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Severe Venous Injury in Acute Trauma Setup – Is There a Role for Endovascular Treatment?

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Background: The role of endovascular treatment of acute traumatic venous injuries (ATVI) remains controversial. Endovascular resuscitation and hybrid trauma management (EVTM) concepts, which constitute the combination of conventional and endovascular capabilities in the treatment of vascular injuries continue to evolve, yet published reports of traumatic venous injuries treated by endovascular means remain confined to sporadic case reports.
Methods: The medical literature from 1990 to 2017 using Pubmed and OVID Medline databases was reviewed to search for reports on the endovascular treatment of ATVI. No publications were excluded due to the small number of publications available. Sixteen reports were found. The manuscripts were analyzed regarding the mechanism, location, and type of injury; endovascular techniques utilized; and both clinical and radiographic outcomes.
Results: Endovascular treatment was reported in only 16 patients with ATVI during the study period. Most cases (10/16; 62.5%) were secondary to blunt trauma, while the rest (6/16; 37.5%) were secondary to penetrating injuries equally divided between gunshot wounds and stab wounds. Endovascular stent or stent graft utilization was employed in 12 of these cases, 2 cases were treated by endovascular embolization and in 2 cases endovascular balloons were used for temporary hemorrhage control to facilitate open surgical exposure and intervention. No mortalities related to the endovascular interventions were reported.
Conclusion: The experience with endovascular treatment of ATVI remains very limited. The results currently available, although very limited in numbers, appear promising. Additional study will prove essential in defining the optimal employment of EVTM concepts in the management of venous injuries, particularly as technology continues to advance and experience with these modalities increases.

Keywords: *EVTM; Venous Injury; Review; Endovascular Treatment*

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INTRODUCTION

Acute traumatic venous injuries (ATVI), caused secondary either to blunt or penetrating mechanisms, are very rare. These injuries are, however, associated with high mortality rates of up to 50% at the scene of injury and 30–50% among those that reach hospital [1,2]. These figures have not changed during the past decades, despite all the advances in prehospital care, damage control resuscitation, and surgery.

ATVI are frequently accompanied by multiple, often severe, organ injuries. Most major veins, which are high

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volume–low pressure systems, are located deep within the neck, mediastinum, and retroperitoneum, and as such are not easily accessible to control with expedient packing. The location of these major injuries often dictates extensive anatomic dissection in order to expose and control the bleeding venous source. Van Rooyen et al. reported a 37% mortality rate among patients with inferior vena cava (IVC) injuries secondary to the penetrating mechanism of injury. These investigators suggested that the consideration of less aggressive treatment for hemodynamically stable patients may improve the high mortality rate [3].

The evolving concepts of endovascular resuscitation and hybrid trauma management (EVTM), which have gained in popularity, represent attractive alternative treatment paradigms for cases which were previously treated with open surgery. Recent publications have demonstrated lower complication and mortality rates among patients treated by such endovascular means [4,5].

The published literature regarding endovascular management of significant ATVI is scarce and remains confined to case reports. The aim of our study was to summarize the cumulative experience of endovascular treatment of ATVI through a review of the available English medical literature.

MATERIALS AND METHODS

A systematic review of the English medical literature was conducted, using the Pubmed (www.pubmed.gov, accessed 1 February 2012) service of the National Library of Medicine/National Institutes of Health and the OVID Medline databases to identify all case reports and case series of endovascular management of ATVI. Only reports regarding acute trauma patients were included while iatrogenic as well as delayed traumatic venous complications were excluded from the search database. Specifically, the search terms "venous", "axillosubclavian veins", "iliac veins", "superior and inferior vena cava", "innominate vein" were combined with "trauma" or "injury" and "endovascular management" and "grafts" to identify articles for review. The following criteria were used to select studies to be included in the analysis: adequate information regarding the mechanism, location, and type of the injury, type of endovascular management, surgical intervention, and follow-up.

