A decade of major vascular trauma: Lessons learned from gang and civilian warfare

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ABSTRACT

INTRODUCTION Trinidad and Tobago is a trans-shipment point for the illegal trade of drugs, arms and ammunition and, as such, has a high incidence of gang-related warfare and drug-related crimes. This has led to a high incidence of gunshot and stab wounds, with associated major vascular injuries. We describe our management strategies learned from a decade of vascular trauma experience.

METHODS A retrospective analysis of age, gender, type of trauma, vessel injured, procedure and outcome for all cases of vascular trauma between 2006 and 2015 at two surgical units in Trinidad and Tobago.

RESULTS There were 198 vascular trauma cases (232 procedures), involving 159 (80%) males at a mean age of 33 years. Gunshots accounted for 103 (52%) cases, followed by stabs/chops (n=50; 25%) and lacerations (n=15; 8%). The most commonly injured vessels were the radial/ulnar arteries (n=39; 20%) and the superficial femoral artery (n=37; 19%). There were seven pseudoaneurysms and three traumatic arteriovenous fistulae. Repair techniques included primary (n=82; 35%), reversed vein (n=63; 27%), polytetrafluoroethylene (n=58; 25%), oversew (n=24; 10%) and endovascular (n=5; 2%) techniques. There were eight (4%) secondary amputations and eight (4%) deaths.

CONCLUSIONS Major vascular trauma causes significant morbidity and mortality in Trinidad and Tobago, with the majority of cases due to gunshot injuries secondary to gang-related warfare and civilian violence. We compare our experience with that in the literature on the epidemiology and management of vascular trauma.

KEYWORDS

Vascular Trauma – Arterial trauma – Venous trauma

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Trinidad and Tobago is a twin island state located at the southern-most point in the Caribbean, off the north east coast of Venezuela. As a result, it has become a trans-shipment point for the illegal trade of cocaine, marijuana, arms and ammunition and, as such, has a high incidence of gang-related warfare and drug-related crimes, resulting in a large number of gunshot and stab injuries.¹ Over the past decade, there has been a major surge in these crimes, resulting in a significant increase in the number of gunshots and stabbings, with associated major vascular injuries. To quote a landmark paper by Barros D'Sa on Northern Ireland: "Progress in managing vascular injuries has only been made in wartime".² We herein report our decade of experience and highlight the learning points in the management of major vascular trauma.

Methods

A retrospective analysis of all cases of vascular trauma presenting to the surgical units of the General Hospital, Port-of-Spain (POSGH) and The San Fernando General Hospital

(SFGH), both in Trinidad, between 2006 and 2015 was conducted. The centres are major teaching hospitals with a significant trauma load and, in particular, vascular-related trauma. They collectively serve the islands of Trinidad and Tobago, which have a population of 1.3 million people.

Data was recorded on the age, gender and type of trauma, which comprised: gunshot wound (GSW); stab; chop with machete; laceration; road traffic accident (RTA); associated orthopaedic injury with fracture/dislocation; dog bite; weedwacker or other machinery; iatrogenic; and blunt-type trauma. The injured anatomic vessel was documented, alongside the procedure performed, with the use of polytetrafluoroethylene (PTFE), a reversed vein, primary repair, endovascular repair, oversew and/or ligation noted.

The primary outcomes were amputation and/or death and the secondary outcomes were other morbidities. Primary and secondary amputations, if any, were documented. The data were analysed and compared with the literature. Learning points were noted with regard to decision-making, repair technique, morbidity and mortality.

Results

There were 198 major vascular trauma cases, involving 232 procedures. These included 115 (58%) procedures at POSGH and 83 (42%) at SFGH. Of the patients, 159 (80%) were male and 39 (20%) female, at a mean age of 33 years (range 7–73 years).

GSWs accounted for the majority of cases (n=103; 52%), with 82% of these presenting to POSGH. These were followed by stabbings and chops (n=50; 25%), lacerations (n=15; 8%), RTAs (n=11; 6%), fracture/dislocations (n=9; 4%), dog bites (n=4; 2%), iatrogenic trauma (n=4; 2%) and weedwackers (n=2; 1%).

