Pediatric vascular injuries management: A single-center 10-years experience

Original Article

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ABSTRACT

Objectives: To analyze pediatric vascular injury patterns, the interventions performed, and subsequent outcomes at a high-volume trauma center.

Patients and Methods: This study is a retrospective review of pediatric patients, who were admitted to the University Emergency Hospital between 2010 and 2020 with an International Classification ninth of Diseases –Revision code for a traumatic vascular injury (900.0–904.9).

Results: During the study period, 217 patients (mean age 12±6, 135 (62%) males) sustained vascular injuries. Upper extremity represented the most common site with 125/217 (58%) vascular injuries. Of these, 122 were arterial injury and three were venous injury. Primary arterial repair of 83/125 (66%) was the most common type of treatment in this group. No amputation was done in this group during follow-up. Lower extremity was the next most common site with 59 (27%) vascular injuries. Of these, 26 were arterial and 22 were venous injury. Iatrogenic injuries of lower extremity accounted for 16 (7%) patients. Primary arterial repair was the most common treatment with 10/59 (17%) patients. Primary below-knee amputation was done in two (1%) patients. One limb amputation was done in one threatened ischemic limb after wrong catheter insertion. Twenty-nine (13%) patients sustained head and neck vascular injuries. There were four arterial injuries and 23 venous injuries. Primary arterial repair was done in four (2%) patients. Venous ligation was done in 23 (11%) patients. One aortic injury and three inferior vena cava injuries during neuroblastoma excision was treated by primary surgical repair without complications. The mean follow-up was 31±11 months.

Conclusion: Pediatric vascular injuries occur most often in the extremities. Mechanism of injury has a role in type of arterial repair. Multidisciplinary team of vascular orthopedic and plastic surgeons with individualized decisions according to presentation is the key to optimum outcome.

Key Words: Pediatrics, vascular injuries, vascular reconstruction.

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INTRODUCTION

Trauma is the leading cause of morbidity and mortality in children[1]. Traumatic vascular injuries in children are uncommon. However, they represent the potential for lifelong disability[2].

Vascular injury has been well understood in the adult population and intervention in pediatric vas-cular injury has traditionally been extrapolated from the adult trauma experience[3]. However, Vascular injuries in children is different from adults in that significant injuries are asymptomatic, are associated with spasm, or have other more severe life-threatening injuries that take priority in the resuscitation process[4,5]. The small vessel size compared with adults and have vessels that need to grow with the child may represent a technical challenge during diagnosis and treatment[6].

There is a paucity of reports describing the occurrence, injury patterns, initial management, and outcomes associated with pediatric trauma vascular injuries. The purpose of this study was to ana-lyze pediatric vascular injury patterns, the interventions performed, and subsequent outcomes at a high-volume trauma center.

PATIENTS AND METHODS:

This study is a retrospective review and was approved by the institutional review board at our insti-tution. The institution's registry was queried to identify patients less than 18 years of age (pediatric age limit considered in study's country) who were admitted to the University Emergency Hospital serving a large population of 7 million and the surrounding metropolitan area between 2010 and 2020 with an International Classification ninth of Diseases –Revision code for a traumatic vascular injury (900.0–904.9).

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Vascular injuries to the torso, upper extremity, lower extremity, and neck were included. Torso vessel injuries were defined as injuries to any major vascular structures within the trunk (thorax, abdomen, or pelvis). Neck vessel injuries were defined as injuries to the jugular vein or carotid artery. Major vascular injury in the extremities was referred to be vessels proximal to the wrist for the upper extremity and proximal to the ankle for the lower extremity. Vascular injuries with an iatrogenic mechanism, such as catheter placement were included.

All data regarding demographics, mechanism of injury, symptoms, hemodynamic status on presen-tation, injured vessels, concomitant injuries, initial diagnostic procedures, treatment option, early outcome, and follow-up outcome was analyzed.

Patients were excluded if they present with crushed limbs, already amputated as there was no role for revascularization according to our spectrum of interest. Totally amputated limbs patients were referred for microvascular assisted re-implantation by plastic surgeon, while crushed nonviable ones were referred to general surgeons for refashioning.

The diagnosis was based on a physical examination and handheld Doppler. Duplex ultrasound was called to confirm the diagnosis in questionable vascular injury as spasm whenever needed. Com-puted tomography (CT) angiography was performed in selected 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.

