



ORIGINAL ARTICLE

# Operative management of non-iatrogenic pediatric and adolescence peripheral arterial trauma: An experience from a resource challenged setting



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**KEYWORDS**

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 Vascular anastomosis;  
 Interposition reversed  
 saphenous vein  
 graft;  
 Prophylactic  
 fasciotomy

**Summary Objectives:** To evaluate the management and outcome of non-iatrogenic pediatric and adolescence extremity arterial injuries in a resource-challenged setting.

**Methods:** A retrospective study of the surgical management for non-iatrogenic extremity arterial trauma in pediatric and adolescence during the period from January 2008 to December 2015. This study was performed in two different countries at tertiary referral university and teaching hospitals having a specialized emergency and trauma centers. A thorough study of each patient record was collected from these centers including, the original demographic data and their clinical presentations. Operative data of each patient was also reported.

**Results:** During the 8-year period of the study, 149 pediatric and adolescent extremity arterial trauma patients were treated. They were 93.3% male, and 6.7% female, respectively. The age ranged from 2 to 18 years with a mean of  $10.25 \pm 4.05$  years. Lower extremity arterial trauma was recorded in 51%, while 49% were having upper extremity injuries. Primary repair with end-to-end vascular anastomosis was performed in 51.7%, while an interposition reversed saphenous vein graft was performed in 48.3%. The operative procedures were performed by an experienced vascular surgeon and well-trained pediatric surgeons and general surgeons. Pseudoaneurysms was recorded in 9% of cases. Fasciotomy was performed in 15% of cases.

**Conclusion:** Treatment of pediatric and adolescent extremity arterial injuries with primary end-to-end vascular anastomoses or with the use of an interposition reversed saphenous vein graft is a reliable, feasible, and more cost-effectiveness technique with good results. Moreover, it should be adopted for all vascular trauma patients, whenever possible.

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## 1. Introduction

Ischemia requiring surgical revascularization is rare among pediatric population.<sup>1</sup> Vascular injuries in the extremities can result in limb loss, serious life-long threatening disability, and even death.<sup>2</sup> Injuries can result from a blunt or penetrating trauma, and these injuries can be isolated or in the setting of a complex multisystem trauma.<sup>3</sup> Vascular trauma (i.e. arterial and venous) in the pediatric population is uncommon, as it occurs only in 0.6–1.4% of all pediatric injuries.<sup>4,5</sup> Penetrating trauma is the most common vascular injuries affecting children. They may be either isolated or associated with extremity injuries in polytraumatized patients.<sup>6</sup> Arterial injury in children presents a challenge to the surgeon; they are different from those in adults as they usually affect atherosclerosis-free, spasm-prone and smaller vessels, with small intravascular volume, and polycythemia in the newborn. It also has many diagnostic difficulties with long-term implications and devastating complications such as a threat to the limb or the life. Children have a major advantage of a rich-collateral circulation, yet, the repair of their arterial injuries needs more than just patency-preserving flow to support adequate limb growth.<sup>7–14</sup> Different kinds of arterial injuries may result in some disorders when considering extremities blood supply and tissue ischemia.<sup>15,16</sup> Most injuries are suitable for direct simple suturing technique or primary end-to-end anastomotic repair. For more injuries that are extensive, they required repair with a graft interposition. The ideal conduit for this graft interposition is the administration of a reversed saphenous vein harvested from the lower limb. Synthetic grafts may be suitable for repair of femoral injury in the thigh but distally, it

should be avoided as it has a lower patency rate.<sup>17</sup> The aim of this study was to evaluate our local experience with the management and outcome results of pediatric and adolescent peripheral arterial trauma in two countries with different resource-challenged settings.

## 2. Methods

This study took place at different tertiary referral trauma, teaching, university, and emergency medical centers. This retrospective descriptive study of an eight-year period from January 2008 to December 2015 reported the management and outcome of surgical repair for pediatric and adolescent patients who presented with non-iatrogenic isolated peripheral arterial injuries. Patients' file in different institutes underwent a thorough review for data retrieval after approval of our institutes' research board (IRB) committee of Faculty of Medicine, Al-Azhar University, Cairo, Egypt; Faculty of Medicine, Suez Canal University, Ismailia, Egypt; Faculty of Medicine, Menoufia University, Egypt; and College of Medicine, King Faisal University, Saudi Arabi. This study was performed at different tertiary referral trauma and emergency medical centers of a university and teaching nature.