The most commonly injured vessels were the radial and/or ulnar arteries (n=39; 20%) followed by the superficial femoral artery (SFA) (n=37; 19%), brachial artery (n=29; 15%), popliteal artery (n=28; 14%) and the infra-popliteal arteries (n=17; 8%). Other vessels accounted for 48 cases (24%), including the common carotid artery (n=4), internal jugular vein (n=3), subclavian artery (n=4), axillary artery (n=9), thoracic aorta (n=1), abdominal aorta (n=1), inferior vena cava (IVC) (n=3), iliac artery (n=4), iliac vein (n=6), common femoral artery (CFA) (n=7), common femoral vein (CFV) (n=5), and profunda femoris artery (PFA) (n=1).

There were seven false aneurysms, comprising four SFAs with three associated femoral fractures, and one case each in the axillary, aortic and posterior tibial arteries (PTA). All of these cases were GSWs, except for one involving the axillary artery, which was a case of prior impalement. The SFAs and the axillary artery were all repaired with PTFE, while the supra-celiac aortic false aneurysm was repaired using a 6-cm covered stent graft, with the PTA oversewn and a reversed vein bypass jump graft performed.

Traumatic arteriovenous fistulae included three cases of SFA to superficial femoral vein (SFV) and one case of CFA to CFV. In all cases, the vein was not repaired, while the SFA and CFA vessels were repaired using PTFE. The patient with a CFV injury developed phlegmasia of the limb.

Of the 232 procedures, 82 (35%) involved primary repair, most of which was to the radial and/or ulnar arteries (n=53; 23%). A reversed vein was used in 63 (27%) cases, the majority being brachial artery repairs (n=22; 9%) and repairs to the popliteal and distal arteries in the legs (n=25; 11%). PTFE was used in 58 (25%) cases, most of which were repairs to the SFA (n=28; 12%) and popliteal arteries (n=10; 4%). Oversew of the vessel was performed in 24 (10%) cases, the majority being the SFV (n=14), EIV (n=4) or CFV (n=5). Only five (2%) stent grafts were placed, most of which were in the SFA, with three for arteriovenous fistulae, one for pseudoaneurysm and one in the supra-celiac aorta for a GSW with a posterior wall pseudoaneurysm. There were 8 (4%) amputations and the same number of deaths, as shown in the Table 1.

With regards to patency, all upper and lower limbs were viable at 2-year follow-up, with functioning grafts. However, two patients who had SFA injury with femoral fracture group had occluded PTFE grafts at 1-year follow-up, which were revised for debilitating lower limb intermittent claudication.

Discussion

Major vascular trauma accounts for significant morbidity and mortality worldwide. It is technically challenging and most general surgeons prefer not to take on such cases. For vascular surgeons, the range of pathology depends on their centre of origin. In our setting, there is a significant load of vascular trauma secondary to gang-related warfare and civilian violence due to the local drug trade. It is with this in mind that we sought to share our experience and review the literature on vascular trauma.

We conducted a PubMed search for relevant papers published from 1980 onwards in Europe, which yielded a few notable articles. Kjellström *et al*, in Sweden, described their series of 82 patients. Stab wounds were the most common, with a mortality of 10.9%, and reconstructive procedures were performed in only 34% of patients. It was concluded that vascular trauma in Sweden was relatively uncommon.³ In 1986, another Swedish article by Bergqvist *et al* examined civilian vascular injuries operated on during a 30-year period from 1955 to 1984. They found evolving angiographic/catheterisation techniques were responsible iatrogenic injuries, and non-iatrogenic injuries were due to multiple trauma from fractures and a variety of penetrating wounds.⁴ In the United Kingdom, Magee *et al* described their experience in 1996, noting that vascular trauma was uncommon, with the exception of Northern Ireland. They noted that, in marked contrast to North America, gunshot and stab wounds were rare. RTAs accounted for 45% of injuries; other accidents for 32% and stabbings 23%. The commonly injured vessels were the brachial artery (30%) and SFA (15%).⁵

