Surgical Outcomes of Peripheral Vascular Trauma in Pediatric Patients at the Cardiovascular and Thoracic Center, Viet Duc University Hospital

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ABSTRACT

Objective: To describe the diagnostic features, surgical methods, and outcomes of peripheral vascular injury management in pediatric patients.

Methods: A retrospective cross-sectional study was conducted on all patients under 16 years of age who underwent surgery with an intraoperative diagnosis of peripheral vascular injury due to trauma (including vasospasm, vascular contusion, and thrombosis) at the Cardiovascular and Thoracic Center, Viet Duc University Hospital, from January 2021 to December 2024.

Results: Among the 35 pediatric patients, 23 (65.7%) sustained upper limb injuries, while 12 (34.3%) had lower limb injuries. The predominant mechanism of trauma was domestic accidents (primarily unassisted falls), accounting for 24 cases (68.5%), followed by traffic accidents (n = 10, 28.6%) and one case (2.9%) of occupational injury. All patients had at least one limb fracture, including 26 closed fractures (74.3%) and 9 open fractures (25.7%). A total of 30 patients (85.7%) showed no signs of acute ischemic syndrome. Regarding treatment, intraoperative pathological findings suggestive of vascular spasm were observed in 27 cases (77.1%). Among them, five patients (14.3%) received topical papaverine to induce vasodilation, while 22 (62.9%) required arterial dilatation using a Fogarty catheter. Four patients (11.4%) with arterial contusions were treated with end-to-end anastomosis, and another four (11.4%) underwent vascular reconstruction using reversed saphenous vein grafts. One patient (2.9%) developed postoperative complications, including infection and thrombosis, requiring reoperation and vascular repair using a saphenous vein homograft.

Conclusion: Vascular trauma presents significant challenges in pediatric cases. Vascular surgeons must consider the patient's future growth potential when planning interventions. Early diagnosis and timely treatment by experienced vascular surgeons at high-volume surgical centers can help reduce mortality and limb amputation rates.

Keywords: *Peripheral vascular trauma, pediatric trauma, pediatric vascular injury, pediatric peripheral vascular injuries.*

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1. Introduction

Peripheral vascular injury is a relatively common surgical emergency in adults, accounting for approximately 2% of all general surgical emergencies and 3.1% of trauma-related surgical admissions.(1) In contrast, the incidence in children is much lower, estimated at 0.6% to 1% of all trauma hospitalizations based on data from the National Trauma Databank (NTDB) in the United States.(2) These vascular injuries in children carry a substantial risk of growth and developmental complications, including limb length discrepancy, claudication, and chronic hypoperfusion, all of which can significantly impair quality of life.(3)

In children, vascular injuries are particularly complex due to the pediatric population's unique anatomical and physiological characteristics.(4) Compared to adults, pediatric vessels are less elastic and adherent to their surroundings, which explains the relative rarity of complete vascular transections in this group. Vasospasm is a widespread and characteristic response in pediatric patients, often obscuring the presence of underlying structural injuries and complicating diagnosis. Management is also technically demanding: small vessel caliber complicates surgical repair options, non-absorbable sutures may interfere with subsequent growth, and harvesting autologous grafts such as the great saphenous vein is particularly challenging in younger children. Furthermore, administering anticoagulation requires careful consideration, given the physiological differences from adults.

This study presents our experience with management strategies and short- to mid-term outcomes of pediatric extremity vascular injuries treated at Viet Duc University Hospital, the largest trauma center in northern Vietnam and the country's leading facility in trauma admission.

2. Methods

We conducted a retrospective cross-sectional descriptive study to collect data on pediatric vascular trauma in patients under 16 years of age who underwent surgery for peripheral vascular injuries at Viet Duc University Hospital from January 2021 to December 2024. All patients were admitted to Viet Duc University Hospital either via referral from provincial hospitals or directly by their families following injury. Data were collected from medical records archived at the Medical Record Department of Viet Duc University Hospital and included epidemiologic characteristics, mechanism of injury, clinical signs, imaging findings for diagnosis, intraoperative vascular injuries (vasospasm, contusion, thrombosis), surgical techniques (ligation, arterial dilation, primary end-to-end anastomosis, interposition grafting), length of hospital stay, postoperative complications (hemorrhage, infection, thrombosis, muscular or skin necrosis), and survival outcomes. Data analysis was performed using SPSS software version 20.0. Quantitative variables were presented as means and standard deviations, whereas qualitative variables were reported as frequencies and percentages.

3. Results

From January 2021 to December 2024, 35 pediatric patients met the inclusion criteria for this study. The mean age was 8.31 ± 4.45 years, ranging from 3 to 15 years old. Of these, 27 patients (77.1%) were between 3 and 11 years old, while eight (22.9%) were aged 12 years or older. Most of the patients were male (n = 24, 68.6%), and the remaining were female (n = 11, 31.4%).

