

Brachial Artery Reconstruction in Trauma Using Reversed Arm Vein from the Injured Upper Limb

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Background: Brachial artery repair may be technically challenging with a paucity of guidelines. The use arm vein (AV) from the traumatized limb is herein described. **Methods:** Data were prospectively collected from 2002 to 2016 on brachial artery injury including age, sex, mechanism/site of injury, and repair technique. Categories included AV and non-arm vein (NAV) groups. One-year outcomes were noted. **Results:** All 31 cases studied were of men with an age range of 16 to 73 years (mean = 28). Injuries included 13 gunshots, 7 stabbings, 6 glass injuries, 2 dislocated elbows, 1 crush, 1 impalement, and 1 avulsion. Site of injuries included the antecubital region in 25, midbrachial in 5, and proximal brachial in 1, with 4 associated fractures. Repair was done using reversed AV from the traumatized limb in 15 cases and NAV in 16. In the AV group, the adjacent basilic vein was used in 9 cases, the adjacent cephalic vein in 3, and the distal (or wrist area) cephalic vein in 3. The limb salvage rates in the AV versus NAV groups were 100% and 94%, respectively (Fisher's exact *t* test, *P* = 1.00), with no major technique-related complications. **Conclusions:** The outcomes of using reversed AV from the traumatized limb are equivalent to those of other standard techniques such as primary repair, polytetrafluoroethylene, or reversed great saphenous vein, with a 1-year limb salvage rate of 100%. Additionally, advantages include decreased wound complications, better vein graft–artery caliber match, and shorter operating times while maintaining acceptable patency rates. (*Plast Reconstr Surg Glob Open* 2016;4:e1034; doi: 10.1097/GOX.0000000000001034; Published online 5 October 2016.)

Brachial artery trauma is an uncommon injury in adults, but in some centers where there is a high incidence of penetrating trauma, its incidence is more. Trinidad and Tobago is a twin island state located at the southern-most point in the Caribbean off the northeast coast of Venezuela. As a result, it has become a transshipment point for the illegal drug trade of cocaine and marijuana and as such has a high incidence of gang-related warfare and drug-related crimes, resulting in a high incidence of gunshot and stab injuries.¹ The literature advocates resection of the traumatized segment of artery and reversed interposition vein grafting from a distant site, usually the great saphenous vein (GSV). This

is well documented by Wolosker et al² in 1994 in a series of 50 patients in which 70% of the brachial artery injuries were repaired with reversed GSV. In 1986, Orcutt et al³ described repair of 163 upper limb vascular injuries and successfully used an end-to-end primary anastomosis in most cases followed by reversed GSV grafting. In 1999, Platz et al⁴ described their experience with blunt brachial artery trauma due to posterior dislocation of the elbow in 4 cases in which most of the injuries were again repaired with reversed GSV, and in 2006, Kurbanov et al⁵ described repair of supracondylar fracture injuries with reversed GSV. Further to these articles, in 2006, Kakar et al⁶ reported on the repair of 7 cases of posttraumatic pseudoaneurysms of the brachial artery with reversed GSV. We herein report the results of a prospective series of 31 cases of brachial artery trauma requiring reconstruction from the 2 main hospitals. Fifteen cases were reconstructed with interposition reversed arm vein (AV) grafting from the ipsilateral traumatized limb, with a 100% limb salvage rate in that group and no major technique-related morbidity. There are no clear guidelines on the venous harvest site, with a

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paucity of data on whether it is safe to harvest from the traumatized arm or limb. With this in mind, the authors have sought to document their experience with regard to the technique of repairing this injury over a 14-year period and highlight the advantages of the technique with reference to operative time, wound complications, artery–vein graft caliber match, and technical success.