The decision-making was individualized for each patient. However, we have general rules in pedi-atric age group: (1) If the patient has associated bone fracture or displacement; reduction and/or fixation then a reassessment of the vascularity of the affected nonthreatened limb, And in case they improved no more intervention was needed otherwise with continued damped vascularity, explora-tion was done (2) If the patient has no associated bony fractures, then the hemodynamic stable ones should be admitted with conservative measured and operated under urgent not emergent conditions if ischemia symptoms persist, (3) Hemodynamic unstable patient because of vascular injury or those with threatened limb ischemia should be operated emergently, and (4) In certain patients with multiple fracture levels and need emergent intervention; intraoperative angiography was done in-stead of CT angiography to save time at the emergency room.

The patient received a single antiplatelet or anticoagulation according to the surgeon discrimination. And follow-up was called for all patients once after 2 weeks, 6 months, and annually after that.

Endpoints

The endpoints were the presentation of our experience with pediatric vascular injuries as a large volume trauma center in Middle East region, early outcome (30-days) in terms of mortality, mor-bidity, vessel patency, and limb salvage during the follow-up.

Statistical analysis

Numerical data are expressed as median and range. Continuous data were reported as a mean±SD. Categorical data were expressed as absolute numbers and percent prevalence (%) in the study co-hort. SPSS 22.0 performed statistical analysis for Windows software (IBM Corp, Armonk, New York, US).

RESULTS:

Study population

During the study period, 3200 patients with pediatric traumatic injuries were admitted, of which 217 (mean age 12±6, 135 (62%) males) sustained vascular injuries. Demographic data, the mecha-nism of injury, and the clinical presentations are illustrated in (Table 1).

Different types of vascular injuries were included; noniatrogenic vascular injury accounted for 195 (90%) patients while 22 (10%) patients were referred from other specialties due to iatrogenic inju-ries. Mechanism of injury was blunt trauma, glass cuts, road traffic accident, stab wounds, and gun shots in 68 (31%), 47 (22%), 45 (21%), 29 (13%), and six (3%) patients, respectively.

At presentation, 130 (60%) patient had viable ischemia, 40 (18%) patients had active bleeding, 26 (12%) patients had the pulseless pink hand of supracondylar humorous fracture, 13 (6%) patients had pseudoaneurysm, five (2%) patients had threatened ischemic limb, one patient had hematoma and two patients had no signs.

Upper extremity vascular injury

By injury location, the most common site was the upper extremity with 125 (58%) vascular injuries. Of these, 122 were arterial injuries and three were venous injury. The most frequently injured arteries in the upper extremity were the brachial artery, 47 (22%), followed by combined radial and ulnar arteries, 32 (15%) followed by the radial artery alone, 20 (9%) and the ulnar artery alone, 18 (8%). Venous injury occurred in three (1%) patients. One patient received the wrong brachial artery injection.

CT angiography was performed in 20/125 (16%) of upper extremity vascular injuries.

Conservative treatment with heparinization from the start was done for three (1%) patients with improvement of distal ischemia and return of distal pulse within 24 h of admission. Return of pulse after bone fixation occurred in 21 (10%) patients. Primary arterial repair, interposition graft, lido-caine injection for spasm was done for 83 (38%), four (2%), and four (2%) patients respectively. (Figures 1 and 2) demonstrate the repair of axillary and brachial artery with interposition graft re-spectively. Ligation of single radial or ulnar artery injury in six (3%) patients without affection to palmar arterial arch flow. Conservative anticoagulation for wrong brachial artery injection with improvement of arterial flow was done in one patient. Venous ligation was done in three (1%) pa-tients. No amputation was done in this group during follow-up.

Lower extremity vascular injury

The next most common site was lower extremity with 59 (27%) vascular injuries. Of these, 26 were arterial injuries [common femoral artery(CFA) (n=13), Superficial femoral artery (SFA) (n=7), popliteal artery (n=4) and tibioperoneal trunk (n=2)] and 22 were venous injury (superficial femoral vein (n=10), popliteal vein (n=8), and great saphenous vein (n=10)). Iatrogenic injuries of lower extremity accounted for 16 (7%) patients; (1) seven missed wires during catheter insertion, (2) four CFA were completely lacerated after trans-femoral cardiac catheterization in patients ages ranging from 5 days to 2 years, (3) two CFA pseudoaneurysm after endovascular procedures, (4) two wrong intra-arterial catheter or cannula insertion and (5) stacked long sheath on the SFA.

CT angiography was performed in 9/59 (15%) of lower extremity vascular injuries.

