Traumatic Vascular Injury and its Management with Temporary Intravascular Shunts: A Puerto Rico Trauma Hospital's Experience

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Objective: Temporary intravascular shunts (TIVSs) are commonly used as a damage-control procedure in trauma settings. Currently, there is scarce literature in the civilian field, and what there is is limited to large trauma centers with multiple resources. Therefore, we aimed to describe TIVS usage, and the outcomes of that usage, at Puerto Rico Trauma Hospital.

Materials and Methods: This is a case series conducted from 2009 to 2013 with 32 patients who suffered vascular trauma, of which 13 needed TIVSs. Data related to age, trauma mechanism, injured vessel, type of shunt, Glasgow Coma Scale, vital signs, and mortality were collected. The analysis was carried out using descriptive statistics. This protocol was approved by the IRB of the Medical Sciences Campus.

Results: The most frequent mechanism of injury was a gunshot (11/13; 84.6%). The most commonly injured vessel was the superficial femoral artery. Indwelling time ranged from 6 to 96 hours. Only 2 of the 13 (15.4%) patients with shunts reported thrombosis. Furthermore, we performed 4 (30.7% of the patients) prophylactic fasciotomies and 4 (30.7% of the patients) amputations; 4 of the 13 (30.7%) patients died from unrelated causes.

Conclusion: Our results are consistent with those in the literature, which supports our contention that a TIVS can be an effective component of damage-control vascular surgery and can, in both military and civilian settings, aid in extremity amputation prevention. Furthermore, it has been established that a TIVS can be fashioned from any available hollow tube. However, further research is needed to evaluate the safety of an improvised catheter of this nature. [*P R Health Sci J 2018;37:220-223*]

Key words: Vascular trauma, Temporary intravascular shunt, Damage-control surgery, Traumatic amputation

Peripheral vascular trauma is defined as an injury to the axillary/brachial trunk branches of the upper extremities or to the femoral/popliteal trunk branches of the lower extremities, either of which injury can arise after acute force is applied on a usually normal and healthy vessel (1, 2). The management of such vascular injuries poses a challenge to the surgeon since he or she needs to focus on life-threatening injuries, such as trunk trauma, but that individual also must keep in mind the need to ensure limb viability, to the degree that such is possible, even if addressing the issue surgically must wait until after the more urgent trauma has been attended to. Therefore, in order to guarantee limb salvage, a temporary measure to restore perfusion has been developed. The procedure employs temporary intravascular shunts (TIVSs) and is used as part of the complete damage-control strategy in 63% of all arterial vascular surgeries (3).

A TIVS is an intraluminal conduit that is placed either in an artery or a vein to maintain perfusion. Back in 1915, French surgeon Théodore Tuffier devised a method that used tubes to bridge arterial defects and maintain perfusion. Hollow, silver cylinders that were lined with paraffin, Tuffier's tubes were inserted into the 2 ends of a severed vessel, which ends were then secured with ligatures (4). Even though the technique was available, it was not widely known. Instead, the ligation of veins and arteries was the technique of choice. Fifty percent of the surgeries in which this technique is used end in amputation, with the chance of mortality being as high as 90% (5).

As time passed and military medicine (where shunts were first used) evolved, a glass tube was exchanged for

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the hollow, malleable one, and casualty transport methods decreased response time. The two developments resulted in an increase in limb salvage rates. Currently, the incidence of vascular injuries is estimated at 1.6% for adult trauma victims (6). Furthermore, TIVS usage has a combined limb/patient survival rate of 73% and an overall survival rate of 83% (7). In terms of trauma mechanisms, those that result in penetrating injuries are the most common in both military and civilian settings. Peripheral injuries account for 80% of all cases of vascular trauma in the United States (US), with the lower extremities being involved in two thirds of all patients with vascular injuries (8).

