general, it can be considered an adjunct to open surgery as there are often concomitant traumas with the IVC injury.

Several unanswered questions remain in terms of long-term durability of stent graft and management of postoperative anticoagulation. In the early months, the stent is highly thrombogenic until endothelization of the endoluminal surface. However, there is limited data on anticoagulation regimen after IVC endografting. An experimental canine model suggested use of coumadin led to greater patency of PTFE-covered stents compared with controls [19]. Routine use of antiplatelet therapy has also not been well established, though mechanistically, platelet inhibition, especially immediately after stenting, would seem beneficial [20].

Balloon occlusion: Resuscitative Endovascular Occlusion of The Aorta (REBOA) is a well described technique in the aorta for traumatic life-threatening hemorrhage below the diaphragm [21]. Case reports have described similar endovascular approach for balloon occlusion of the IVC (REBOVC) as an adjunctive to temporize bleeding and allow for surgical repair, which is particularly helpful in difficult retrohepatic and suprahepatic cases [22-24]. In a proof-of-concept swine model of trauma (n=13), REBOVC demonstrated superior control of bleeding with significantly less blood loss [25]. In one case series of 5 patients, REBOVC served as a useful adjunct in the management of IVC injury and demonstrated the feasibility of hybrid open-endovascular approach with 80% survival to discharge [26]. Four of the 5 underwent IVC repair whereas one underwent ligation.

Stent graft: To date, there have been only 15+ single case reports of using arterial devices for treating IVC injuries, ranging from stent grafts to aortic cuff to self-expanding covered stents summarized in Table 1 [27-41]. Overall, while biased reporting, all 15 endovascular procedures were successful with 14/15 (93.3%) surviving to discharge. One patient died two days post-op due to traumatic brain injury. Seven cases were due to blunt trauma, 3 due to penetrating trauma, and remaining 5 due to iatrogenic causes during other invasive procedures. Four cases were infrarenal while the remaining 11 cases were suprarenal. The latter of which, as previously discussed, portends worse outcomes, and implantation of an endovascular stent as adjuvant to control bleeding may be life-saving in these instances. In the 5 case studies that reported duration of procedure, all were completed within an hour (ranging from 8 to 53 minutes), which again highlights the advantages of endovascular approach. Only 9 of the 15 cases reported some form or combination of antiplatelet/ anticoagulation therapy on discharge, though it remains unclear whether there is clinical benefit for endograft patency given paucity of data. Limited follow-up ranged from 1 to 18 months with patent stent graft.

Case report	Year	Demographic	Anatomic location	Type of injury	Endovascular repair	Duration of procedure (mins)	Outcome	Anticoagulant / antiplatelet
Watarida, et al.	2002	62 yoM	juxtahepatic		2 self-expanding Gianturco Z stents (30 mm × 50 mm and 30 mm ×50 mm)	52	patent endograft at 16 months	warfarin
Erzurum, et al.	2003	37 yoF	retrohepatic	iatrogenic during resection of RP leiomyosarcoma	Endoluminal stent graft (2 AnuRx aortic extension cuffs 28 mm × 37.5 mm)		patent endograft at 6 months	
de Naeyer, et al.	2005	51 yoF	infrahepatic	iatrogenic during lumbar vertebral fusion	Talent endoluminal stent graft 44 mm		patent endograft at 18 months	warfarin
Castelli, et al.	2005	65 yoF	infrarenal	blunt (MVA)	Stent graft 31 mm × 14 mm × 150 mm Gore	9	died 2 days post-op due to brain injury	
Sam, et al.	2006	62 yoM	infrarenal	Blunt (construction)	Gore TAG × 2 (28.5 mm endograft cuffs)		patent endograft at 14 months	warfarin (popliteal DVT)
Hommes, et al.	2010	29 yoF	juxtahepatic	Penetrating (stabbing)	Gore aortic extenders × 2 (32 mm × 45mm and 32 mm × 45 mm)		discharged	
Filippini, et al.	2013	25 yoM	juxtahepatic	blunt (MVA)	NuMED Covered CP stent × 2		patent stents at 15 months	aspirin
Pittaretti, et al.	2013	23 yoM	suprarenal	blunt (MVA)	Zenith 32 mm × 58 mm endograft	8	patent endograft at 12 months	

