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Incidence of Vascular Injury in Supracondylar Humeral Fracture in Pediatrics

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ABSTRACT

Background: Supracondylar fractures of the humerus are the most common fractures in children under 7 years old and the most common pediatric fracture requiring surgery. Supracondylar humeral fractures may be accompanied by a vascular injury that is worse than the fracture. The early recognition of vascular complications is crucial to performing an adequate and rapid treatment that provides a good prognosis.

Objective: To determine the incidence of vascular injuries in Supracondylar humeral fractures.

Patients and methods: This was a prospective observational analytical study that included a total of 100 pediatric patients who were presented by SFH to the Emergency Hospital (MUEH), Mansoura University Mansoura. Entire pediatric cases were further classified into 2 groups according to the state of vascular affection; Group 1 which included cases who were presented with vascular injuries and Group 2 which included cases having no vascular injury.

Results: Incidence of vascular injury was demonstrated to be significantly increased with increased age and male sex. However, no significant correlation was recorded between the incidence of vascular injury and past history. Incidence of vascular injury was demonstrated to have a significant correlation with advanced grades of fractures (III and IV)), positive hard signs, and positive soft signs (P<0.001). No associated mortality was recorded among the studied cases.

Conclusion: Vascular injury seems to be a frequent critical adverse event of pediatric supracondylar humeral fractures which was demonstrated to be correlated positively with advanced grades of fractures (III and IV).

Keywords: Vascular Injury, Supracondylar Humeral Fracture, Pediatrics.

INTRODUCTION

Supracondylar fracture of the humerus (SFH) is the most common fracture of the elbow in the pediatric population (60%). It mostly occurs by falling on an outstretched hand (FOOSH). The incidence of vascular injury in children after a completely displaced supracondylar fracture has been reported to be around 12%, with the brachial artery being most commonly involved (38% of all cases in Campbell *et al.* series) [(1, 2)].

Five types of arterial injuries can occur intimal injury, complete wall defect, complete transection, arteriovenous fistula (AVF), and spasm. Penetrating injuries usually cause wall defects. But, blunt traumas usually cause intimal defects via shearing or crush injury [(3)].

Displaced SFH in children is commonly associated with vascular insult in the form of absent distal pulses. In such cases, the limb can be cold and cyanotic or warm and pink despite the loss of pulse. The vascular injury is a priority over the treatment of the fracture itself in such cases. Immediate exploration of the cold cyanotic limb is the treatment of choice for most surgeons [(4)].

Prevention of these complications depends largely on a timely diagnosis, aggressive treatment, and a high index of suspicion in a child with a suggestive history and physical exam. In the evaluation of supracondylar fractures of the humerus, the physician must pay close attention to the neurovascular exam [(1)].

Failure to assess a distal pulse in a patient may result in the loss of the child's limb. It is important to realize that by the time a patient develops pain, paraesthesia, pallor, or paralysis of an affected limb, muscle necrosis has already begun, and may be too late for limb salvage. Early diagnosis and prompt management of the fracture and arterial injuries are mandatory to prevent these, and disabling complications[(1, 2)].

However, the treatment of pink, warm, pulseless limbs is still under debate. Therefore, the current trends in the management of such vascular injuries associated with SFH where microvascular experts are available at all times have to be discussed[(5)].

The purpose of this study was to determine the incidence of vascular injuries in Supracondylar humeral fractures in the pediatric age group and to define the mechanism of injury, diagnostic approach, short-term management, and outcome in these patients.

PATIENTS AND METHODS

This was an analytical study that included pediatric patients who were presented by SFH to the Mansoura University Emergency Hospital (MUEH), Mansoura, Egypt: a level 1 trauma center with about 250,000 visits and 25000 trauma cases admission per year. This study was conducted for one year **(from January 2020 to January 2021).**

Inclusion criteria: Pediatric cases in the age group below 18 years old with SFH within the first 24 hours, and both genders.

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Exclusion criteria: Old trauma of more than 24 hours, history of peripheral vascular diseases, and patient with minor trauma who doesn't need admission.