In the Middle East, Sfeir *et al* wrote of their experience with 386 patients in 1995, with 65% due to femoral and 30% popliteal trauma. The amputation rate in the popliteal group was twice that in the femoral group, at 11.86%. Delayed transfer and associated femoral fractures were associated with higher amputation rates.⁶ More recently, Starnes *et al* wrote in 2006 about the surgical management of casualties on the battlefield. They noted that vascular injuries of the extremities accounted for 50% to 70% of all injuries treated during Operation Iraqi Freedom, and exsanguination from extremity wounds was the leading cause of preventable death on the battlefield.⁷ In Kuwait, Asfar *et al* looked at 155 patients from 1992–2000, most of whom had vascular trauma of the extremities (76%). The most common procedure was revascularisation, primarily with the long saphenous vein, via a direct repair or end-to-end anastomosis.⁸

In West Africa, Igun *et al* examined 52 cases over 10-years, with RTAs being most common cause of vascular trauma, in 44%. Penetrating trauma accounted for 96% of cases, and blunt trauma for 4%. Aneurysms of various types occurred in 14%. Direct lateral suture of vessels was employed in 13 vessels, anastomosis in 12, graft interposition in four, ligation in 49 and aneurysmectomy in three.⁹

In Perth, Australia, Gupta *et al* described in 2001 the vascular trauma seen in five major anatomic groups: the neck; thorax; abdomen; upper limb; and lower limb. One

Table 1 Summary of procedures and outcomes in cases of major vascular trauma

Vessel injured	N	Mechanism of injury	Repair with PTFE	Repair with reversed vein	Primary Repair	Oversew	Stent	Outcome
Carotid	4	3 stabs 1 GSW	0	0	4	0	0	3 Survived. No complication. 1 postoperative CVA, died.
Internal jugular vein	3	3 stabs	0	0	1	2	0	No complications
Subclavian artery	4	3 GSWs 1 iatrogenic	4	0	0	0	0	3 Survived with 3 sternotomies 1 died DIC
Axillary artery	9	3 GSWs 2 stabs (1 false aneurysm) 1 fracture/dislocation 2 dog bites 1 laceration	3	5	1	0	0	2 deaths craniectomy and stroke
Brachial artery	29	15 GSWs 8 stabs 2 fracture/dislocations 3 lacerations 1 crush in RTA	4	22	3	0	0	1 amputation in the crush injury – Gustilo-Anderson IIC. Graft viable but internal fixation devices infected
Radial and/or ulnar artery	20 radial and 20 ulnar combined 12 radial 7 ulnar (39 patients)	23 chops 3 stabs 8 lacerations 1 GSW 2 RTAs 2 dog Bites	0	6	53	0	0	1 amputation at wrist due to macerated wound 7 Successful complete hand replants, tendon & nerve repairs
Thoracic aorta	1	Stab	0	0	1	0	0	Survived
Abdominal aorta	1	GSW with supra-celiac false aneurysm	0	0	0	0	1	Survived
Inferior vena cava	3	3 GSWs	0	0	2	1	0	All exsanguinated and died on table. Renal, pancreatic, DIC, liver
Iliac artery	4	2 GSWs 2 iatrogenic	3	0	1	0	0	No major complications
Iliac vein	6	5 GSW 1 iatrogenic	2 EIV/CFV	0	0	4 EIV	0	1 died on table, exsanguinated
CFV	5	5 GSW	1 EIV/CFV	0	1	3	0	No major complications. One AVF CFA to CFV.
CFA	7	6 GSWs 1 Stab	3	3	1	0	0	No major complications

