

 **Original Article** 

Peripheral Arterial Injuries in Children: An Audit at a University Hospital in Developing Country

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Objectives: To review the prevalence, pattern, management, outcome, and predictive factors for limb loss of pediatric peripheral arterial injuries (PAIs) at a university hospital in Pakistan.

Methods: Medical records of children (age <18 years) managed for PAIs at the university hospital between Jan 2008 and Dec 2018 were reviewed for demographic data; mechanism, type, and severity of injury; management; and outcome.

Results: During the study period, of the 1718 children managed for trauma, 75 (67 males and 8 females) had PAI secondary to glass cut (33.3%), gunshot (28.0%), and road traffic accidents (24.0%). Forty-nine patients (65.3%) presented to the emergency room within 6 h of injury. Brachial (28.0%), superficial femoral (20.0%), and radial (20.0%) arteries were the frequently injured vessels. At presentation, the mean revised trauma score and Mangled Extremity Severity Score (MESS) were 3.86 ± 0.55 and 3.4 ± 1.92 , respectively. Sixty-eight patients (90.66%) underwent vascular procedures: interposition saphenous vein bypass graft or PTFE graft in 38.7% and primary repair in 29.3%. Limb salvage was achieved in 92.65% of the patients. Late presentation (>6 h) was a risk factor for limb loss ($p=0.014$).

Conclusion: Of the 23 children who presented with trauma, 1 had major PAI. Early presentation (<6 h) and appropriate vascular interventions can salvage limbs in most of the patients.

Keywords: pediatrics, vascular injuries, graft interposition, children

Introduction

Peripheral arterial injuries (PAIs) are usually assumed to be uncommon in children.^{1,2} PAIs in children differ from those in adults, as the vessels of children are not well protected by soft tissues (e.g., fat) and exhibit prolonged vasospasm after the injury. Moreover, the children's collateral circulation is robust. Delayed and inappropriate management of vessel injuries in children or adolescents can result in limb loss or may affect the growth and development of the limb.³ Available experience and literature (particularly from Pakistan) on pediatric PAIs are limited, and guidelines based on the adult practice are realized in the management of such injuries. This study was conducted to determine the archetype of pediatric vascular trauma, management, and morbidity and mortality. We also attempted to identify the factors associated with limb loss following vascular repair.

Patients and Methods

The study was conducted from Jan 2008 to Dec 2018 at the Department of Surgery, Aga Khan University Hospital, Karachi (Pakistan). After obtaining approval from the institutional ethical review committee (ERC 2018-0664-728), children aged <18 years who presented to the emergency room for the management of trauma were identified using the ICD-9 coding system. Those with vessel injury in the upper and lower limbs were included in the study. Patients with iatrogenic vascular injuries (e.g., secondary to vascular cannulation), isolated venous injuries, and incomplete or missing documentation were excluded. Medical records of the selected patients were reviewed for demographic data, mechanism and type of injury, time from injury to presentation, injury severity score, mangled extremity score, associated injuries, management including surgical procedure, and outcome (limb loss and complications).

The patients were initially managed in the emergency room according to Advanced Trauma Life Support pro-

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tocol, and management was expedited for those with definitive signs of arterial injury, e.g., reduced or absent distal pulse, arterial bleeding, and expanding or pulsatile hematoma. Careful sensory and motor evaluation of the limb was conducted upon presentation to determine the potential for limb salvage. Handheld Doppler ultrasound was used as a diagnostic aid when necessary. Angiography was performed in patients with unequivocal signs of arterial injury and those with complex injuries associated with long bone fractures or degloved and mangled limbs to determine the need for vascular intervention. Standard vessel exposure and repair techniques were employed.

After the control of relevant arterial segment, both ends were debrided, and embolectomy was performed when deemed necessary to ensure adequate blood flow from both ends. Subsequently, the vessel was flushed with heparinized saline (4IU/ml) solution. The arterial repair method was selected according to the site, extent, and type of injury. Long arterial defects were bridged by autologous saphenous vein or synthetic grafts [polytetrafluoroethylene (PTFE)]. Concomitant venous injuries were repaired or ligated accordingly, and fasciotomy was performed liberally when necessary. Postoperatively, limb circulation and viability were assessed every hour for 24 h; by examination of pulses, color of the limb, capillary refill, and handheld Doppler. Failure to detect distal pulses clinically and by handheld Doppler, and signs of limb ischemia (skin discoloration) were considered failures. Primary amputation was defined as amputation without an attempt at revascularization. It was taken into consideration when limb salvage was deemed impossible (in those with high Mangled Extremity Severity Score (MESS) or in those who presented late with skin changes). Secondary amputation was defined as amputation after an unsuccessful revascularization.