METHODS

A 14-year analysis of trauma related to the brachial artery was prospectively conducted by the vascular surgeons at the General Hospital, Port of Spain, and the San Fernando Teaching Hospital in Trinidad, West Indies, from January 2002 to March 2016. The data were prospectively monitored by vascular surgeons at both hospitals on all cases requiring brachial artery surgery for penetrating or blunt trauma including gunshot and stab wounds, injury with a shard of glass, elbow dislocation, impalement, and avulsion injuries. All patients were emergency cases, and careful informed consent was obtained from each individual and relatives involved in the consent process. It was explained that these were all limb-threatening problems and the surgeon would make appropriate and safe decisions at the time of exploration in the best interest of saving the limb. The decision on technique for repair, type of graft and if vein was used, and the harvest site was left to the best judgment of the lead vascular surgeon. This involved 3 main factors: (1) the degree of trauma (it was important that adjacent upper limb veins were not traumatized or damaged in any way), (2) the need to harvest the vein quickly and efficiently in the after-hour situation where there are staff limitations and other trauma and surgical emergencies to clear on the emergency list (the cases usually presented after midnight and therefore time-wasting needed to be limited and influenced the lead vascular surgeon to harvest from the traumatized upper limb instead of GSV of leg), and (3) the basilic or cephalic vein of the traumatized upper limb always presented itself as part of the incision to expose the brachial artery and had an almost perfect/equal caliber to the brachial artery. Therefore, there was little modification of the vein or artery to be done during the anastomosis, and there was no significant size mismatch to be concerned about. Institutional consent was obtained to analyze and publish the data and outcomes.

The data collected included the date of presentation, age, sex, mechanism of injury, site of injury, associated injuries (fractures, nerve injury), and type of repair, whether primary, with polytetrafluoroethylene (PTFE), with ipsilateral reversed AV from the affected limb, or with reversed vein used from the GSV or another limb. Also, the operating time and wound complications were noted. The 1-year limb salvage rates and outcomes were recorded and monitored by clinical and radiologic (duplex scanning) follow-up. Any morbidity such as prolonged swelling of the limb, pain, neurologic dysfunction, ischemia or amputation, and mortality if any were recorded. The data were divided into 2 groups according to the technique used for repair. These were (a) the AV group

in which the vein was harvested from the traumatized limb and (b) the non–arm vein group (NAV) in which treatment included a primary repair, PTFE, or GSV from the lower limb. The Fisher's exact *t* test (SPSS version 20) was used to determine any statistical difference for 1-year limb salvage rates.

Institutional approval was obtained from the relevant ethical committee to conduct and publish the scientific work.

RESULTS

Data on 31 cases of brachial artery trauma were available for over a 14-year period. All cases were male, with an age range of 16 to 73 years, a mean of 28, and mode of 16. Injuries included 13 gunshot wounds, 7 stabs, 6 injuries with a shard of glass, 2 dislocated elbows, 1 crush injury from a road traffic accident, 1 impalement, and 1 avulsion with an arteriovenous malformation. The location of injury was in the antecubital region in 25 cases, midbrachial artery in 5 cases, and proximal brachial artery in 1 case. There were 4 associated fractures including 3 comminuted fractures of the humerus and 1 supracondylar fracture. In the AV group ($n = 15$), repair was done using ipsilateral reversed AV from the traumatized limb in all 15 cases. In the NAV group ($n = 16$), the repair techniques included 3-mm PTFE grafting in 3, primary repair in 2, and reversed GSV in 11 cases. Additionally, in the AV group, the adjacent arm basilic vein was used in 9 cases, the adjacent arm cephalic vein in 3, and the distal (or wrist area) cephalic vein in 3. The overall limb salvage rate in both groups was 97% at 1-year follow-up, with no major complications except for 1 case with residual median nerve palsy in the AV group and 1 amputation within 2 weeks of repair due to a Gustilo–Anderson IIIC from a crush injury in the NAV group, both of which were not graft related. The case of residual median nerve palsy was not repaired because a long segment of median nerve was avulsed during a fall from a scaffolding, and the patient did not want any further procedures done. There was no need for fasciotomies in any cases because all presented acutely and were operated on immediately. We did not consider endovascular approaches suitable in our setting and for the type and nature of the trauma.