Primary arterial repair, interposition graft, and short bypass were done in 10 (5%), four (2%), and five (2%) patients respectively. Primary below knee amputation was done in two (1%) patients. Primary venous repair of the superficial femoral vein was done in 10 (6%) and venous ligation was done in 12 (6%) patients. Seven missed wires were removed through surgical exposure and direct repair. Lacerated four common femoral arteries during endovascular interventions were ligated after failure of attempt to repair. However, no ischemic manifestations were observed. Two common femoral arteries pseudoaneurysm were repaired surgically. Stucked long sheath during endovascular procedure was removed with end-to-side anastomosis of SFA to CFA (Fig. 3). In two wrong arterial catheter insertion, conservative measures were received with improvement of one limb while amputation was done in one threatened ischemic limb.

Head and neck vascular injury treatment

Twenty-nine (13%) patients sustained head and neck vascular injuries. There were four arterial injuries [two common carotid artery (CCA) injuries and two external carotid artery injuries] and 23 venous injuries (five external jugular vein injuries and 18 internal jugular vein injuries). One patient had a CCA pseudoaneurysm after wrong catheter insertion and one had a missed wire inside the brachiocephalic vein.

Primary arterial repair was done in four (2%) patients. Venous ligation was done in 23 (11%) pa-tients. CCA pseudoaneurysm surgical repair was done in one (0.5%) patient. In one patient with a missed wire in the brachiocephalic vein, endovascular snaring of the wire was tried but failed, and then open surgical repair through thoracotomy was done.

Torso vascular injury treatment

One aortic injury and three inferior vena cava injury during neuroblastoma excision was treated by primary surgical repair without complications.

Table 2 summarizes the location of injury and the injured vessel.

Table 3 summarizes different treatment modalities of the entire cohort of patients.

All patients with arterial injury regardless of the treatment option, were received heparin drip dur-ing admission and discharged on aspirin for at least one month. For venous injuries; enoxaparin (1 mg/kg dosage) was described for varying period depending on surgeon prescription.

The mean follow-up was 31±11 months. No amputation was done during follow-up. There was only three (1%) below-knee amputation occurred during the first admission. No major vascular complications observed during follow-up.

Table 1: Demographic data, mechanism of injury, and the clinical presentations of 217 pediatric patients with vascular injury

Variables	All patients *n*=217 (%) *or mean±SD*
Demographics	
Age (years old)	12±6
Male sex	135 (62)
Residence	
Urban	116 (54)
Rural	101 (46)
Mechanism of injury	
Blunt trauma	68 (31)
Glass cuts	47 (22)

Road traffic accident	45 (21)
Stab wound	29 (13)
Gunshot	6 (3)
Iatrogenic	22 (10)
Presentation at ER	
Normal	2 (0.9)
Viable ischemia	130 (60)
Threatened ischemia	5 (2)
Pulseless pink hand (S.C.H)	26 (12)
Hematoma	1 (.5)
Pseudoaneurysm	13 (6)
Active bleeding	40 (18)

ER, emergency room; S.C.H, supracondylar humorous fracture.

Table 2: Location of injury and the injured vessel of 217 pediatric patients with vascular injury

Region and vessel injured	All patients *n*=217(%) or mean±SD
Upper extremity	**125 (58)**
Axillary artery	4 (2)
Brachial artery	47 (22)
Radial artery	20 (9)
Ulnar artery	18 (8)
Combined radial and ulnar arteries	32 (15)
Venous injury	3 (1)
Iatrogenic (wrong BA injection)	1 (0.5)
Lower extremity	**59 (27)**
Common femoral artery	13 (6)
Superficial femoral artery	7 (3)
Popliteal artery	4 (2)
Tibioperoneal trunk	2 (0.9)
Superficial femoral vein	4 (2)
Popliteal vein	8 (4)
Great saphenous vein	10 (5)
Iatrogenic injury	16 (7)
CIV missed wire	6 (3)
EIA missed wire	1 (0.5)
CFA laceration	4 (2)
CFA pseudoaneurysm	2 (0.9)
Wrong arterial catheter or cannula insertion	2 (0.9)
SFA stucked sheath	1 (0.5)
Head/Neck	29 (13)
Common carotid artery	2 (0.9)
External carotid artery	2 (0.9)
External jugular vein	5 (2)
Internal jugular vein	18 (8)
Iatrogenic	2 (0.9)
CCA pseudoaneurysm	1 (0.5)
Brachiocephalic vein missed wire	1 (0.5)
Torso (Iatrogenic)	4 (2)
Aorta	1 (0.5)
Inferior vena cava	3 (1.5)

BA, brachial artery; CCA, common carotid artery; CFA, common femoral artery; CIV, common iliac vein; EIA, exter-nal iliac artery; SFA, superficial femoral artery.