At present, commercially available shunts, such as those manufactured by Pruitt-Inahara and Argyle, are used in trauma centers in the US, predominantly. According to Subramanian et al. (2008), Argyle shunts and small-caliber chest tubes are very simple and quick to place, as well as very practical in damage-control settings (7). However, the shunts are expensive, representing a financial burden for trauma centers in times of hard economic conditions. In such cases, a TIVS can be crafted easily using a high-flow intravenous line, a nasogastric tube, or a chest tube.

Several studies have been performed in animal models to assess which catheters might be better, but no definite trend has been established. For instance, Ding et al. (2008) found that plastic tubing and custom-designed shunts have equally good patency rates when used as TIVSs during orthopedic fixation (9). Granchi et al. (2000), meanwhile, demonstrated that in complex extremity injuries, the shunts could be left in place, maintaining distal perfusion for as long as 52 hours without the need for systemic anticoagulation measures (10).

The placement of a TIVS is considered part of damage-control surgery in civilian level I trauma centers, but the effectiveness of and complications associated with this process have not been fully described (11). Puerto Rico Trauma Hospital (PRTH) is an underfunded trauma center with a high incidence of penetrating injuries. However, our experience with these types of injuries has not been documented in detail, yet. Thus, the aim of the current study was to describe TIVS usage, and the outcomes of that usage, in patients with peripheral vascular trauma at PRTH.

Material and Methods

A case-series study was conducted with patients, admitted to PRTH from 2009 through 2013, who had sustained vascular injuries and who, it was felt at the time, might benefit from the insertion of a TIVS prior to the commencement of definitive repair. A total of 32 patients with vascular trauma were identified, of whom 13 had received a TIVS.

Information on these patients was retrieved from the trauma registry of the hospital, which is part of the US National Trauma Registry System. We considered several demographic variables, such as sex and age. Clinical data, diastolic and systolic pressures, base excesses, operative procedures, complications, and final outcomes were also collected. Other participant-specific information included the location of the trauma, the injured vessel, and the presence (when such was the case) of a concomitant fracture, either open or closed. The outcomes of the study comprised the types of shunt used, the number of thrombosis events, the amputation rate, and the mortality rate.

The data analysis was performed using descriptive statistics. Continuous variables were summarized using measures of central tendency (mean, median) and dispersion (standard deviation); whereas, for categorical ones, absolute (n) and relative (%) frequencies were used. This research received approval from the Institutional Review Board of the Medical Sciences Campus of the University of Puerto Rico.

Results

The mean age of the sample population was 30.8 years; males predominated in the sample (11/13; 84.6%). The most common trauma mechanism was a gunshot (11/13; 84.6%). The other 2 mechanisms of injury reported were motor vehicle collisions (1/13; 7.7%) and falls (1/13; 7.7%). Patients arrived at the hospital with a mean systolic pressure of 102.62 mmHg (SD ± 21.75), a mean diastolic pressure of 62 mmHg (SD ± 17.11), and a mean arterial pressure of 75 mmHg (SD ± 18). Moreover, the patients had a mean pH of 7.26 (SD ± 0.16) with a base deficit of -10.39 (SD ± 6.56); their average temperature was 35.55°C (SD ± 2.46).

The most common vessel injured was the left superficial femoral artery (4/13; 30.7%), followed by the left brachial artery (2/13; 15.4%). The mean time from arrival to the initiation of surgery was 281 min., with an SD of approximately 213 min. Prophylactic fasciotomies were performed on 4 of the 13 (30.7%) patients and amputation was eventually needed in 4 of 13 (30.7%) cases, as well. It is important to note that those patients who required amputation had already undergone a prophylactic fasciotomy. Furthermore, only 2 of the 13 (15.4%) patients with shunts (IV tube line and a #8 Fr tube) presented

Table 1. Demographics and Mechanism of injury (N=13)

Characteristic	Frequency (%)
Age	
Mean (SD)	30.8 (12.83)
Glasgow Coma Score	
Mean (SD)	14 (2.30)
Gender	
Male	11 (84.6)
Female	2 (15.4)
Mechanism of Injury	
Penetrating	
GSW	11 (84.6)
Blunt	
Fall	1 (7.7)
MVC	1 (7.7)

SD: standard deviation; GSW: gunshot wound; MVC: motor vehicle collision with thrombosis. In terms of mortality, 4 out of 13 (30.7%) patients died from unrelated causes.