SPSS version 19 was used for data analysis. Quantitative variables were expressed as means and/or medians and were assessed by independent t-test/Mann-Whitney U test. Categorical variables were expressed as frequency and assessed by chi-squared test/Fisher's exact test. P-value <0.05 was considered statistically significant.

Results

Results are presented in **Tables 1** and **2** and **Fig. 1**. Of the 1718 children (1 out of 23) admitted to the emergency room for the management of trauma, 75 (67 males and 8 females) had peripheral vascular injuries. The mean age was 11.38 years (range 1–18). Most of the patients (>65%) presented to the emergency room within 6 h after injury due to glass cut (33.3%), gunshot (28.0%), or road traffic accidents (24.0%), and 64 patients (85.3%) had associated injuries, including 45 (60.0%) with complex long bone fractures and nerve injuries. Brachial artery

(21 patients, 28.0%), superficial femoral artery (15 patients, 20.0%), and radial artery (15 patients, 20.0%) were the frequently injured vessels. At presentation, 9 patients (12.0%) had compartment syndrome, and 27 (36.0%) manifested neurological deficit. The mean revised trauma score and MESS at presentation were 3.86 ± 0.55 and 3.4 ± 1.92 , respectively. Primary amputations were performed in three children (4.0%) who were assessed to have non-salvageable limbs upon presentation (mean MESS, 7.7). Four patients (5.3%) who had intact circulation despite the arterial injury but were unstable for surgery were managed nonoperatively. Vascular procedures

Table 1 Patients, procedures and outcome (n=75)

Variables	Point estimates
Age (years)	11.38±4.82
Gender	
Male	67 (89.3%)
Female	8 (10.7%)
Types of injuries	
Glass cut	25 (33.3%)
Gunshot/blast	21 (28.0%)
Road traffic accidents	18 (24.0%)
History of fall	11 (14.7%)
Limbs involved	
Upper arm	42 (56.0%)
Lower leg	33 (44.0%)
Vessels involved	
Brachial	21 (28.0%)
Radial	15 (20.0%)
Superficial femoral	15 (20.0%)
Popliteal	11 (14.7%)
Others (e.g. ulnar)	13 (17.3%)
Time of presentations	
Less than 6 h	49 (65.3%)
6–12 h	16 (21.3%)
12–48 h	5 (6.7%)
Greater than 48 h	5 (6.7%)
Mean revised trauma score	3.86±0.55
Mean MESS	3.4±1.92
Associated injuries	
Long bone fractures+nerve injuries	45 (60.0%)
Venous Injuries	19 (25.4%)
Operative procedures	
Ligation	9 (12.0%)
End-to-end repair	22 (29.3%)
Interposition vein graft	29 (38.7%)
Interposition PTFE graft	6 (8.0%)
Patch repair	2 (2.7%)
Fasciotomy	17 (22.7%)
Primary amputation	3 (4.0%)

MESS: Mangled Extremity Severity Score; PTFE: polytetrafluoroethylene

Table 2 Predictive factors for the secondary amputation (n=68)

Variable	Number of patients N=68	Secondary amputations n=5	p-value
Artery injured			0.159
Superficial femoral	14	3 (21.4%)	
Popliteal	9	2 (22.2%)	
Brachial	18	0 (0.0%)	
Radial	15	0 (0.0%)	
Others	12	0 (0.0%)	
Injury type			0.199
Penetrating	45	2 (4.4%)	
Blunt	23	3 (13.0%)	
Time to presentation			0.014*
≤6 h	47	1 (2.1%)	
>6 h	21	4 (19.0%)	
MESS			0.163
<7	64	4 (6.2%)	
≥7	4	1 (25.0%)	
Associated injuries			0.57
Yes	53	5 (9.4%)	
If yes			
Head	2	1 (50.0%)	
Compound fractures	20	4 (20.0%)	
Others (chest, venous, nerve)	31	0 (0.0%)	
Methods of repair			0.123
Ligated	9	0 (0.0%)	
Primary repair	22	0 (0.0%)	
Interposition vein grafting	29	5 (17.2%)	
Interposition PTFE grafting	6	0 (0.0%)	
Patchplasty	2	0 (0.0%)	