Vessel injured	N	Mechanism of injury	Repair with PTFE	Repair with reversed vein	Primary Repair	Oversew	Stent	Outcome
SFA/SFV (3 fractured femurs 4 pseudoaneurysms 3 AVFs SFA to SFV)	37 SFA, SFV involved in 15 cases	32 GSWs 3 stabs 2 RTAs	28 SFAs	2 SFAs	3 SFA 1 SFV	14 SFVs oversewn	4	2 amputations >2days delay, transfer to vascular surgery 2 occluded grafts at 1 year
PFA	1	GSW	0	0	0	1	0	Limb salvaged
Popliteal artery /vein (2 fractured femurs 3 fractured tib-fib 2 false aneurysms)	28 Popliteal vein involved in 5	15 GSWs 1 stab 1 laceration 6 fracture/dislocation 5 RTAs	10 5 Pop vein repairs	13 Pop-Pop 2 Pop-AT 1 Pop-PT Bypasses	2	4 amputations all with combined popliteal artery and vein injuries with fracture or dislocation or delayed transfer to vascular surgery 1 occluded graft at 1 year 1 postero-medial abscess at 1 year		
PT/AT peroneal arteries	17	10 GSW (6 involving trifurcation, 1 false aneurysm of the PT artery), 2 chops 2 weedwhackers 2 lacerations, 1 RTA	0	3 Pop-AT 3 Pop-PT 1 PT oversew 2 PT-PT	8	0	0	100% Salvage rate. No major complications
Total	198	103 GSWs 25 stabs 25 chops 15 lacerations 11 RTAs 9 fracture/dislocations 4 dog bites 4 iatrogenic 2 weedwhackers	58	63	82	24	5	8 deaths (presented moribund) 8 amputations 232 procedures on 198 patients over 9 years
AVF = arteriovenous fistula; AT = anterior tibial; CFA = ; CVA = common femoral artery; CFV = common femoral vein; DIC = disseminated intravascular coagulation; EIV = external iliac vein; GSW = gun shot wound; PTFE = polytetrafluoroethylene; PT = posterior tibial; RTA = road traffic accident; SFA = superficial femoral artery; SFV = superficial femoral vein								

hundred and fifty three patients had 175 vascular injuries, the commonest being stabs (neck and lower limb), RTA (thorax and abdomen) and work-related machine injuries (upper limb). Mortality was highest for thoracic injury (44%), followed by abdominal injury (34%). The most common artery-vein combination injury was to the femoral vessels.¹⁰

In 2002, Lakhwani *et al* looked at 84 patients in Malaysia with RTAs, which accounted for 58% of vascular trauma cases. Primary arterial repair was the most frequently employed surgical procedure (64%), followed by autogenous reverse long saphenous vein repair (17%) and PTFE, in 4%. Amputation was performed in 15% of cases.¹¹ With regard to conduit choice in vascular trauma, in 1982 White *et al* reviewed and compared the use of autogenous saphenous vein versus PTFE. Late graft occlusion was more common with PTFE, but PTFE was better in situations in which infection was a concern and extra-anatomic bypass was not possible. Additionally, an infected saphenous vein was at greater risk of sudden hemorrhagic disruption than PTFE.¹²

Shah *et al* reinforced this dogma in 1984 when they documented the safety of PTFE in potentially contaminated wounds in 25 vascular reconstructions in cases of life-threatening multiple trauma and severe local tissue damage, along with arterial and venous injuries in open contaminated wounds. All patients received 6mm PTFE grafts for interposition bypass of arterial injuries, while 8mm PTFE grafts were used in five patients for concomitant venous interposition bypasses. There was one death. There was also one arterial and one venous graft thrombosis in the same patient 3 months after a shotgun blast injury to the groin. There was, however, no limb loss. All other grafts remained patent without wound infection, sepsis or anastomotic disruption.¹³ In 1985, Feliciano *et al* published their series of 206 cases with 236 PTFE grafts. More than 85% of injuries were due to gunshot, shotgun or stab wounds, with grafts most commonly placed in the brachial or superficial femoral arteries. PTFE was found to be an acceptable prosthesis, although long-term patency was inferior to that of the saphenous vein. Occlusions were a significant problem with 4-mm PTFE grafts in the brachial artery.¹⁴

In 1997, Porcellini *et al* described their experience of arterial injuries and associated fractures in 34 cases of blunt trauma with repairs performed, using ligation in three cases, patch angioplasty in six patients, autogenous veins in 15 patients and PTFE in four cases. Coil embolisation was performed in three arteriovenous fistulae of small limb arteries. External fixation of long-bone fractures was made in 29 patients before vascular reconstruction.¹⁵