### 2.1. Data collection

A special data collection form was used to retrieve the data from the filing system. Retrieved data included; patient demographics, clinical status in the emergency department and the types and mechanisms of injury. It also included; the site of injury (anatomical location), the indications for any

additional investigations, the time lag between the occurrence of injury and the repair. In addition to the type of repair and the used surgical technique with its mean operative time as well as diagnostic imaging modalities, anticoagulation, and the length of hospital stay. The study included highly selected pediatric and adolescent age group (2–18 years) with a mean age of  $10.25 \pm 4.05$ , presented with non-iatrogenic traumatic peripheral arterial injuries. All cases of extremity arterial trauma involving the upper and lower extremity were involved in this study. Diagnosis mainly relied on history and clinical examination, including the hard and soft signs of arterial injury. The operative repair was performed by an experienced vascular surgeon as well as well-trained pediatric and general surgeons.

## 2.2. Exclusion criteria

In order to avoid any bias in judging the outcome of the surgical procedure and the surgeons efficiency and to ban any uncertainty as regards the vascular outcomes; the following patients were excluded from this retrospective study, patients with iatrogenic vascular injury, massive vascular injury associated with severe orthopedic or muscular injury (i.e. crush injury), fine vascular injury necessitating microvascular anastomosis with the aid of surgical microscope, as well as combined peripheral arterial and venous injury. Initial resuscitation was performed for all patients according to the Advanced Trauma Life Support (ATLS) guidelines provided by the American College of Surgeons (ACS).<sup>17–19</sup> Patients who showed hemodynamic instability were transferred immediately to the operating room for operative exploration. Moreover, patients with active bleeding were treated by the application of a local wound dressing for compression. If hemorrhage was controlled, computed tomography angiography (CTA)/digital subtraction angiography (DSA) was performed. If a major arterial injury was detected the patient would be transferred immediately to the operating theater for vascular repair. If hemorrhage control was not established, immediate surgical exploration was done. Surgical treatment included primary repair with end-to-end vascular anastomoses. It also entailed the use of an interposition reversed saphenous vein graft rather than synthetic materials.<sup>20</sup> The indication of an interposition graft placement in our cases was the large arterial defect in the main artery along with the inability to perform a primary end-to-end anastomosis. Patency was documented and assessed postoperatively before leaving the operating room by using hand-held continuous wave Doppler ultrasound/DSA as well as clinical assessment by checking peripheral pulses.<sup>21,22</sup> Prophylactic fasciotomy was performed for patients with lower extremity trauma presented with symptoms and signs of severe pain out of proportion to injury that is aggravated with passive stretching of the muscles in the affected compartment, numbness, paraesthesia with limb tightness, weakness of movement, swelling of the calf and absent pulses.<sup>23,24</sup>

## 3. Results

One-hundred and forty-nine ( $n = 149$ ) patients were treated for isolated extremity arterial trauma. There were

139 (93.3%) males and 10 (6.7%) females with a mean age of  $10.25 \pm 4.05$  years (Range: 2–18). Seventy-six (51%) patients were having lower extremity arterial trauma, 60 patients showed a superficial femoral arterial (SFA) injury and 11 patients were having a popliteal injury. The remaining 5 patients suffered from posterior tibial injury (Fig. 1). Out of 73 patients (49%) who suffered from upper extremity injuries, 58 had brachial artery injury and 12 patients had radial artery injury, while the remaining 3 patients had ulnar artery injury. The anatomical sites of arterial injuries are summarized in Table 1. The cause of trauma was a blunt injury in 108 patients (72.4%). Most of the 69 (74.5%) were victims of road traffic accidents (RTA) including car and train accidents, while 39 (25.5%) had different causes, ranging from building collapse to sports injury in 20 (21.5%) and 19 (20.5%) patients respectively. While 41 (27.6%) had vascular trauma due to penetrating injury. The different mechanisms of arterial injuries are illustrated in Table 2. Primary repair was adopted using end-to-end vascular anastomosis in 77 patients (51.7%), while a reversed saphenous interposition vein graft (Fig. 2) was initially performed in 72 patients (48.3%). The indications for reversed saphenous vein interposition graft in our series depended on the extent of vessel involvement, segmental resection and reconstruction (Table 3).<sup>25</sup>