Table 3: Different treatment modalities of 217 pediatric patients with vascular injury

Type of treatment	All patients *n*=217 (%) or mean±SD
Upper extremity	125 (58)
Primary arterial repair	83 (38)
Arterial repair with interposition graft	4 (2)
Conservative treatment with heparinization	3 (1)
Return of pulse after fixation	21 (10)
Arterial ligation	6 (3)
Lidocaine injection for spasm	4 (2)
Venous ligation	3 (1)
Conservative measures for wrong BA injection	1 (0.5)
Lower extremity	59 (27)
Primary arterial repair	10 (5)
Arterial repair with interposition graft	4 (2)
Short bypass with GSV	5 (2)
Primary venous repair	10 (5)
Venous ligation	12 (6)
Primary BKA	2 (0.9)
Iatrogenic injury	16 (7)
CIV missed wire open extraction	6 (3)
EIA missed wire open extraction	1 (0.5)
Lacerated CFA ligation	4 (2)
CFA pseudoaneurysm repair	2 (0.9)
Conservative measures for wrong arterial catheter or cannula insertion	2 (0.9)
SFA stucked sheath removal and repair	1 (0.5)

Head/Neck	29 (13)
Primary arterial repair	4 (2)
Venous ligation	23 (11)
Iatrogenic	2 (0.9)
CCA pseudoaneurysm repair	1 (0.5)
Brachiocephalic vein missed wire open thoracotomy after failure of snaring	1 (0.5)
Torso (Iatrogenic)	4 (2)
Aortic direct repair	1 (0.5)
Inferior vena cava direct repair	3 (1.5)

BA, brachial artery; BKA, below knee amputation; CCA, common carotid artery; CFA, common femoral artery; CIV, common iliac vein; EIA, external iliac artery; GSV, great saphenous vein; SFA, superficial femoral artery.

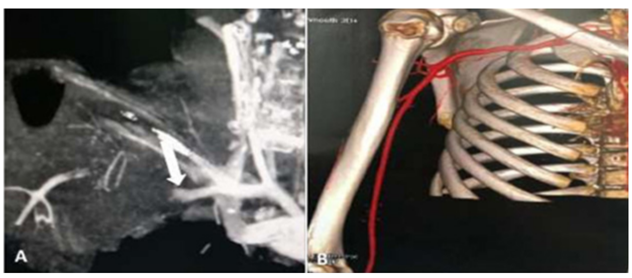

Fig. 1: Computed tomography angiography demonstrates the filling defect associated with axillary artery injury, B) Postoperative three-dimensional reconstruction demonstrates repaired axillary artery with interposition graft.

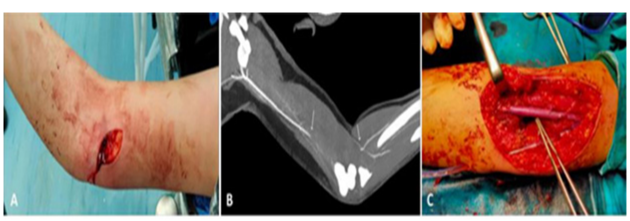

Fig. 2: A) Open supracondylar humorous fracture underwent immediate fixation, B) computed tomography angiography demonstrates the filling defect associated with brachial artery injury, C) repair of brachial artery with interposition graft.

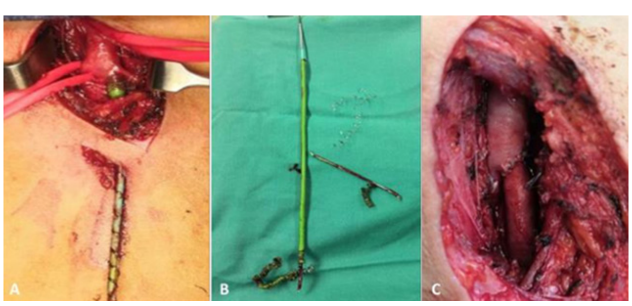

Fig. 3: Iatrogenic injury of superficial femoral artery (SFA) during trans-femoral dilatation of renal artery stenosis. A) introducer sheath was stucked to the superficial femoral artery, B) the sheath after removal, C) open surgical end-to-side anastomosis of superficial femoral artery to common femoral artery.