The different materials used to fashion shunts included the following: IV tube lines (4/13; 30.7%), plastic shunts (2/13; 15.4%), arterial line made plastic shunts (2/13; 15.4%), suction catheter tubing (3/13; 23.1%), #8 Fr tubes (1/13; 7.7%), and cardiac catheters (1/13; 7.7%).

Table 2. Injured vessel and Shunt used (N=13)

Injured vessel	Frequency (%)	Shunt used	Frequency (%)
BRA	5 (38.5)	Plastic/arterial shunt	
8Fr tubing	4 (30.7)		
1 (7.7)			
AxA	1 (7.7)	IV tubing	1 (7.7)
SUB	1 (7.7)	Suction tubing	1 (7.7)
SFA	4 (30.7)	IV tubing	
Suction tubing	2 (15.4)		
2 (15.4)			
POA	1 (7.7)	Cardiac catheter	1 (7.7)
COM	1 (7.7)	IV tubing	1 (7.7)

BRA: brachial artery; AxA: axillary artery; SUB: subclavian artery; SFA: superficial femoral artery; POA: popliteal artery; COM: common femoral artery

Discussion

The management of severe vascular injuries continues to be a challenge, even for the most experienced trauma surgeons. Currently, wounds tend to be more complex and affect more body parts, as the use of high-caliber weapons in street wars has increased. Consequently, civilian trauma surgery has had to borrow and adapt military techniques, such as the placement of TIVSs. As a matter of fact, we receive a high number of patients with complex vascular traumas at the PRTH and, therefore, the usage of TIVS has become imperative.

Interestingly, however, the scientific literature on TIVSs is quite scarce. A 2005 study of the National Trauma Registry noted that the institutions reporting more than 1 TIVS were level I certified (12). Furthermore, Subramanian et al. (2008) reported having used TIVSs in the treatment of only 67 patients over the course of 10 years at a regional trauma center (7). Oliver et al. (2013), meanwhile, observed that the injuries of 35 subjects had been managed with these shunts over the course of a similar 10-year period (11). Although the PRTH is a level II certified center, the number of patients registered in our study is comparable to the number of patients reported by level I certified institutions, since gunshots predominate as the mechanism of trauma that causes vascular injury (penetrating trauma is more prevalent in Puerto Rico than in the United States or Europe).

The demographic characteristics of our cohort are very similar to those reported previously by Subramanian et al. (2008) and Oliver et al. (2013), with a predominance of males (85%) and an average age of 31 years. In terms of trauma mechanisms, TIVSs were required for more patients with penetrating injuries (85%) than for those with blunt trauma (15%). Some scientific literature suggests that blunt vascular trauma is associated with a higher amputation rate, because of the high energy transfer, which causes extensive tissue destruction (13, 14). We found, however, that 75% of those patients who underwent amputation had sustained penetrating injuries, while only 25% had suffered blunt trauma. Moreover, in our study, TIVS use was most commonly associated with damage-control surgery, followed by staged repair for orthopedic injuries. Contrary to what has been observed in the military experience, the lack of a vascular skillset among surgeons was not a cause for TIVS insertion.

Patients arrived at our institution in extreme distress. The literature has suggested that the critical warm ischemia time for striated muscle is 6 to 8 hours and that blood flow should be reestablished within that time in order to avoid muscle and nerve damage. However, soft tissue loss, disruption of arterial and venous collateral vessels, or hypotension, may decrease the length of this critical period (15). All the patients that required an amputation were admitted at our unit with base excess values ranging from -11.5 to -24.7, which suggests that those patients were already critically ill (showing signs of tissue hypoperfusion and cell death) upon their arrival at the hospital. Additionally, 2 of the patients who required amputation arrived (from the scene) on ACLS and had leg compartment syndrome, which suggests that they were suffering from irreversible ischemia; the other 2 cases were related to permanent graft thrombosis.