For lower limb vascular trauma, Palmieri *et al* documented in 2001 their experience with 45 vascular injuries, of which 27 were arterial and 18 venous, over 15 years. The mortality rate was 7.4%. The amputation rate 26.7% for popliteal trauma, compared with 8.3% for others locations.¹⁶ Huyhn *et al* in 2006 discussed 57 cases of combined arterial and musculoskeletal injuries in the distal femoro-popliteal region. The approach was much

like ours, in that they performed surgical revascularisation without intraluminal shunting. Vascular reconstruction was achieved with autogenous saphenous vein graft in 91% of cases, with a vein patch in 5% and primarily in 4%. The limb salvage rate was 92%.¹⁷ In Northern Ireland, Barros D'Sa *et al* noted in 2006 that complex lower limb vascular injuries in high-energy penetrating or blunt trauma wounds are associated with an unacceptably high incidence of complications, including amputation. They proposed that early artery and vein shunting led to significantly improved outcomes.¹⁸ More recently, in 2015, Al Ganadi *et al* described 63 cases of high-velocity gunshots mostly to the lower limb in the Yemeni revolution. They noted that arterial repair with autologous vein grafts was highly successful, whereas ligation of venous injuries in watershed areas such the iliofemoral and popliteal vein should be avoided to prevent leg phlegmasia.¹⁹

In abdominal trauma with vascular injury, Baeshko *et al* in 2000 documented their experience in 87 patients operated on by general surgeons, including 73 patients with stab wounds, nine blunt traumas and five gunshot wounds. IVC trauma occurred in 29 patients, aortic trauma in 21, trauma to the iliac vessels in 22 and visceral trauma in 15. The mortality rate was 46%, and the authors recommended better surgical training to achieve better outcomes.²⁰ With regard to iatrogenic injury, Pálfalvi *et al* published an article in 1993 on 184 radical gynaecological interventions, 13 of which resulted in injury, primarily to the iliac vessels or cava.²¹

Combining our experience with evidence from the literature, we can see that injuries to the IVC, axillary, subclavian or carotid arteries are associated with a high risk of mortality that is related to other major injuries, such as major chest and head trauma. In the upper limb, trauma to the brachial artery can be safely managed using autologous veins from the traumatised limb, as we did during the study period. Injuries to the radial and ulnar arteries can be safely repaired most of the time with a primary repair or, in cases in which a segment is damaged, a reversed interposition vein graft. In the trunk region, the thoracic and abdominal aorta should be treated using endovascular techniques, once cardiovascular stability has been achieved, and the visceral arteries can be oversewn in most cases of GSW to the abdomen.

With regard to the lower limb, the iliacs can be safely repaired with PTFE, and the CFA and CFV should always be repaired, again using PTFE. In the superficial femoral region, the SFA can be safely repaired with PTFE and the SFV oversewn at the injury site with little phlegmasiac morbidity, due to the rich collateral supply and Hunterian perforators. Blunt injuries are associated with increased lower limb amputation rates, combination venous and arterial injuries at the popliteal region, fracture/dislocations of the knee, obesity and delayed referral to vascular surgery.

In the region of the infra-popliteal vessels, including the anterior tibial, posterior tibial and peroneal arteries, we noted that revascularisation using a reversed saphenous vein around the traumatised segment was successful. With respect to the tibial-peroneal trunk, a reversed vein graft

from the popliteal artery to a distal vessel is effective, with good success rates. Where there is a concomitant bony injury to stabilise, intraluminal shunting is quite unnecessary in competent and skilful hands. We also noted that, in cases of lower limb trauma, Afro-Caribbean patients, who appeared to have greater muscular mass than other ethnicities, had a higher rates of muscle necrosis, despite having open extended four-compartment fasciotomies and adequate and timely revascularisation. We postulate this may be due to the greater muscle mass leading to toleration of a shorter ischaemic time.

Conclusions

Major vascular trauma causes significant morbidity and mortality in Trinidad and Tobago, with the majority of cases due to gunshot injuries, especially in the Port-of-Spain area. Our experience and that learned from the literature has shown that there are a number techniques that can be used to safely repair major vascular trauma and minimise the risk of morbidity and mortality.

Conflicts of interest

None declared.

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