The limb salvage rates in the AV group versus the NAV group were 100% and 94%, respectively, at 1-year follow-up. Fisher's exact *t* test was used to compare the groups ($P = 1.000$), demonstrating no statistical difference between the 2 groups (Table 1).

Of note, there was no significant morbidity such as prolonged swelling of the limb, pain, neurologic dysfunction, ischemia, or amputation, which was graft related in either group. However, there were 4 wound hematomas noted in the NAV group where the GSV was harvested and 2 wound infections. Mild swelling occurred in the immediate postoperative period in all cases, which resolved within one-week period, and all patients were sent home on a therapeutic dose of enoxaparin for at least 1 month. The swelling was clearly attributable mainly to the trauma due to gunshot wound, stab, crush, or other significant injury rather than harvesting a short segment of basilic or ce-

Table 1. Table Showing the Demographic Data of the Study Population and 1-Year Outcomes and Complications

Date	Age	Sex	Mechanism of Injury	Site of Injury	Type of Repair	Harvest Site	Outcome/Complication
NAV group							
2002	17	M	Stab	Antecubital	Reversed GSV	Thigh	Salvaged
2002	25	M	Stab	Antecubital	Reversed GSV	Thigh	Salvaged/hematoma at harvest site
2002	23	M	Shard of glass	Antecubital	Reversed GSV	Thigh	Salvaged
2003	20	M	Shard of glass	Antecubital	Reversed GSV	Thigh	Salvaged
2003	23	M	Stab	Antecubital	Reversed GSV	Thigh	Salvaged/hematoma at harvest site
2006	45	M	Shard of glass	Antecubital	Reversed GSV	Thigh	Salvaged
2008	24	M	Shard of glass	Antecubital	Reversed GSV	Thigh	Salvaged
2010	21	M	GSW	Antecubital	Interposition 3-mm PTFE graft	PTFE	Salvaged
2011	73	M	Impairment 50 y before from a spike on a fence with false aneurysm	Proximal brachial	Interposition 3-mm PTFE graft	PTFE	Salvaged
2012	49	M	Crush injury with a comminuted compound fracture of the humerus and elbow joint; Gustilo-Anderson IIIC	Antecubital	Reversed GSV	Thigh	Amputation (not graft related), hematoma at harvest site with wound infection
2012	16	M	Stab	Antecubital	Interposition 3-mm PTFE graft	PTFE	Salvaged
2012	24	M	Avulsion of brachial artery and median nerve with AVM and steal syndrome	Midbrachial	Reversed vein brachial artery bypass and ligation of fistula; GSV of lower limb used	Thigh	Salvaged; median nerve palsy/hematoma at harvest site with wound infection
2013	29	M	Dislocated elbow	Antecubital	Reversed GSV	Thigh	Salvaged
2014	43	M	Stab	Antecubital	Primary repair	—	Salvaged
2014	30	M	GSW	Antecubital	Primary repair	—	Salvaged
2015	46	M	Dislocated elbow	Antecubital	Reversed GSV	Thigh	Salvaged
AV group (harvested from the ipsilateral traumatized upper limb)							
2006	16	M	GSW	Antecubital	Ipsilateral reversed basilic vein interposition graft	Arm	Salvaged
2007	16	M	Stab	Antecubital	Ipsilateral reversed basilic vein interposition graft	Arm	Salvaged
2007	16	M	GSW	Antecubital	Ipsilateral reversed cephalic vein interposition graft	Arm	Salvaged
2008	16	M	Stab	Antecubital	Ipsilateral reversed cephalic vein interposition graft	Arm	Salvaged
2008	16	M	GSW	Antecubital	Ipsilateral reversed basilic vein interposition graft	Arm	Salvaged
2008	25	M	GSW with comminuted humeral fracture	Midbrachial	Ipsilateral reversed basilic vein interposition graft; external fixator to humerus	Arm	Salvaged/swelling that resolved with time
2009	20	M	GSW	Midbrachial	Ipsilateral reversed cephalic vein interposition graft	Wrist	Salvaged
2009	26	M	GSW	Midbrachial	Ipsilateral reversed cephalic vein interposition graft	Arm	Salvaged
2010	24	M	GSW	Midbrachial	Ipsilateral reversed cephalic vein interposition graft	Wrist	Salvaged
2012	31	M	GSW with supracondylar fracture	Antecubital	Ipsilateral reversed cephalic vein interposition graft; wiring supracondylar fracture	Wrist	Salvaged/mild swelling that resolved
2014	37	M	GSW	Antecubital	Ipsilateral reversed basilic vein interposition graft	Arm	Salvaged
2014	34	M	Shard of glass	Antecubital	Ipsilateral reversed basilic vein interposition graft	Arm	Salvaged
2014	17	M	GSW	Antecubital	Ipsilateral reversed basilic vein interposition graft; brachioradial artery bypass done	Arm	Salvaged
2015	25	M	GSW with comminuted fracture of the humerus	Antecubital	Ipsilateral reversed basilic vein interposition graft; brachioradial artery bypass done	Arm	Salvaged
2016	28	M	Shard of glass	Antecubital	Ipsilateral reversed basilic vein interposition graft	Arm	Salvaged