Entire pediatric cases were further classified into 2 groups according to the state of vascular affection: Group 1: cases who were presented with vascular injuries, and Group 2: cases having no vascular injury.

Methods:

Initial assessment and management: It is a linear progression of steps that consists of the primary and secondary surveys. It mandates synchronized non-dissociated evaluation and intervention for life-threatening injury when identified.

The primary survey includes:

A. **Airway maintenance with cervical spine protection**
B. **Breathing and ventilation**
C. **Circulation with bleeding control:** Assessment of hypovolemia and capillary refill time was performed followed by the establishment of venous line and replacement of fluids and blood transfusion if needed and Control of extremity hemorrhage.
D. **Disability/Neurologic assessment:** All the previous maneuvers were re-assessed again, and neurological status and Glasgow coma scale (GCS) were performed. Assessment of pupillary size and check for a history of ingestion of depressant drugs were also carried out
E. **Exposure and environmental control:** Patients were completely undressed, usually by cutting off the garments to ease a detailed examination and assessment. It was vital to cover the patient with warm blankets to prevent hypothermia in the trauma receiving area

To complete the primary survey, all unstable polytrauma patients were exposed in the resuscitation room to the following: (1) FAST (Focused assessment sonography for trauma patient): in polytrauma patients for possible internal hemorrhage. (2) Portable chest and pelvis X-ray.

The secondary survey:

Once the primary survey is achieved, all patients are subjected to the secondary survey including:

I. All patients will be subjected to full history including age, gender, occupation, mode of trauma, time of trauma, arrival, and resuscitation.
II. **AMPLE History:** **A** = **A**llergies, **M** = **M**edication currently used, **P** = **P**ast illnesses, **L** = **L**ast meal, and **E** = **E**vents/**E**nvironment related to injury (Exactly what happened?).
III. **Clinical examination** of the patients at the trauma room including vital signs, GCS, complete general examination: head-to-toe examination including log-roll to define the potentially life-threatening and/or occult injuries.
IV. **Upper extremity examination:** Vascular assessment, peripheral nerve assessment:(motor and sensory examination), and bone and soft tissue assessment.
V. **Laboratory investigations:** Complete blood count (CBC), international normalized ratio (INR), ABO grouping, and serum creatinine.
VI. **Radiological examinations:** (1) X-ray anteroposterior and lateral view of the elbow. (2) Duplex Ultrasound (DUS) on Upper Limb: It is a Combination of 2 imaging modalities: B-mode and Doppler. The machine used was the LOGIQ P5 model with a linear probe(7.5 MHz), and we used it to evaluate arterial injuries (arterial stenosis, arterial occlusion, pseudoaneurysm, and AVF).

Ethical consideration:

Approval of the study was obtained from Mansoura University's academic and ethical committee. The research objectives were explained to the participants' relatives individually and in groups. Informed written consent was obtained from each participant's relatives sharing in the study. Confidentiality and personal privacy were respected at all levels of the study. This work has been carried out following The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis:

Data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using numbers and percentages. Quantitative data were described using median (minimum and maximum) and mean, the standard deviation for parametric data after testing normality using the Kolmogorov-Smirnov test. The significance of the obtained results was judged at the (0.05) level. Chi-Square test, Monte Carlo and Fischer exact test for comparison of 2 or more groups. A student t-test was used to compare 2 independent groups. P-value < 0.05 was considered significant.

RESULTS

The mean age was 6.25. The percentage of male/female (M/F) was 57/43. All cases had no history of medical problems. Most of the studied cases had grade I (43%) followed by grade II (26%) then grade IV (16%) and grade III (15%) **Table (1)**.