However, seven patients (9%) of those who were treated with primary end-to-end vascular anastomoses developed postoperative pseudoaneurysm at the anastomotic site that was discovered on the second to the fourth postoperative day. Those patients underwent a secondary surgical repair with the use of an interposition-reversed graft of the great saphenous vein. All of our patients underwent many different tools to guard against ischemic-reperfusion injury post anastomosis including, good hydration using plenty of intravenous fluids, early forced alkaline diuresis using sodium bicarbonate.<sup>26</sup> Moreover, prophylactic fasciotomy was performed in 10 patients (15%), the indication for prophylactic fasciotomy in these patients was the fear of developing ischemic-reperfusion injury that might develop because of muscle cell swelling following limb revascularization. In these 10 patients, the wound was eventually closed with a split-thickness skin graft. The operative

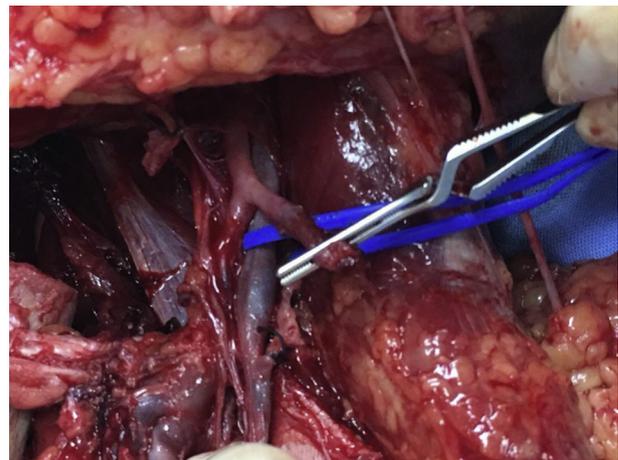


Figure 1 Posterior tibial injury in a 12-years old child.

**Table 1** Anatomical sites of arterial injury.

The injured limbs	<i>n</i>	%
Lower limb injury	76	51
Superficial femoral artery	60	69
Popliteal artery	11	14.5
Posterior tibial artery	5	6.5
Upper limb injury	73	49
Brachial	58	79.5
Radial	12	16.4
Ulnar	3	4.1

**Table 2** Different mechanisms of arterial injury.

Type of trauma	<i>n</i>	%
Blunt		
Road traffic accident	69	47
Building collapse	25	17
Sports injury	14	10
Penetrating		
Utensil, knives	18	12
Glass lacerations	11	8
Gunshot injury	9	6

procedural time ranged between 40 and 130 min with the mean operative time ( $84.66 \pm 27.15$ ) min. Yet, the ischemia time for interposition reversed saphenous vein graft ranged from 179 to 310 min (mean =  $232.5 \pm 41.9$ ) with a median = 215.

Intraoperative blood loss was 60–330 ml with the mean volume loss of ( $110 \pm 40$  ml). Whole blood transfusion was performed preoperatively in 54 patients (36%), intraoperatively in 8 (5.3%), and postoperatively in 22 (14.7%) including those 7 patients who underwent reoperation because of a pseudoaneurysm formation. Different types of surgical repair and postoperative complications are summarized in Table 4. Among 149 patients, technical success was accomplished in (91%). Moreover, general non-specific postoperative complications were recorded in six patients (4%), including postoperative fever due to pulmonary atelectasis in two patients while the remaining four patients showed other complications including drug allergy and urinary tract infection due to catheterization as well as venous access site infection. Surgical technique-related complications included pseudoaneurysm formation in seven patients (9%) mainly due to suture dehiscence

**Table 3** Indications of interposition reversed saphenous vein graft.

	<i>n</i>	%
1 Large defect in the injured artery associated with loss of a large segment	42/81	52
2 Severely lacerated artery	32/81	39.5
3 Secondary surgical repair following failure of the primary repair with end-to-end anastomosis in 7 (9%) of our patients in the current study	7/81	8.5

**Table 4** Different types of surgical repair and post-operative complications.

Procedure	<i>n</i>	%
Primary repair with end-to-end anastomosis	77	51.7
Interposition reversed saphenous vein graft	72	48.3
Reoperation	7	9
Fasciotomy	30	20
Amputation	2	3