Results are presented as n (%). *p<0.05. PTFE: Polytetrafluoroethylene

(e.g., ligation, patch/end-to-end repair, or interposition saphenous vein bypass graft or PTFE graft) were performed in 68 children. Concomitant fasciotomy was performed in 17 patients (22.7%). Five (7.35%) out of 68 children underwent secondary amputation following failed revascularization; thus, limb salvage was achieved in 92.65% of patients. Two patients (2.67%) died of associated injuries (e.g., severe head injury). The median length of stay was 11 [inter quartile range (IQR) 17.0] days. Further analysis revealed that presentation after 6 h of injury ($p=0.014$), blunt injury associated with soft tissue loss and bone fracture, involvement of distal vessels, MESS >7, and associated life-threatening injuries (e.g., head injury) were risk factors for limb loss. The arterial repair method did not influence the rate of secondary amputation (Table 2).

Discussion

This study demonstrates that peripheral vascular injuries are not uncommon in children (1 out of 23) presenting to the emergency room with limb trauma. Penetrating trauma was the common cause of injury to the brachial,

superficial femoral, and radial arteries and companion veins. This is consistent with the report by Mills et al., O'Neill et al., Klinkner et al., and de Virgilio et al. from the developed world.⁴⁻⁷ More than one third of these patients had complicated long bone fractures and other fatal injuries, e.g., head injury. These occurrences, aside from late presentation (>6 h), were risk factors for limb loss ($p=0.014$). However, we were able to achieve limb salvage in 94.6% of patients after vascular repair.

The concept of "golden hour" in PAIs, though very relevant, is not always absolute. Patients with no or minimal sensory or motor loss had immediate vascular repair. In "few" patients with "questionable limb salvage potential," fasciotomy was performed before vascular repair to check the viability of the muscles by diathermy stimulation. If muscles of more than one compartment were viable, arterial repair was performed. In patients with severe sensory and motor loss, indicating significant devitalized muscles, or with severe tissue loss, primary amputation was performed to prevent unwanted consequences of reperfusion injury.

This series excludes iatrogenic injuries to portray the archetype of vascular injuries in children who presented

to a university hospital in a developing country for the management of trauma. Nazem et al. reported male predominance and penetrating trauma as a common etiology of upper extremity vessel injuries.⁸⁾ They reported high morbidity and mortality in children with lower extremity arterial injuries, as observed in our study. Patients who

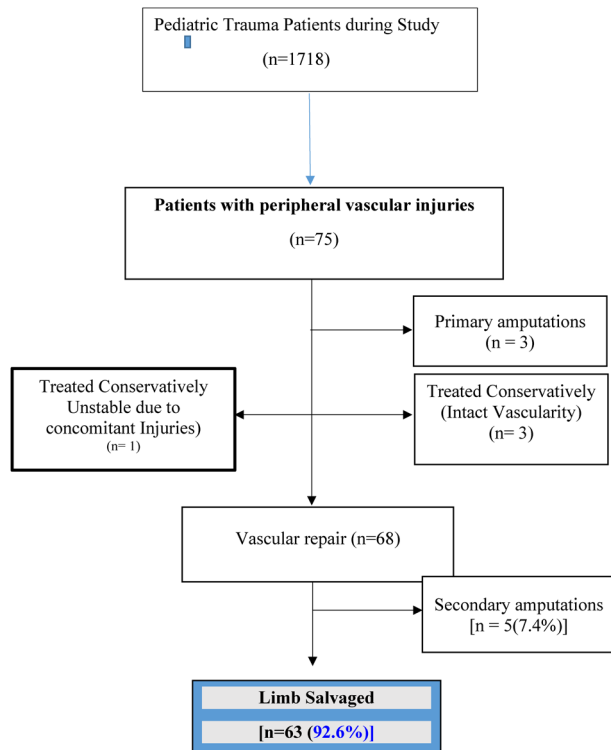


Fig. 1 Showing the total number of patients having vascular interventions.

had secondary amputations had popliteal or superficial femoral artery injury and were associated with soft tissue loss and complex fractures. Gunshot injuries are rare in children, as reported by Mommsen et al.,⁹⁾ but in this study, 28.0% of the patients had gunshot injuries, indicating law and order conditions and lack of effective weapon control in the Low-to-Middle Income Countries (LMICs). Ammar et al. reported pediatric vascular trauma over 13 years from Iraq and found missile/gunshot injuries causing significant upper extremity vascular injuries.¹⁰⁾

Small vessel caliber poses technical challenges in the repair of damaged vessels in children,¹¹⁾ highlighting the importance of meticulous technique.¹²⁾ Interposition saphenous vein bypass graft or PTFE synthetic graft was a common form of arterial repair in this study. This is contrary to the report by Corneille et al.¹²⁾ and Nazem et al.,⁸⁾ who were able to perform primary repair more frequently. End-to-end anastomosis is the procedure of choice in cases of clean-cut injury with slight tissue loss. As a significant number of the patients in this study were of gunshot wounds and road traffic accidents, the vessel ends required debridement before anastomosis. This led to vessel defects requiring interposition grafts.