RESULTS

The use of endovascular techniques for the treatment of ATVI was described in only 16 cases, constituting 13 males and 3 females, during the 20 years period from 1997–2017. The mean age of patients was 43.1 years old (18–76). Blunt trauma was the leading cause of ATVI, comprising 62.5% (10/16) of cases. Penetrating trauma comprised the remaining 37.5% (6/16), with equal distribution between gunshot wounds (GSW) and stab wounds (3 cases each). Stent or stent grafts were utilized in 12 cases – 5 IVC, 4 iliac, 1 subclavian, 1 axillary, and 1 hepatic vein stents (Table 1). Femoral veins were the preferred access portal for intra-vascular approach to injuries. Stent or stent graft placement achieved 100% angiographic as well as clinical hemorrhage control. Radiographic follow-up images were available for only 7 cases, all of which demonstrated patent veins. The timing of follow-up ranged from 48 hours to 12 months after the injury. Endovascular balloons were used in 2 cases in order to gain temporary hemorrhage control while surgical exposure was conducted to facilitate repair of IVC injuries secondary to GSW [18,19]. Endovascular embolization was used in 2 cases of zone III penetrating neck injuries with isolated jugular vein injury [20,21]. The details of these 4 cases are described in Table 2.

There were no endovascular-related mortalities reported. One patient, successfully treated for IVC bifurcation injury with good clinical and angiographic results, died of a concomitant brain injury [12]. No complications related to the endovascular procedures were reported.

DISCUSSION

The use of venous stents and stent grafts in cases of chronic venous stenosis, as in May Thurner syndrome, has proven a successful and commonly adopted practice for many years. Primary patency rates of 71% and secondary patency of 90% over 24 months following the utilization of this approach, have been reported by Raju and colleagues [22]. The optimal role of endovascular treatment in cases of acute trauma venous injury, however, has not been well elucidated. The main purpose of our present review was to review the accumulated world experience with such treatments in human clinical applications.

ATVI are extremely rare and are associated with high mortality rates – up to 50% in subclavian and axillary vein injuries as described by Demetriades and co-investigators [23]. The traditional treatment of ATVI has been limited to surgical exploration with primary or lateral repair, or ligation of the vein in extreme cases.

EVTM, however, is becoming the preferred mode of treatment among selected hemodynamically stable patients in capable centers, either as a replacement or as an adjunct to traditional open surgical treatment at distinct injury locations [24]. The tendency to use EVTM is gaining more and more popularity with the improved understanding of the ability of this modality to minimize the "secondary hit" associated with major open surgical intervention associated with open surgical repair [25].

Several previous animal studies have demonstrated the potential feasibility and benefit of EVTM technology application in significant venous injury. In addition to human studies outlined in our results, our review identified a number of exploratory studies describing endovascular hemostasis of severe venous injuries in animal hemorrhagic models. In one of these studies, Porta et al.

Table 1 Summary of studies on severe venous trauma patients treated by endovascular stenting.

	Age	*Sex*	*Mechanism*	*Injured Vein*	*Access*	*Treatment*	*Mortality*	*Follow-Up Imaging*
Denton [6]	27	Male	Blunt	Retrohepatic IVC	Trans hepatic right hepatic v.	Two 12 × 40 mm Wallstents (Schneider, Inc., Minneapolis, MN, USA)	No	Venography
Uppot [7]	18	Male	Blunt	Right common iliac	N/A	A 10 × 40 mm Cordis Endovascular SMART nitinol stent (Johnson & Johnson, Miami, FL, USA)	No	N/A
Watardia [8]	62	Male	Blunt	Retrohepatic IVC	RFV	A 24-mm 3 10-cm endoluminal graft was constructed from 2 self-expanding 30-mm 3 5-cm Gianturco Z stents (Cook Diagnostic and Interventional Products, Bloomington, IN, USA) covered with collagen-coated 24-mm Dacron graft (Hemashield, Meadox Medicals, Inc., Oakland, NJ, USA)	No	US+CT
Jeroukhimov [9]	35	Male	Blunt	Left subclavian	LFV	Covered stent-graft (Jostent 12-48, Jomed, Germany)	No	N/A
Kumar [10]	27	Male	Stab wound	Left Axillary	LBV	10 × 50-mm Viabahn endoprosthesis (WL Gore and Associates, Flagstaff, AZ, USA)	No	US
Zieber [11]	44	Male	Blunt	Left EIV	LFV	Two 14 × 50-mm Wallgraft endoprostheses (Boston Scientific, Natick, MA, USA)	No	US
Castelli [12]	65	Female	Blunt	IVC at the ilio-caval bifurcation	RFV & LFV	14 × 31 × 140-mm stent graft (Excluder-WL Gore and Associates)	Yes	N/A
Sam [13]	62	Male	Blunt	Infrarenal IVC	RFV	Two 28.5-mm aortic cuffs (WL Gore and Associates)	No	US
Hommes [14]	29	Female	Stab wound	Retrohepatic IVC	RFV	Two overlapping stent grafts 32 mm diameter and 45 mm length each (GorePXA320400, WL Gore and Associates)	No	CT
Sofue [15]	52	Female	Blunt	Left EIV	LFV	Two 14-mm-diameter, 64-mm-long self-expandable uncovered stent (Easy Wallstent, Boston Scientific, Natick, MA, USA)	No	CT
Beitner [16]	36	Male	Stab wound	Middle hepatic	IJV	Covered stent, Gore Viator Tips endoprosthesis (WL Gore and Associates)	No	N/A
Merchant [17]	47	Male	Blunt	Right EIV	RFV.	16-mm (distal diameter) × 14.5-mm (proximal diameter) Excluder stent-graft (WL Gore and Associates)	No	N/A