Table (1): Demographic characteristics and Grade of fracture among studied cases

	n=100	%
Age/years mean±SD (MIN-MAX)	6.25±3.32 (2-15)	
Sex Male Female	 57 43	 57.0 43.0
Past history -ve +ve	 100 0	 100.0 0.0
Grade of fracture I II III IV	 43 26 15 16	 43.0 26.0 15.0 16.0

Motor vehicle Collision, fall to the ground, Road traffic accidents, falling from a height, and Falling downstairs were recorded in 74%, 6%, 11%, 5%, and 4% of cases respectively. Doppler US was abnormal in 9% and normal in 91% of cases **(Table 2).**

Table (2): Fracture characteristics among studied cases

	N=100	%
Mode of fracture		
MVC	74	74.0
Fall to ground	6	6.0
Road Traffic accident	11	11.0
Falling from height	5	5.0
Falling downstairs	4	4.0
Doppler US		
Abnormal	9	9.0
normal	91	91.0

All the studied cases with threatened limb ischemia (pale, pulseless, and cold) were presented within eight hours. They had an immediate reduction and fixation by orthopedics followed by vascular exploration that revealed different injuries to the brachial artery **(Table 3).**

Table (3): Type of injury and surgical intervention in threatened ischemic cases:

Type of injury &intervention	N=4	%
Contused segment of the brachial artery (interposition graft from GSV)	2	50%
Spastic brachial artery (proximal and distal thrombectomy)	1	25%
Intimal tear of the brachial artery (repair by patch graft)	1	25%

Incidence of vascular injury was demonstrated to be significantly increased with increased age and male sex. However, no significant correlation was recorded between the incidence of vascular injury and past history **(Table 4).**

Table (4): Relation between demographic characteristics and incidence of vascular injury among studied cases:

	Total number	No vascular injury n=89	Vascular injury n=11	Test of significance
Age/years mean±SD	 6.25±3.32	 5.88±2.77	 9.18±5.57	t=3.25 P=0.002*
Sex n(%) Male Female	 57 43	 46(80.7) 43(100)	 11(19.3) 0	 χ^2=9.32 p=0.002*
Past history -ve	 100	 89(89.0)	 11(11.0)	

T=Student t-test χ^2=Chi-Square test *statistically significant

Incidence of vascular injury was demonstrated to be significantly increased with advanced grades of fractures (III and IV)) **(P<0.001) (Table 5).**

Table (5): Relation between Grade of fracture and incidence of vascular injury among studied cases

		No vascular injury n=89	Vascular injury n=11	Test of significance
Grade of fracture n(%)				
I	43	43(100)	0	χ^{2MC}=34.6
II	26	26(100)	0	p<0.001*
III	15	12(80)	3(20)	
IV	16	8(50)	8(50)	

T=Student t-test χ^2=Chi-Square test MC: Monte Carlo test, FET: Fischer exact test *statistically significant

Incidence of vascular injury was demonstrated to be significantly increased with positive hard signs and positive soft signs **(P<0.001) (Table 6).**

Table (6): Relation between hard and soft signs and incidence of vascular injury among studied cases

		No vascular injury n=89	Vascular injury n=11	Test of significance
Hard sign n(%)				
-ve	94	89(94.7)	5(5.3)	χ^{2FET}=51.64
+ve	6	0	6(100.0)	p<0.001*
Soft signs n(%)				
-ve	89	88(98.9)	1(1.1)	χ^{2FET}=80.6
+ve	11	1(9.1)	10(90.9)	P<0.001*

t: Student t-test χ^2=Chi-Square test MC: Monte Carlo test, FET: Fischer exact test *statistically significant

There were no significant correlations between incidences of vascular injury and both mode of fracture and Doppler US **(P>0.05) (Table 7).**

Table (7): Relation between Mode of fracture, Doppler US, and incidence of vascular injury among studied cases:

		No vascular injury n=89	Vascular injury n=11	Test of significance
Mode of fracture (%)				
MVC	74	65(87.8)	9(12.2)	
Fall to ground	6	5(83.3)	1(16.7)	χ^{2MC}=3.08
Road Traffic accident	11	11(100)	0	P=0.545
Falling from height	5	5(100)	0	
Falling downstairs	4	3(75)	1(25)	
Doppler US n (%)				
Abnormal	9	0	9(81.8%)	χ^2=80.02
Normal	91	89(100%)	2(18.2%)	P< 0.001

t: Student t-test χ^2=Chi-Square test MC: Monte Carlo test, FET: Fischer exact test *statistically significant

The outcome of the studied cases was estimated according to limb salvage, limb amputation, ICU admission, and mortality rate within seven days of admission. The outcome of the studied cases was worse in patients with vascular injuries as cases with vascular injuries had more surgical intervention, and more ICU admission, with significant statistical differences between the 2 study groups **(Table 8).**