because of severe infection. Interposition graft thrombosis in 10 patients (6.7%), this may have happened due to the presence of severe wound sepsis. Inadequate peripheral vascular perfusion distal to the anastomotic site was recorded in 23 patients (15.4%), 16 in the lower limb and 7 in the upper limb. These were verified clinically by the weakness or absence of the distal pulses and a distal oxygen ( $O_2$ ) saturation of 75 or less as verified by peripheral oximetry together with color Duplex ultrasound examination. Two patients (3%) required above knee amputation secondary to the revascularization procedure. This occurred due to the delay of intervention as they attended the hospital in a late stage of acute post-traumatic ischemia. None of the upper extremity repairs were complicated by a disabling vascular complication and does not required reoperation. One blunt lower extremity trauma patient who originally underwent a primary end-to-end vascular anastomosis needed reoperation. This patient had a natural grafting and fasciotomy within the first postoperative day due to a failure of the initial anastomosis and to guard against developing a devastating compartmental syndrome aiming at salvaging the limb. Two patients (3%) were expired. The most probable cause of mortality may be severe septicemia, although necropsy was not done.

**Figure 2** Repair of posterior tibial injury with an interposition reversed saphenous vein graft.

### 4. Discussion

Most general surgeons in the third world countries are lacking the experience to deal with vascular injuries. Therefore, extremity arterial trauma, especially in the child and adolescent periods, remains a significant challenge to most of them, as they prefer not to deal with such cases.<sup>27</sup> In the past 10 years, this problem was frequently discussed in the literature as it does accounts for a significant morbidity and mortality worldwide.<sup>5,28–33</sup> Most of our patients (93%) were male with a mean age of 10.25 ± 4.05. This data may be compared to a recently published report of 1928 patients treated in specialized university trauma centers with male percentage accounting for (85%) with an average age of about 15 years.<sup>29</sup> Similar data were also reported in the literature.<sup>30–33</sup> This may be attributed to the fact that males in this age group are hyperactive and venturous thus more susceptible to sustaining trauma. Nevertheless, the stigmatizing and secretive nature of some types of traumatic events makes measuring their prevalence and incidence difficult.<sup>16</sup> Blunt trauma was the most dominant cause of arterial injuries (72.5%) of our series. Similar data were reported in the literature with a variable percentage range.<sup>29–33</sup> Trauma to the lower limb with an injury to the superficial femoral artery was the most frequently encountered pathology in our studied series (79%). This data coincides with a previously mentioned data.<sup>30</sup> Summary of current data in relations to those reported in the literature within the past 10 years is illustrated in Table 5.<sup>4,5,29–35</sup> Repair of the damaged vessels was done using the standard technique, including both primary repair with end-to-end vascular anastomosis taking into consideration not stretch the artery by performing a proper dissection of both the proximal and distal segments entailing more length to facilitate the process, or otherwise an interposition graft using a reversed long saphenous vein was done. Because of our limited resource situation, we could not adopt the recently practiced techniques that evolved in a yet more resourceful hospital setting including (substitute conduits) to autologous saphenous vein graft such as the synthetic one either PTFE or Dacron grafts used as an interposition or as a bypass graft. In addition to the presence of an endovascular suit for interventional vascular procedures using endovascular stent graft.<sup>36</sup>

We achieved an operative technical success in 91%. While 9% were having graft failure due to pseudoaneurysm formation and infected hematoma that led to severe sepsis resulting in suture dehiscence that necessitated the reoperation in 7% of those patients using an interposition graft. Postoperative complications were encountered in 10 (6.7%) of our patients, in the form of an interposition saphenous vein graft thrombosis. Nevertheless, other interposition saphenous vein graft-related complications that are reported to take place rather than thrombosis do include; saphenous vein graft stenosis, intimal hyperplasia,<sup>37</sup> vein graft aneurysms, recurrent aneurysmal dilatation, and pseudoaneurysm fistula formation,<sup>38–41</sup> in addition, to some very rare complications such as the rupture of an old occluded saphenous vein graft.<sup>42</sup> This rupture of the grafts despite being rare might mostly be associated with collagen vascular disease.<sup>43,44</sup> The remaining 3% underwent above-