Note that in the AV group, all cases that were harvested from the “arm” were harvested close to the zone of injury. AVM indicates arteriovenous malformation; GSW, gunshot wound.

phalic vein. We did not use aspirin or clopidogrel on these cases. No further angiography or imaging was required in any of the cases as all patients had viable limbs with a palpable radial pulse at 1-year follow-up.

Three secondary end points were noted: (1) the fact that there were no wound complications in the AV group compared with the NAV group where there were 4 hematomas from the GSV harvest site and 2 wound infections; (2) the average operating time was less in the AV group (112 min) compared with the NAV group (157 min), which worked out to be a difference of 45 minutes; and (3) it became obvious after doing these cases that the vein graft-to-artery match was better and more suitable in the AV group because the cephalic and basilic veins were harvested from the same limb and therefore naturally had a close match to the caliber of the artery and worked and sat better as an interposition graft than the GSV.

DISCUSSION

Trinidad & Tobago is a prosperous democratic state and is considered high income by the World Bank.⁷ The main hospitals in Trinidad manage a high volume of trauma due to the gang- and drug-related violence, hence the genesis of this article. Einstein once said, "In the middle of difficulty lies opportunity." The authors were practicing in a high-volume setting of vascular trauma and made appropriate decisions leading to the technique of using a suitable AV from the injured limb for brachial artery reconstruction. On a search of the literature, it was noted that there was a paucity of data regarding the topic except for a few considerations.

It is well established that reversed vein grafting is one of the best options in bypass grafting for the coronary vessels,⁸ the lower limb in peripheral arterial disease and trauma,^{9,10} reconstruction of the brachial artery in aneurysmal disease,¹¹ repair of the brachial artery in penetrating trauma,¹² and repair of the axillary artery.¹³ It is also well known and accepted that the use of PTFE is safe and efficacious as a replacement graft for traumatized vessels as demonstrated in one of the first series by Vaughan et al¹⁴ and published in *The Journal of Trauma* in 1979, where the authors described a series including 8 axillary arteries, 12 brachial arteries, 11 common, superficial, and profunda femoris arteries and common femoral veins, 8 popliteal arteries or veins, 3 superior mesenteric arteries, 1 carotid artery, 1 iliac vein, and 2 axillary veins. All patients had a segmental repair of the vessels with PTFE, with no graft thrombosis and no infections.¹⁴

With regard to arterial reconstruction in the upper limb, there are a few relevant articles. The first is by Casey et al¹⁵ published in the *Irish Medical Journal* in 2002 where they noted that arterial reconstruction in their center was rare, accounting for 5% of the workload, with reconstruction carried out only in 7 of 92 cases (4 emergency and 3 elective cases). There was 1 case of penetrating injury, 2 cases with injuries due to blunt trauma, 3 patients with thoracic outlet syndrome, and 1 with chronic ischemia. It

was noted that in 3 cases, interposition reversed cephalic vein grafting was used; however, it was not specified whether these were ipsilateral or contralateral.¹⁵