Table (8): Outcome of the studied cases:

Outcome	Without vascular injury n=89	With vascular injury n=11	Test of significance
Limb salvage	88(98.9%)	9(81.8%)	^{2FET}=0.031
Amputation	1(1.1%)	2(18.2%)	P=0.03*
Mortality 7 days admission	0	0	P=1.0
ICU admission	2(2.3%)	3(27.3%)	^{2FET}=0.009 P=0.008*

FET: Fischer exact test *statistically significant

CASE (1)

Figure (1): Male patient, 9 years old presented to ED after falling from a height. By examination: vitally stable, swelling in the right elbow and cold, pale, and pulseless right hand. X-ray of Rt elbow joint was done as shown. Doppler US shows No flow in radial and ulnar arteries. Management: immediate open reduction and fixation by orthopedics and exploration by vascular surgeons which revealed contused segment of brachial artery managed by interposition graft from GSV**.**

CASE (2)

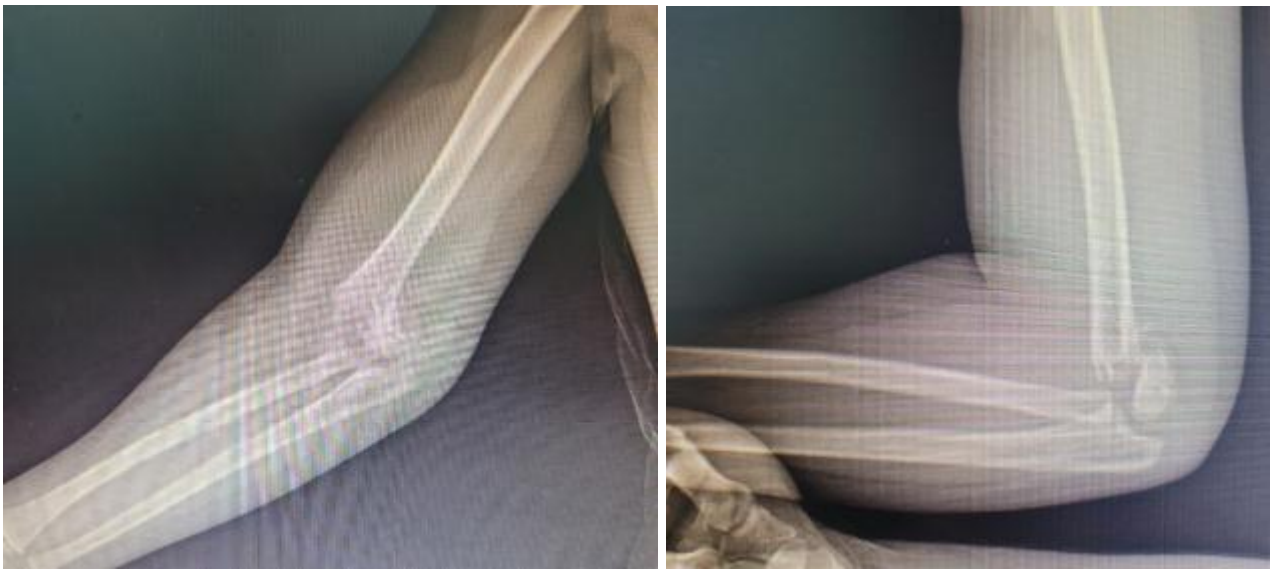

Figure (2): Male patient, 6 years old presented to ED by road traffic collision. By examination: vitally stable, pink pulseless right hand. An X-ray of the right elbow was done as shown. Management: closed reduction and percutaneous pinning by orthopedics and exploration by vascular surgeons which revealed hematoma compressing brachial artery managed by hematoma evacuation.

DISCUSSION

Concerning demographic characteristics of the studied cases, the mean age was 6.25±3.32. The percentage of male/female (M/F) was 57/43.