**Table 5** Summary of our results in relation to the others literature.

Type of injury	Current Study	Barmparas et al 2010 <sup>4</sup>	Wahlgren et al 2015 <sup>5</sup>	Allen et al 2015 <sup>29</sup>	Sciarretta et al 2014 <sup>30</sup>	Gurien et al 2017 <sup>31</sup>	Klinkner et al 2007 <sup>32</sup>	Kayssi et al 2017 <sup>33</sup>	Cornelle et al 2011 <sup>34</sup>	Villamaria et al 2014 <sup>35</sup>
N of treated cases	149	1,138	222	1928	2844	94	102	106	116	155
Age (mean ± SD)	14.4 (3.2)	10.7 (4.4)	9.6 (4.1)	11 (6)	14.7 (2.6)	12.1 (5)	10.7 (4.3)	9 (5)	12.7 (4.1)	12 (7)
Sex (male/female)	139/10	838/300	148/47	1350/578	17/1	62/32	75/27	80/26	82/34	122/33
Blunt trauma	72.4% (108)	58% (660)	66% (146)	76% (1465)	18% (3)	44% (41)	31% (32)	38% (40)	42% (49)	5% (5)
Penetrating trauma	26.6% (41)	42% (478)	23% (51)	24% (463)	78% (14)	56% (53)	68% (70)	72% (76)	58% (67)	95% (148)
Building collapse	21.5% (20)	NA	NA	NA	6% (1)	7% (7)	8% (8)	NA	NA	2% (3)
Upper limb	49% (73)	36% (406)	60% (134)	58% (30)	NA	37% (35)	36% (37)	34% (36)	37% (43)	28% (52)
Lower limb	51% (76)	19% (212)	29% (65)	42% (21)	94% (17)	32% (31)	30% (31)	13% (14)	25% (29)	38% (70)
Primary repair with end-to-end anastomosis	51.7% (77)	NA	12% (27) <sup>a</sup>	17% (13) <sup>a</sup>	6% (1) <sup>a</sup>	27% (25) <sup>a</sup>	20% (21) <sup>a</sup>	49% (52) <sup>a</sup>	25% (26) <sup>a</sup>	56% (78)
Interposition vein graft	48.3% (72)	NA	24% (54) <sup>a</sup>	24% (18) <sup>a</sup>	39% (7) <sup>a</sup>	33% (31) <sup>a</sup>	1% (1) <sup>a</sup>	14% (15) <sup>a</sup>	26% (27) <sup>a</sup>	NA
Reoperation	9% (7)	NA	22.2% (10)	NA	NA	NA	NA	NA	NA	NA
Fasciotomy	15% (10)	NA	23% (51)	NA	39% (7)	NA	NA	NA	NA	10% (15)
Amputation	3% (2)	1.4% (16)	7% (3)	NA	6% (1)	3% (3)	7% (7)	1% (1)	2.6% (3)	6% (9)

<sup>a</sup> Other modalities for treatment of vascular injuries rather than our used techniques were excluded from this table.

knee amputation due to a failure of revascularization. Despite the lack of many facilities at our setting, the overall morbidity and mortality rates were considerably low, accounting to approximately 6% as compared to that reported in the literature.<sup>4,5,29–35</sup> This could be ascribed to the fact that most of our cases were initially treated either by a specialized vascular surgeon as well as a well-trained pediatric/general surgeon in tertiary referral centers, mostly of a university nature. Furthermore, our patients were initially assessed and managed by experienced general surgeons. They have a good talent for dealing with vascular trauma, contrary to most trauma centers in the third world countries where the trauma settings are lacking such experienced surgeons.<sup>24</sup> Because of economic limitations, we had not used any synthetic graft rather than primary anastomosis; yet, morbidity and mortality are considered low. This might highlight the road for a vascular surgeon in suitable situations and settings, to adopt the primary anastomosis, which if done properly would result in low morbidity and mortality rates. In other words, a shortage of resources should not be necessarily considered detrimental. It could be rather regarded as a sort of challenge. This retrospective study might not be so accurate in thoroughly explaining this problem, notably that the patients' number is not adequately large. Actually, not all patients across the country are registered; only those treated in big university-affiliated well-equipped hospitals/centers. The dark figures across the country remain uncertain, likewise the difference in the management-quality, and fate of patients. The creation of patients-network across the country – although connected with high technology and coasts – might help elucidate this problem and avoid such a bias. Further future studies may be needed for a better clarification of this notion. It could be concluded that pediatric and adolescence extremity arterial injuries although, not frequently encountered in clinical practice, it should be considered as a trigger for mortality and morbidity among this age group. Moreover, it is highly recommended that to use primary end-to-end arterial anastomosis whenever possible, or alternatively, the use of an interposition autologous saphenous vein grafts, especially in a resource-challenged setting. As it is better more cost-effectiveness, reliable, feasible, and has a good outcome and highly successful in the pediatric population.

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None.

## Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

## Signed consent

N/A.

## Checklist statement

All authors read carefully and agree with all of the statements on the checklist that signed and attached to this manuscript.

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