Benjamin et al¹⁶ in 1999 in *Journal of Vascular Surgery* described their techniques of repair of mycotic pseudoaneurysms due to drug abuse. They mentioned in 1 case the use of a deep vein for brachial artery reconstruction.¹⁶

With regard to the use of reversed AV grafting from the traumatized limb to repair the brachial artery in trauma, the literature has a paucity of data. The PubMed search herein documented reveals 3 relevant articles. The first article by Lewis et al,¹⁷ from Belfast and published in *Plastic and Reconstructive Surgery* in 2003, documents authors' experience with arterial reconstruction using basilic vein from the zone of injury in pediatric supracondylar humeral fractures. In 8 children, aged 3 to 10 years, supracondylar humeral fractures and vascular injury were all successfully reconstructed using reversed, interposition basilic vein graft from the zone of injury. Grafts were all harvested from the ipsilateral arm, with an anatomically consistent finding of few side branches and no major complications recorded.¹⁷ The second is an Egyptian study by Hassan and Noaman et al¹⁸ published in *Microsurgery* in 2006 on microsurgical reconstruction of brachial artery injuries in displaced supracondylar humeral fractures in children. There were 31 vascular injuries, with 22 median nerve injuries, 17 traumatic aneurysms, 8 complete division of the brachial artery, 2 partial tear, 3 thrombosis, and 1 brachial artery entrapment at the fracture site. Repair was done using reversed veins from a distal harvest site of the long saphenous vein in 6, excision and repair in 17, partial repair in 2, thrombectomy in 3, and release from entrapment in 1. Of note, there were 2 brachial arteries repaired with ipsilateral reversed basilic vein grafts 4 cm in length from the trauma site and ipsilateral limb. There were no major complications related to the use of reversed vein grafting in the 8 cases recorded and none with regard to the basilic vein grafts.¹⁸

The third article was a case report by Jeyartna et al.¹⁹ in 2007, which documented successful repair of a brachial artery disruption as a result of elbow hyperextension. The vessel was successfully repaired with a segment of cephalic vein used from the ipsilateral limb.¹⁹

CONCLUSIONS

In conclusion, the evidence provided in these considerations shows that in cases of penetrating or blunt brachial artery trauma, resection of the traumatized segment of artery and repair using suitable reversed interposition AV grafting from the ipsilateral traumatized limb or close to the zone of injury is safe and efficacious. Also, the outcomes are equivalent to those of conventional techniques for repair such as PTFE, primary anastomosis, or use of lower limb GSV. This is dependent on surrounding tissue not being severely crushed or devitalized, and the cephalic or basilic vein is in good condition. The 1-year follow-up limb salvage rate in this study was 100% and gives credence to the fact that the venous supply to the

upper limb is adaptable and naturally designed to compensate even if there may be suspicion of damage to the deep venous system.

Additionally, 3 secondary end points were noted and support the use of AV: (1) the fact that there were no wound complications in the AV group compared with the NAV group where there were 4 hematomas from the GSV harvest site and 2 wound infections; (2) the average operating time was less in the AV group (112 min) compared with the NAV group (157 min), which worked out to be a difference of 45 minutes; and (3) it became obvious after doing these cases that the vein graft-to-artery match was better and more suitable in the AV group because the cephalic and basilic veins were being harvested from the same limb and therefore naturally had a close match to the caliber of the artery and worked and sat better as an interposition graft than the GSV.

Limitations of this study include the mixture of PTFE and GSV use in the NAV group, but because of the small numbers, it was not sensible to separate the 2 techniques. We propose future research with regard to the size/caliber match of vein graft to artery that actually measures the diameter of each before performing the anastomosis and compare it to the diameter difference with the use of the GSV.

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