This came in the same line as an Egyptian study conducted by **Hosam Roshdy *et al.*** [6] on a total of 462, there were 295 males (64%) and 167 females (36%). Their age range from (1 to 16 years) with a mean of 6±2 years, right limb 138 patients (30%) left limb 324 patients (70%).

Additionally, **Pilla *et al.*** [7] have demonstrated in their study that; there were 42 males (56%) and 33 females (44%). The average age was six years.70 of the 75 patients were older than the age of three. In another study that was carried out by **Cheng *et al.*** [8] the median age at presentation was 6 years (6.6 years in boys, and 5 years in girls), with the nondominant humerus 1.5 times more commonly injured.

In the present study, most of the studied cases had grade I (43%) followed by grade II (26%), then grade IV (16%), and grade III (15%) fractures. This comes along with a previous study made by **Barr** [9] the 155 (97 %) extension-type injuries comprised 46, 28, and 26 % Gartland type I, II, and III fractures, respectively.

Regarding mode of fracture, most of the studied cases had motor vehicle collisions (74%). In addition, Road Traffic Collision, falls to the ground, falling from a height, and falling downstairs was recorded in 11%, 6%, 5%, and 4% of cases respectively.

We disagree with **Cheng *et al.*** [8] **and Farnsworth *et al.*** [10] it was demonstrated that; the usual mechanism of injury is a fall onto an outstretched hand.

On the other hand, **Farnsworth *et al.*** [10] have reported that; falls from a height accounted for 70% of the fractures. Children ≤3 years old tended to fall off household objects (beds, couches, other objects 3-6 feet high), and children 4 years and older tended to fall from playground equipment such as monkey bars, slides, and swings. Safety precautions should be implemented in homes of young children and at playgrounds to avoid these fractures.

In accordance **Pilla *et al.*** [7] have revealed that; all supracondylar fractures in their study were owing to a fall. Falls from playground equipment resulted in 29 fractures. There were 10 from falls off furniture, six from falls during sports, three from falls on the stairs, and three from falls off bikes. The remaining fractures resulted from running, tripping, falling from a toy ball, sled, tree, wagon, fence, bounce house, van, deck, power wheels car, ATV, and a go-cart.

In the context of incidence of vascular injury, the current study demonstrated that 11 out of 100 subjects were associated with vascular injury i.e. 11% of the studied cases. Of the studied cases, 63.6% (7 cases) presented with pink pulseless hand and 36.4% (4cases) presented with threatened limb ischemia.

Incidence of vascular injury was demonstrated to be significantly increased with increased age, male sex, advanced grade of fractures (III and IV)) (P<0.001), positive hard signs, and positive soft signs (P<0.001). However, no significant correlation was recorded between the incidence of vascular injury and history.

Our results are in harmony with **Schoenecker *et al.*** [11] have reported that about 10% of children with supracondylar fractures have an acute vascular injury.

It was demonstrated that the prevalence of vascular insufficiency accompanying supracondylar fractures ranged from 5% to 12% [12].

It has been displayed that; the range of supracondylar fractures presenting with vascular injury has been reported as few as 2.6% and as many as 17% [7].

Another novel study conducted in 2020 by **Pilla *et al.*** [7] has illustrated that; out of 75 patients with supracondylar fractures, four (5.3%) presented with a vascular injury.

Also, **Benedetti Valentini *et al.*** [13] have reported that; Of the 48 patients, 37 (77%) had no signs of vascular impairment. In total, 11 patients (23%) presented with signs of vascular impairment. Eight had a pink pulseless hand without other signs of ischemia, whereas three had severe pain and a white pulseless hand that was cold with areas of paraesthesia and/or anesthesia, and impaired movement.

Minimal incidence was recorded by **Hosam Roshdy *et al.*** [6] who have displayed in their study that thirty-five patients (7.6%) had a pulseless hand. Twenty-four patients showed a return of radial & brachial pulses after the reduction of the fracture. Surgical interference was done in 11 patients (2.4 %) out of 462 patients and (31.5%) out of the 35 patients who had pulseless hands.

Notably, vascular injury in a supracondylar fracture can occur in several ways. The brachial artery can be stretched kinked over the displaced fragments. There may be a direct injury causing a contusion and an intimal tear. It may also be partially lacerated or completely transacted [14].