Briggs, et al.	2014	46 yoF	retrohepatic	iatrogenic (adrenalectomy)	Talent covered stent graft × 2 (32 × 115 mm and 34 × 158 mm)		patent endograft at 13 months	warfarin
Marsala, et al.	2018	72 yoF	infrarenal	Iatrogenic (IVC filter removal)	Gore aortic extender stent graft × 2 (23 mm × 33 mm) and Gore tag × 1 (21 × 100 mm)		patent endograft at 3 months but occluded at 12 months	
Frenk, et al.	2019	75 yoM	infrarenal	Iatrogenic (vertebroplasty)	Endurant II aortic extension stent graft 32 mm × 57 mm		patent endograft at 1 month	aspirin + plavix
Tariq, et al.	2019	27 yoF	suprahepatic	blunt (MVA)	Endurant endografts × 2 (13 mm × 82 mm and 16-13 mm taper × 124 mm)		50% endograft clot burden after stopping warfarin	warfarin × 6 weeks; aspirin + plavix indefinitely
El Khoury, et al.	2019	22 yoM	suprarenal	penetrating (GSW)	Endurant endografts × 2 (28 mm × 82 mm and 28 mm × 70 mm)		patent endograft at 2 months	
AllMulhim, et al.	2021	52 yoM	retrohepatic	blunt (MVA)	BENTYL Be graft 24 × 48 mm; balloon mounted covered stent	12	discharged	aspirin + 5 months warfarin
Santini, et al.	2022	40 yoM	suprarenal	penetrating (GSW)	Gore × 2 (28.5 mm × 33 m and 28 mm × 45 mm endograft cuffs)	53	patent endograft at 1 month	aspirin + plavix × 1 month, then plavix for 6 months

Table 1: Summary of case reports for use of endografts for various IVC injuries.

A variety of stent grafts, aortic extender cuffs, and covered stents were utilized, in part likely limited by equipment availability at the respective facilities. Notably, all commercially available devices are not intended for veins, which have theoretical risks for erosion and rupture of the IVC. Depending on the anatomy and anatomic level of injury, there may also be concern for branch occlusion, necessitating need for fenestrated endografts but would not be readily available. In a proof-of-concept canine model, the use of stent graft showed drastic improvement in outcome from 100% mortality to 100% survival rate in the setting of juxtahepatic IVC injury (n=20) [42].

Furthermore, once the decision to place stent graft is made, identifying level of IVC injury *via* venogram and selecting appropriate size of stent graft are crucial. Angiographic sizing can be challenging due to dynamic respirophasic nature of the IVC, depending on the hemodynamic and volume status of patient. If time allow, intravascular ultrasound can be helpful to obtain more objective diameter measurements. Given lower pulse pressure and thinner layers of the IVC as opposed to aorta, less aggressive oversizing of the endograft such as oversizing by 10%-15% based on transverse diameter may be reasonable.

CONCLUSION

IVC injuries, particularly due to blunt trauma and suprarenal, can be devastating and often fatal. Rapid control of bleeding is essential. There is lack of expert consensus in terms of best approach to IVC injuries given infrequent incidence and scarce prospective data. Open surgery is typically first-line, especially in unstable patients with multiple visceral and organ injuries. Repair is preferred over ligation, latter of which is considered in damage-control situations and leads to higher complication rates such as lower extremity swelling and prolonged hospitalization. Newer endovascular therapies including balloon occlusion and stent graft have shown promise in case reports and can be considered as adjuncts for controlling bleeding and primary therapy options.

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