BV, left basilic vein; EIV, external iliac vein; IJV, internal jugular vein; IVC, inferior vena cava; LFV, left femoral vein; RFV, right femoral vein; SCV, subclavian vein.

Table 2 Summary of studies on severe venous trauma patients treated by hybrid approach without stenting.

	Age	*Sex*	*Mechanism*	*Description*	*Access*	*Treatment*	*Mortality*	*Follow-Up Imaging*
Angeles [18]	24	Male	GSW	IVC transection	LFV &. RIJV	Proximal and distal control	No	N/A
Bui [19]	50	Male	GSW	IVC transection -	RFV	Proximal and distal balloon control	No	US
Sanabria [20]	35	Male	GSW	Right internal jugular vein transection	LIJV	Embolization	No	CT
Yamanaka [21]	76	Male	Stab wound	Right jugular bulb transection	RIJV & LIJV	Embolization	No	N/A

GSW, gunshot wound; IVC, inferior vena cava; LFV, left femoral vein; LIJV, left internal jugular vein; N/A, not available; RFV, right femoral vein; RIJV, right internal jugular vein.

created angiographic retrohepatic vena cava injury in 20 canines, demonstrating that all animals treated by stent grafts (10 dogs) in their model could achieve survival compared with the control group (10 dogs) in whom mortality was 100% [26]. Additional work conducted by Wang et al. in a swine injury model showed that temporary stent graft insertion through the infrahepatic vena cava could be utilized effectively to facilitate surgical repair of major hepatocaval injury when combined with a Pringle maneuver [27]. Finally, in a study of retrohepatic IVC injuries conducted by Reynolds et al., researchers examined the efficacy of balloon occlusion of the suprahepatic IVC as an adjunctive maneuver. In this swine model, injury was created to the retrohepatic vena cava and hepatic inflow control was achieved by clamping of the hepatoduodenal ligament and infrahepatic vena cava. In their intervention group, suprahepatic IVC control was obtained by resuscitative balloon occlusion. In the intervention group, time to death was significantly prolonged and the blood loss was significantly reduced compared with the control group [28].

Endovascular treatment adjuncts have increasingly proven attractive for the treatment of specific severe vascular injuries due to the complexity and poor results of traditional open treatments [29,30]. The repair of traumatic major venous injuries presents a similar surgical challenge traditionally associated with a myriad of complications. The challenge with the open surgical treatment of these injuries is attributed to the distorted anatomy secondary to ongoing bleeding and associated obscuring hematoma. Exposures can be time-consuming, and iatrogenic injuries to adjacent tissues during harried exposures in obscured hemorrhagic fields represent a significant risk. The exposure itself, by its very nature, disrupts any tamponade effect which may have been temporizing ongoing hemorrhage – often to a disastrous effect.