Therefore, instead of the type of shunt used or the technique performed, the amputation rate could be attributable to the prehospital time, which was not well documented in our analysis. Furthermore, complications such as thrombosis were reported in 2 patients, regardless of the type of shunt used. As stated in the literature, a prophylactic fasciotomy is performed to prevent compartment syndrome (16). In our study, it was performed in 6 cases, and amputation was required in 2 patients. Nevertheless, we cannot establish a direct connection between amputation and prophylactic fasciotomy, since there were some data (e.g., prehospital time) missing from some of the medical records.

Another important issue for this analysis was that we did not have commercial TIVSs at our institution and, thus, in-house catheters had to be developed. This was of particular significance considering the fact that researchers have reported that up to 90% of their applicable cases used commercially available shunts (17). Nevertheless, we were able to perform definitive surgery that allowed us to provide successful placement of permanent grafts to all the patients without any major complications, apart from those mentioned above.

The current study has some shortcomings; the majority of them are related to the way in which the data were collected. For example, the time elapsed from a trauma's having occurred to a patient's receiving health care at the hospital, as well as the catheter indwelling time, was not well documented. Another limitation was the small sample size.

The use of TIVSs is very infrequent in civil trauma centers; however, this technique presents very favorable results. For instance, the limb salvage rate for this analysis was around 70%, and other investigations have observed limb salvage rates of up to 96.3% (17). The experience at the PRTH coincides with what has been described in the literature, suggesting that TIVSs might justifiably be considered the standard of care for vascular injuries during damage-control surgeries.

The temporary intravascular catheter in the setting of civil trauma surgery serves as a bridge to vascular surgery in the event that major damage-control surgery is required. TIVSs can be made with any sterile hollow tube available, which decreases the need for specialized equipment. Further research is necessary to establish the optimal period for shunt placement. Furthermore, randomized controlled trials should be conducted to evaluate the effectiveness of improvised TIVSs vs. commercially available ones, in terms of the development of thrombosis. TIVSs, as part of damage-control surgery, are part of our vascular-injury protocol, and their implementation has shown good results.

Resumen

Objetivo: La colocación del catéter intravascular temporero (CTIV) se utiliza para controlar el daño en el escenario de trauma. Existe escaza literatura en el campo civil, y lo que hay se limita a grandes centros de trauma con múltiples recursos. Nuestro objetivo fue describir el uso de los CTIVs y sus resultados en el Hospital de Trauma de Puerto Rico. Materiales y Métodos: Presentamos una serie de casos realizada en 2009-2013 con 32 pacientes que sufrieron trauma vascular, de los cuales 13 necesitaron CTIVs. Se recolectaron datos relacionados con edad, mecanismo de trauma, vaso dañado, tipo de catéter, escala de Glasgow, signos vitales y mortalidad. El análisis se realizó utilizando estadísticas descriptivas. Este protocolo fue aprobado por el Comité de Derechos Humanos del Recinto de Ciencias Médicas. Resultados: El mecanismo de trauma más común fue el disparo (11/13; 84.6%). El vaso más comúnmente lastimado fue la arteria femoral superficial. Los CTIVs permanecieron colocados entre 6 y 96 horas. Solo 2 de los 13 (15.4%) pacientes con catéteres sufrieron trombosis. Se realizaron 4 (30.7% de los pacientes) fasciotomías profilácticas y 4 (30.7% de los pacientes) amputaciones; 4 de los 13 (30.7%) pacientes murieron de causas no relacionadas. Conclusión: Nuestros resultados son consistentes con los de la literatura, lo que respalda nuestra afirmación de que los CTIVs pueden ser un componente eficaz de la cirugía vascular de control de daños y pueden, en entornos militares y civiles , ayudar en la prevención de la amputación de extremidades. Se ha establecido, además, que un CTIV puede ser desarrollado con cualquier tubo hueco disponible. Sin embargo, se necesita más investigación para probar la seguridad de los catéteres no comerciales.

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