DISCUSSION

Pediatric vascular traumatic injury remains an uncommon but potentially fatal condition[7]. Both iatrogenic and noniatrogenic pediatric vascular trauma represents a challenge in diagnosis and treatment[8,9].

The incidence of iatrogenic and noniatrogenic vascular injury among pediatric trauma patients in the current study was 7 and 6%, respectively, that was higher than reported in literature from de-veloped countries[8-10]. However, the distribution of injuries mostly in upper then lower extremi-ties is consistent with that reported in previous studies[8-12]. This high incidence can be explained by the noncompliance to the child safety law and the high referral rate to our institution in the mid-dle of the Delta region in Egypt. For example; road traffic accidents accounted for 21% of patients in this study which can be prevented with the implementation of sound policies of appropriate re-straints and car seats to 8 assure children's safety is of paramount importance.

Similar to data obtained from developed trauma registries such as the Nationwide Swedish Registry and the American National Trauma Data Bank[9,12], results demonstrate that blunt trauma of (31%) is the most common reason for sustaining vascular injuries in this experience. Penetrating trauma by glass was the most common injury mechanism in Morão *et al*.[10] In this study, penetrating trauma of 22% was the second most common cause of vascular injury.

The main concern of this study was the excellent limb preservation and recovery of torso and neck vascular injuries irrespective of the procedure. And the no intraoperative mortality similar to Morão *et al*.,[10] and Kirkilas *et al*.[13] However, the rate of pediatric vascular injury mortality ranged 13-42% in literature, mainly because of intraoperative exsanguinating hemorrhage and in torso injuries[3,8,14-16]. Throughout follow-up, all reconstructions remained patent; this high rate of limb salvage found in this study is consistent with that reported in the previous studies[3,8,10–13].

There were no formal criteria used to decide to pursue expectant management. Authors can learn from this study that (1) No hurry toward vascular injury repair in case of viable extremity, and anti-coagulation should be started with observation of distal pulse, (2) Spasm is a major sequela with bone fracture especially in supracondylar fracture of upper extremity and bone fixation can improve distal pulse as described in 10% of patients, (3) primary arterial repair is more common in penetrating clean injury while blunt trauma creates more shear and traction-type injuries with injury to a greater length of the vessel making it unsuitable for primary repair that mandate bypass or interposition graft, (4) great saphenous vein was the preferred conduit in this study, because syn-thetic conduit are more prone to infection, thrombosis and poor patency[3,16], (5) we performed mainly interrupted suture repairs to allow the growth of vessel and prevent anastomotic site stenosis during follow-up, (6) ligation of arteries was chosen for radial or ulnar arteries in six patients with adequate distal perfusion through the intact other artery, and in four lacerated common femoral arteries due to gapped and unstable patients after endovascular procedures resulted in no conse-quence in terms of function or growth, (7) CT angiography should be limited to patients with threatened ischemia and debatable site of arterial injury especially in blunt trauma and absence of hard signs to avoid the high complication rates associated with angiograms in small arterial caliber, including arterial thrombosis[3,5,15,17]. In case CT angiography was called; hand injected rather than the power injected was recommended to limit the contrast bolus[3,18], (8) Anticoagulation and antiplatelet has a major effect on the patency of the vessels[19], and (9) at our institution, all pediatric vascular injuries were managed initially by vascular surgeon. We think that vascular sur-geon availability at emergency hospitals contributed significantly to the good outcome in this study.

This study was limited by its retrospective design and relatively small sample of cases. Another limitation is the heterogeneity of iatrogenic and noniatrogenic vascular injuries beside the different treatment modalities. However, it is one of the biggest single-center studies describing the mecha-nism of trauma, incidence, presentation of pediatric vascular injury in one of high volume trauma center in the Middle East region and how they were treated. There is obvious need for a larger mul-ti-center trial to determine the optimal for still unanswered questions; such as the relation between the mechanism of injury and the type of repair, optimal duration of inpatient and outpatient antico-agulation, and the role and types of surveillance imaging, frequency and duration of follow-up vis-its.

CONCLUSION

Pediatric vascular injuries occur most often in the extremities. Mechanism of injury has a role in type of arterial repair. A multidisciplinary team of vascular and orthopedic surgeons with individu-alized decisions according to the presentation are the key to optimum outcome. Anticoagulation may play a role in vessel patency. Future multi-centric clinical trials are needed to guide the opti-mum for diagnosis, treatment and surveillance.

CONFLICT OF INTEREST

There are no conflicts of interest.

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