Table 1. Epidemiologic and Clinical Characteristics (N=35)

	N	%
Anatomical location of injury		
Upper extremity	23	65.7%
Lower extremity	12	34.3%
Mechanism of injury		
Traffic-related accidents	10	28.6%
Domestic accidents	24	68.5%
Work-related accident	1	2.9%
Mode of admission		
Direct admission	14	40%
Referral from provincial hospital	21	60%
Signs of limb ischemia on admission		
Present	5	14.3%
Absent	30	85.7%
Associated fractures		
Closed fractures	26	74.3%
Open fractures	9	25.7%

As shown in Table 1, the most common mechanism of injury was domestic accidents (n = 24, 68.5%). Notably, one patient (2.9%) sustained a vascular injury due to a work-related accident. Most of vascular injuries involved the upper extremities (n = 23, 65.7%). Fourteen patients (40%) were admitted directly to our hospital, while twenty-one (60%) were referred from provincial hospitals after receiving initial first aid. Most patients presented without signs of acute limb ischemia upon admission (n = 30, 85.7%). All patients had associated fractures, with nearly two-thirds having closed fractures (n = 26, 74.3%).

Table 2. Paraclinical Findings (N=35)

	N	%
Doppler ultrasound findings		
Signal attenuation	27	77.1%
Absent signal	8	22.9%
CT angiography (CTA)		
Performed	23	65.7%
Not performed	12	34.3%
Findings on CTA		
Contrast cut-off (no opacification)	22	95.7%
Arterial spasm	1	4.3%

Vascular Doppler ultrasound revealed abnormalities in all patients, with the most common finding being diminished arterial signals (n = 27, 77.1%). Computed tomography angiography (CTA) was performed in 23 patients (65.7%) with suspected vascular injury (Table 2). The arterial lesions identified by contrast-enhanced CTA included complete contrast cut-off (n = 22, 95.7%) and arterial spasm (n = 1, 4.3%). Regarding vascular repair, intraoperative findings revealed vasospasm in 27 patients (77.1%). Of these, five cases (14.3%) were treated with papaverine application, while twenty-two (62.9%) underwent arterial dilation using a Fogarty catheter. Four patients (11.4%) with arterial contusion underwent primary end-to-end anastomosis, and another four cases (11.4%) required reversed great saphenous vein grafting (Table 3).

Table 3. Intraoperative Vascular Findings and Surgical Techniques (N=35)

Type of vascular lesion	Surgical technique performed	N	%
Arterial spasm (n = 27, 77.2%)	Papaverine application	5	14.3%
	Arterial dilation	22	62.9%
Arterial contusion (n = 4, 11.4%)	Primary end-to-end anastomosis	2	5.7%
	Segmental resection with interposition vein graft	2	5.7%
Arterial contusion + thrombosis (n = 4, 11.4%)	Thrombectomy + primary end-to-end anastomosis	2	5.7%
	Thrombectomy + segmental resection with vein graft	2	5.7%

Table 4. Postoperative Outcomes and Follow-up (N=35)

	Mean	Range	
Hospital stay (days)	8.6 ± 7.2	3 - 34	
Follow-up duration (months)	24.6 ± 15.0	4 - 50	
		N	**%**
Signs of postoperative limb ischemia			
Present		0	0%
Absent		35	100%
Postoperative complications			
Infection		1	2.9%
Thrombosis		1	2.9%
Muscle or skin necrosis		1	2.9%
Surgical re-intervention			
Debridement		1	2.9%
Arterial graft replacement		1	2.9%
Limb function at follow-up			
Normal function		24	68.6%
Limited mobility		11	31.4%
Follow-up Doppler ultrasound findings			
Not performed		16	45.7%
Normal		15	42.9%
Arterial stenosis		4	11.4%

As shown in Table 4, the mean hospital stay was 8.6 ± 7.2 days, and the mean follow-up duration was 24.6 ± 15.0 months. No patients exhibited postoperative signs of limb ischemia. Reported postoperative complications included infection and arterial thrombosis (n = 1, 2.9%) and muscle or skin necrosis (n = 1, 2.9%). One patient who developed both infection and thrombosis underwent reoperation with vascular reconstruction using a homograft of the great saphenous vein. Overall, 24 patients (68.6%) achieved normal limb function during follow-up after surgery.