In contrast, To the best of our knowledge, vascular injuries secondary to supracondylar fractures are relatively rare injuries and by their nature are usually managed by a variety of orthopedic and vascular surgeons on an urgent basis [15].

Hard and soft signs were recorded in 6% and 11% of cases respectively. Most cases had no recorded mode of fracture (74%). In addition, road traffic collision, falls to the ground, falling from a height, and falling downstairs was recorded in 6%, 11%, 5%, and 4% of cases respectively. Doppler US was biphasic in 5% and average in 95% of cases.

In the present study, hard signs appeared to be positive in 6% of cases. They included expanding hematoma in 33.3% (2 cases), pulsatile bleeding in

zero%, and ischemia in 66.7% (4 cases). Soft signs appeared in 11% of the studied cases with the proximity of trauma to an artery being the most common sign (100%) followed by a reduced pulse (81.8%). Doppler US was abnormal in 9% and normal in 91% of cases.

Clinical examination findings in patients with vascular injury are the hard sign and soft signs. Hard signs are strong predictors of the presence of an arterial injury and therefore there is limited need for imaging which may take more time and can lead to serious implications. In these cases, instantaneous operative exploration of the injured extremity is a must to enable vascular repair [(16)].

Although soft signs are suggestive of an arterial injury, evaluation of the extremity trauma with only soft signs of arterial injury continues to be a subject of debate. Much of the controversy of vascular trauma evaluation centers on the workup of patients with soft signs. With only soft signs, non-invasive methods (IEI and DUS) are applicable and valuable. While CTA must be retained for more complex and multilevel arterial injuries as it is positive in fewer than 10% of patients [(17)].

In this study, the vascular intervention was chosen according to the clinical status of the patient. Immediate exploration was performed in 36.4 % of cases with a vascular injury that ended with interposition graft, proximal and distal thrombectomy, and repair by patch graft in 50%, 25%, and 25 % of those cases respectively. The conservative trial was chosen in 45.5 % of cases with vascular injury (5 cases).

We agree with **Wali [(18)],** as interposition vein graft was used in 48% as the most frequently used repair method, while synthetic grafts were not used for repair, ligation in 19%.

Correspondingly**, Shalabi *et al.* [(19)]** stated that interposition vein graft was the most frequently used single technique of arterial repair in 53.4%. Other techniques used were ligation in 17.2%; end-to-end anastomosis in 29.3%.

In contrast, **Sharma *et al.* [(20)]** stated that completion of the arterial repair was preferred over orthopedic fixation when there was advanced ischemia with a threatened limb. End-to-end anastomosis after the resection of the contused segment was the most frequently used repair method with 58.3%. Interposition vein graft was the favored conduit for reconstruction with 41.1%.

In this study, the outcome of the studied cases was worse in patients with vascular injuries who had more limb amputation (18.2%) and more intensive care unit admission (27.3%) with significant statistical differences between the two study groups. limb salvage was better in cases without vascular injury (98.9%) vs (81.8%) in cases with vascular injury. Finally, no associated mortality was recorded among the studied cases.

194 children with supracondylar fractures of the humerus were reviewed. Of the 49 children with Gartland grade III displacement, signs of vascular compromise were clinically suspected in 5 cases. Immediate open reduction, internal fixation, and exploration were performed. Four children had a satisfactory outcome. One child required amputation. A careful clinical evaluation for vascular injury and an aggressive surgical approach is suggested when indicated [(21)].

CONCLUSION

The vascular injury seems to be a frequent critical adverse event of pediatric supracondylar humeral fractures which was demonstrated to be correlated positively with advanced grades of fractures (III and IV). Hard signs are strong predictors of the presence of an arterial injury and the need for operative intervention.

RECOMMENDATIONS

Emergency physicians should have a high index of suspicion of vascular injury in pediatric supracondylar humeral fractures cases and be able to refer promptly.
All pediatric patients with supracondylar humeral fractures should be assessed for hard signs. Ischemic hard signs need to be immediately explored. Non-ischemic hard signs need additional workup by DUS and if needed arteriogram to identify injury site and extent.

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