We managed arterial injuries and associated bony fractures in the same setting with the “vessel-first” approach. Fractures were stabilized once vascularity had been reestablished. There is always a risk of graft kinking/thrombosis during fracture manipulation, but fortunately, none of the patients had graft issue during fracture handling in this series. The vascular surgery team was present while the fractures were being treated so as to inform the orthopedic colleagues if excessive traction was being applied.

Table 3 Summary of the main studies published on peripheral vascular injuries in children in the last 10 years ^{*)}

No	Study/year	Duration (years)	No. of patients	Inclusion criteria	Exclusion criteria	Common vessels involved	Limb salvage rate
1	Mommsen et al. 2010 ⁹⁾	35	44	<14 years	Venous injuries iatrogenic	Femoral Brachial	81.8%
2	Corneille MG et al. 2011 ¹²⁾	13	73	Peripheral I., Truncal I., <17 years	—	Ulnar Brachial	97.4%
3	Almeida CD et al. 2016	11	71	Peripheral I., Truncal I.	—	Ulnar Radial	—
4	Ammar AA et al. 2016 ¹⁰⁾	10	36	Traumatic I., Iatrogenic I.	>13 years	Brachial	97.2%
5	Kirkilas M et al. 2016 ²⁾	5	23	Traumatic I., <18 years	—	—	87.0%
6	Sofia M et al. 2018 ¹⁾	6	21	Traumatic I. <18 years	Iatrogenic	Brachial	100%
7	Wang SK et al. 2019 ¹⁴⁾	7	36	Traumatic I.	—	Upper extremity	—
8	Rehman ZU et al. 2020	10	75	Traumatic I. <18 years	Iatrogenic venous	Brachial Superficial Femoral	92.6%

RS: retrospective study design; P: penetrating injuries; I: injuries

* All were retrospective studies. [‡] Penetrating trauma was the most common cause for these injuries.

Nerve repair was performed in the later setting once the patients were stabilized and was referred to hand or orthopedic surgeons.

Compartment syndrome is an atrocious complication of peripheral vascular injury and can result in limb loss if not dealt with promptly. The risk factors for compartment syndrome are prolonged ischemia time (>6h) and concurrent bone and venous injuries.¹³⁾ Liberal application of fasciotomy (22.7% of patients) in this case series may explain the high rate of limb salvage (92.6%), as is reported by others (87%–100%)¹⁴⁾ (Table 3). The critical factors are the extent of soft tissue and vessel defect, concomitant injuries, hemodynamic status, and early presentation (<6h) of patients to facilities that are well-equipped to deal with such injuries. In this study, patients who underwent primary amputations had severe soft tissue loss and presented late.

Over the years, our team dynamics matured. Early exploration, multidisciplinary team approach, “vessel-first strategy” in case of long bone fractures, use of autogenous vein graft, liberal application of fasciotomy, and improvement of expertise in handling small arteries in trauma setting had probably contributed to these outcomes.

This study has limitations. It is a single-center and retrospective study. Despite this, it portrays the architype of peripheral vessel injuries in children presenting with penetrating trauma and gunshot and road traffic accident injuries to the limbs with concomitant soft tissue loss and complex long bone fractures. Moreover, it emphasizes the importance of vascular surgery services at a university hospital and pediatric trauma centers. Early referral (<6h), expedited diagnosis, and management based on standard vascular surgery techniques can save limbs and prevent long-term disability.

Conclusion

One out of 23 children presenting with trauma had peripheral arterial injuries. Early presentation (<6h) and appropriate vascular interventions can salvage limbs in most of the patients.

Disclosure Statement

The authors declare no conflict of interest.

Author Contributions

Study conception: ZUR

Data collection: AR

Analysis: ZUR

Investigation: ZUR

Writing: ZUR, ZN

Critical review and revision: ZUR, ZN

Final approval of the article: All authors

Accountability of all aspects of the work: All authors

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