4. Discussion

In Vietnam, most general surgeons receive only limited theoretical instruction or short-term practical experience in managing vascular trauma. Consequently, diagnosis often relies primarily on clinical signs such as the presence of fractures or the absence of distal pulses. There are three major limitations in vascular trauma care at lower-tier healthcare facilities that require urgent attention. First, there is a significant shortage of specialized vascular surgeons. Second, the complexity of severe injuries in pediatric patients, particularly those with a high risk of limb loss, discourages general surgeons from intervening due to insufficient training in pediatric vascular surgery. Third, there is a lack of specialized equipment and materials necessary for vascular reconstruction procedures.(5)

In our study, no patients were under the age of 3; most were between 3 and 15 years of age – an age range corresponding to school-age children. This suggests that these injuries may have lasting effects on both physical development and educational attainment. The majority of injuries were sustained in domestic settings, most commonly from accidental falls. Notably, we observed one case involving a 12-year-old boy who presented with a type IIIc open fracture of both tibia and fibula, along with posterior tibial artery contusion and posterior tibial nerve transection, following a work-related injury caused by entrapment in a tractor mechanism. Although Vietnamese law (Clause 3, Article 145, Labor Code 2019) prohibits child labor under 13 years of age, such incidents still occur in some areas of the country.

A total of 23 patients (65.7%) sustained upper extremity injuries, including 22 with brachial artery trauma associated with supracondylar humerus fractures. The remaining 12 patients (34.3%) had lower extremity injuries (Table 1). These findings are consistent with reports by Sohail (6) and Vu TN (7), who noted that approximately 62% of pediatric peripheral vascular injuries involve the upper limbs. In contrast, the distribution of injuries between the upper and lower extremities in adults is nearly equal. All patients in our study had associated limb fractures, with 26 presenting with closed fractures (74.3%) and the remaining 9 with open fractures (25.7%) (Table 1). Most open fractures were caused by high-energy trauma. This suggests that multiple injuries may be present in patients, and signs of vascular compromise may be masked by other systemic conditions such as polytrauma or hypotension.

In total, 14 patients (40%) were admitted directly to our hospital, while 21 (60%) were referred from lower-tier hospitals after initial stabilization (Table 1). Prieto et al. emphasized that management in dedicated pediatric trauma centers improves clinical outcomes and reduces the risk of complications following peripheral vascular injuries.(8) In northern Vietnam, only

two to three pediatric centers are equipped to perform vascular surgery in children. Therefore, timely referral to an appropriate tertiary facility is critical to optimize outcomes once a definitive diagnosis is made.

Most children in our cohort presented without overt signs of limb ischemia. More than four-fifths of our patients (n = 30, 85.7%) (Table 1) exhibited no clinical features of acute limb ischemia. This may be due to better tissue viability, more robust collateral circulation, and greater arterial elasticity in pediatric patients, allowing vessels to dilate more effectively in response to occlusion than in adults.(5) In our study, we observed a noteworthy case involving a 15-year-old female who sustained a tibial plateau fracture with associated popliteal artery injury following a self-inflicted motorcycle accident, presenting on day 10 post-trauma. Remarkably, the patient exhibited no signs of limb ischemia upon admission. The distal extremity was warm and pink, with preserved motor and sensory function, despite the absence of palpable popliteal, dorsalis pedis, and posterior tibial pulses. Doppler ultrasound and CT angiography of the lower extremities revealed a complete occlusion of the left popliteal artery at the fracture site. However, the anterior and posterior tibial arteries remained contrast-filled due to robust compensatory collateral flow.

All vascular injuries in this study were managed surgically, consistent with the findings of Kirkilas et al.(9) All procedures were performed under general anesthesia, given that pediatric patients have lower physiological tolerance for surgical stress compared to adults. More than two-thirds of the patients in our cohort (n = 27, 77.2%) (Table 3) exhibited intraoperative arterial spasm. This form of vascular injury is relatively uncommon in adult populations. One key physiological distinction between pediatric and adult patients lies in the arterial wall composition: children have a higher elastin content, rendering their arteries more prone to vasospasm. In contrast, adult arteries contain less elastin and show degenerative and regenerative changes in collagen, making them more susceptible to contusion-type injuries.(5) For vasospastic lesions, we advocate initial management with papaverine blockade. If this approach proves ineffective, we will proceed with arterial exploration and dilation using a Fogarty catheter. This technique has proven particularly effective, especially in brachial artery spasm secondary to supracondylar humerus fractures (Figure 1).

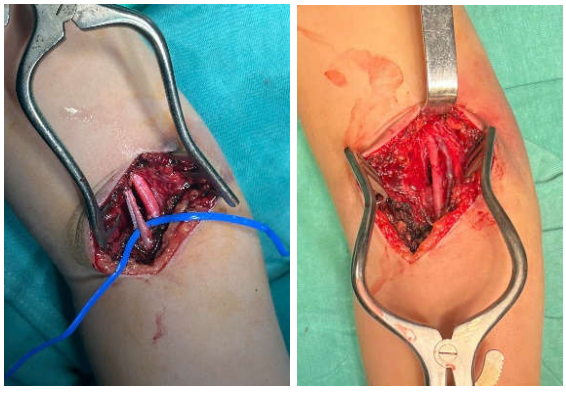

Figure 1. Preoperative: brachial artery spasm (left); Postoperative: brachial artery after dilation with Fogarty catheter (right).