While attractive options, the present endovascular treatments do possess some limitations. Effective access and imaging are required, in addition to the appropriate expertise. Long-term patency of employed stent-grafts in low flow states remains a matter about which little is known and, accordingly, their use should likely be reserved for high flow large diameter veins, such as the vena cava or iliac veins, among hemodynamically stable patients [31].

Our present review demonstrates that existing literature is devoid of well-organized studies of endovascular treatment of ATVI. At present, they appear encouraging in their reported results, all that has yet been demonstrated in the literature is based on case reports or case series. Reporting bias almost certainly exists – as all published reports describe only the successful treatment of patients who survived the ATVI.

Existing case reports also demonstrate that endovascular adjuncts have been applied across a variety of large venous structures. As these capabilities represent a range of modalities that can be utilized – from balloons to embolization techniques to stent grafts – they also represent a menu of adjuncts that can be effectively considered for utilization in isolation or in conjunction with open repair. In one case reported by Denton et al., primary repair, embolization, and stenting were used in sequence to treat venous injuries in the same patient [6]. Despite the array of potential options, there remains no effective consensus on the ideal anatomic sites for endovascular adjuncts. Regardless, the present consensus among trauma and vascular surgeons suggests that the vessels most likely to prove amenable are those which are difficult to approach surgically and are associated with the greatest risk of iatrogenic injury during the exploration and exposure for open treatment [32].

The use of the femoral vein as the preferred access site was noted from the available review. This finding is easily explained by the maneuverability and versatility this site allows the treating physician and the fact that the upper part of the body is usually much more "crowded" with the staff members who take care of the

airway and breathing systems of the patient during the acute phases of treatment.

Balloon occlusion of major venous injuries likely represent the most expedient and applicable modality for employment in major venous injury. Reynolds and colleagues were the first to describe the successful use of resuscitative balloon occlusion of the IVC (REBOVC) in an experimental setting. In the hands of these researchers, REBOCC demonstrated superior hemorrhage control and prolonged time to death in a swine model of liver hemorrhage as compared to a non-intervention control group [28]. Balloons were utilized by multiple groups in our review. Descriptions of use included the use of two balloons, proximal and distal to the injured vein, in order to control the bleeding and allow a proper definitive solution, either by a surgical or endovascular approach.

Although the majority of injuries employed stent grafts to provide for venous injury repair, Sofue and colleagues used a non-covered stent to facilitate repair. In their described use, this bare metal device was utilized due to the unavailability of a covered one, as part of the treatment of an iliac vein injury [15]. Covered stent grafts, however, have shown superiority in other similar vascular uses [33,34], and should be the device of choice – as they provide one deployment coverage of the injury location from intravascular access. The use of heparinized stents, the degree of the stent oversize (compared to estimated or measured vessel diameter), and types of balloons that should optimally be employed as adjuncts remain to be elucidated more effectively.

Post-intervention management after endovascular repair also requires additional study in the trauma setting – particularly as it relates to optimal surveillance of patency and anti-platelet or anticoagulation regimens. The use of anti-aggregation therapy, specifically via dual antiplatelet (DAP) use, is advised when stents are used in order to treat arterial pathology [35]. The venous system may be even more prone to thrombosis following intimal injury as compared to the arterial system due its basic low flow state. Select reported literature suggests that primary venous repair is associated with a 15% risk for thromboembolic events [36]. It is important to note, however, that there remains no significant meaningful data to guide anti-aggregation or anticoagulation therapy following venous repair by any modality – open or otherwise. [35]. Strong consideration of DAP or anticoagulation therapy is warranted, however, little is known about the ideal dose or duration.

Although our study is the largest review of its kind to date, it has important limitations that must be recognized. Reporting bias among case reports of these types must be considered. While successful in their results, the reports also represent the practices of multiple centers across which standardization of evaluation, treatment, and capabilities are unlikely.

CONCLUSIONS

Our present review, which gathers together existing available case reports, demonstrates that the endovascular treatment of major venous injury is both feasible and potentially effective. Well-organized studies should be conducted regarding the type of endovascular repair modalities that are most likely to be beneficial. Optimal post procedure pharmacological adjuncts and follow-up require additional study.

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