The success rate of arterial dilation using a Fogarty catheter in our study was 100%. This high success rate can be attributed to the ability to directly visualize and access the affected artery during surgery, allowing for precise differentiation between vasospasm and arterial contusion. In cases of arterial contusion, the vessel wall typically appears abnormally purplish in color and contains an intraluminal thrombus. In contrast, vasospastic arteries have a normal intimal appearance and no visible intraluminal clot.

In our series, 23 patients (Table 2) underwent contrast-enhanced computed tomography angiography (CTA) with 3D vascular reconstruction for preoperative assessment. Among them, 17 patients were ultimately diagnosed with vasospasm and successfully treated with Fogarty catheter dilation. Although CTA may not clearly show the difference between vasospasm and contusion, it provides critical information regarding the location, length of the lesion, and the patency of collateral circulation. In most cases involving arterial contusion, we attempted primary end-to-end anastomosis whenever feasible, often requiring dissection and mobilization of the proximal and distal segments. When direct repair was not possible, typically when the injured segment exceeded 2 cm in length, autologous vein grafting was employed, as it is associated with superior long-term outcomes.

To prevent vascular luminal narrowing during the child's growth, and avoid progressive anastomotic stenosis over time, we recommend either interrupted sutures, or a combination of running sutures posteriorly and interrupted sutures anteriorly.(10) In our study, we adopted a hybrid technique in which the posterior half of the anastomosis was performed using continuous sutures, while the anterior half employed interrupted sutures. This approach offered the dual benefit of reducing operative time and minimizing the risk of anastomotic bleeding. Importantly, no anastomotic stenosis was observed during follow-up, and the technique ensured adequate space for vascular growth in pediatric patients.

We encountered a case of a 7-year-old male patient who was admitted after sustaining a crush injury to the left upper limb caused by a falling rock. The patient was initially managed at a district hospital and referred to our center 8 hours post-injury. On arrival, he presented with deformity of the left arm, loss of elbow mobility, and a wound on the anterolateral aspect of the left elbow. Both radial and ulnar pulses were faintly palpable; however, the distal extremity was warm, and finger extension was limited. Plain radiography revealed a distal one-third humeral shaft fracture. Doppler ultrasound showed monophasic waveforms with blunted peaks and reduced flow velocities in the radial and ulnar arteries. The patient underwent surgical debridement, fracture stabilization with Kirschner wires, and segmental resection of the contused brachial artery and vein, followed by primary anastomosis. The surgical drain was removed on postoperative day 3. However, by day 5, the patient developed swelling in the forearm, with wound dehiscence, redness, and purulent discharge at the elbow. The pulses remained palpable, and the distal extremity stayed warm and pink. Suture removal and pressure dressing were performed, but purulent drainage persisted, and signs of skin necrosis at the elbow fold were noted. A vacuum-assisted closure (VAC) device was applied, but no clinical improvement was observed. A second surgery was performed on postoperative day 12, after multidisciplinary consultation. Intraoperative findings included devitalized soft tissue, extensive necrosis, de-vascularized bone, and active bleeding at and

distal to the arterial anastomosis site, with friable vessel walls. Surgical debridement was carried out, necrotic bone was curetted, and the damaged segment of the brachial artery was reconstructed using a cryopreserved allogeneic reversed great saphenous vein graft. The culture of the wound revealed multidrug-resistant Staphylococcus aureus sensitive to vancomycin; however, the patient had a known allergy to this antibiotic. Therefore, a combination of two alternative antibiotics was administered according to susceptibility testing. The wound was managed carefully, healed progressively, and the patient made a favorable recovery, being discharged 21 days after the second surgery.

All 35 patients in this study were followed postoperatively for an average of 24.6 months (24.6 ± 15.0; range, 4 – 50 months) (Table 4). Among them, 24 patients (68.6%) (Table 4) fully restored limb function after surgical intervention.

5. Conclusion

Diagnosing peripheral vascular injury in pediatric patients remains challenging when relying solely on clinical signs. We recommend contrast-enhanced computed tomography angiography as a diagnostic tool in all suspected cases. Pediatric vascular surgery presents unique technical considerations that must be carefully addressed. Early diagnosis and timely intervention by experienced vascular surgeons are essential for achieving favorable outcomes and minimizing procedure-related complications.

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