Reaching a crossroads in the management of pink pulseless hand in pediatric supracondylar humerus fracture: exploration Versus conservation

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Introduction

Supracondylar fracture of the humerus (SFH) is the most common fracture of the elbow in the pediatric population (60%)[1, 2]. 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. Immediate exploration of the cold cyanotic limb is the current recommendation[3]. The treatment of pink, warm pulseless limbs is still under debate[4].

Aim

The aim of this study is to evaluate the role of intraoperative in situ conventional angiography in the same setting of fracture fixation in cases of SFH with pink pulseless hands.

Patients and methods

This is a comparative study between two groups of pediatric patients admitted to Tanta University Hospitals, who suffered from SFH associated with a pink pulseless hand, and who underwent reduction and closed fixation of the fracture. Group (A) includes prospective data from 30 pediatric patients recruited from January 2021 to January 2023, who were managed by same-session conventional in situ brachial artery angiography. Group (B) includes retrospective data records from December 2016 to December 2019, composed of 50 similar age-group patients who were managed conservatively for 6–12 h after fracture fixation. Then after failure to regain distal pulse, CTA was performed to disclose the underlying arterial condition.

Results

The mean age of patients was 6.4 years ±2.73. The main mode of trauma was falling to the ground on outstretched hand (47% in group A, and 54% in group B). The types of arterial injury were as follows: brachial artery entrapment (27% in group A, 18% in group B), complete transection (7% in group A, 6% in group B), intimal contusion and thrombosis (43% in group A, 56% in group B), arterial spasm (23% in group A, 20% in group B). The mortality rate was 0% and the limb salvage rate was 100% in both groups, however, the number of anesthesia sessions, the mean total operative time, and the duration of hospital stay were significantly lower and in favor of group (A).

Conclusion

We believe that *in situ* conventional angiography is the most appropriate, accurate, and rapid diagnostic tool to define the lesion and plan the procedure in pediatrics with a pink, warm, well-perfused pulseless hand associated with SFH.

Keywords:
arterial injury, conventional angiography, supracondylar fracture of the humerus

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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. The incidence of vascular injury in children after a completely displaced supracondylar fracture has been reported to be around 12% [1,2]. 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. Immediate exploration of the cold cyanotic limb is the current recommendation [3]. The treatment of pink, warm pulseless limbs is still under debate. Many authors recommend conservative management of such cases

[4,5]. However, some authors also recommend early aggressive surgical intervention to prevent limb loss and serious long-term complications such as Volkmann's ischemic contracture [6,7].

The usual use of angiography in these situations is to wait for some hours for the distal pulses to return after fracture reduction, if no return, then, either computed tomography angiography (CTA) or conventional angiography is performed under general anesthesia especially for the younger age group. If arterial injury is detected, the child would have a third round of anesthesia for arterial exploration and repair. The sequlae of multiple anesthesia sessions may cause additional morbidity to the original trauma. Moreover, the delay in diagnosis and repair of arterial injuries may lead to limb disabilities. Our study tries to avoid the delay in diagnosis, to diminish anesthesia sessions into only once and to avoid negative vascular exploration in cases such as arterial spasm. We introduce our experience in performing *in situ* angiography of the limb through either a mini-incision over the brachial artery or a percutaneous brachial approach within the same session of fracture reduction and fixation. If injury is detected, repair takes place immediately.

Patients and methods

This is a comparative study between two groups of pediatric patients (below the age of 18) admitted to Tanta University Hospitals, suffered from SFH associated with pink pulseless hand, who underwent reduction and closed fixation of the fracture.

Group (A): includes a prospective data from case-series of 30 pediatric patients recruited from January 2021 to January 2023, who were managed by same-session conventional *in situ* brachial artery angiography.

Group (B): includes retrospective data records from December 2016 to December 2019, composed of 50 similar age-group patients who were managed conservatively for 6–12 h after fracture fixation. Then after failure to regain distal pulse, CTA was performed to disclose the underlying arterial condition.

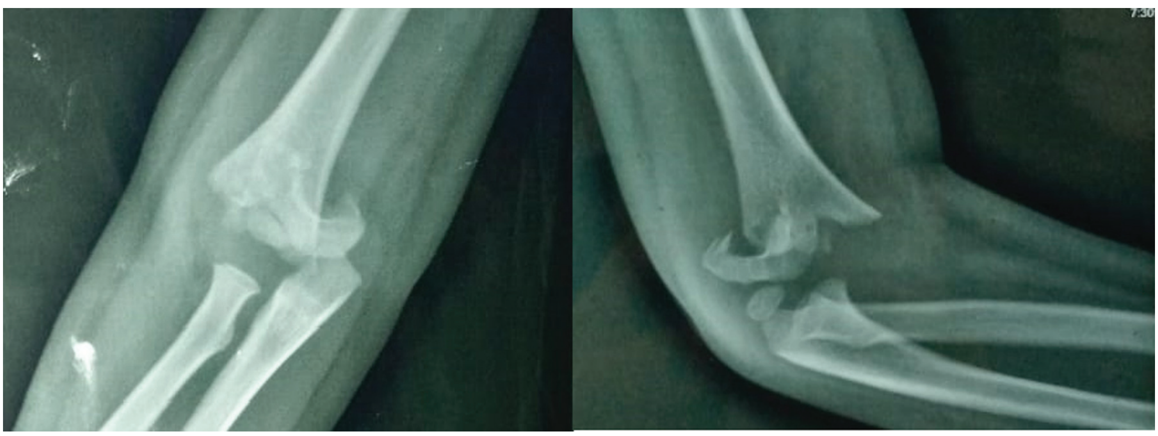
The study was approved by the local Research Ethical Committee with a written informed consent obtained from the guardians of the patients.

Children with SFH with intact distal pulses were excluded from the study. Also, cases with evidently ischemic hand (pallor or cyanosis) or nonviable ischemic upper limb were excluded from the study.

Methods

Demographic and preoperative data including, age, sex, mode of trauma and time of presentation were obtained from the patients or their guardians. Clinical assessment included vascular assessment (palpation of distal pulse, capillary refill time in fingers, and oxygen saturation using pulse oximeter), peripheral nerve assessment (sensory and motor examination), bone and soft tissue assessment. Routine preoperative laboratory investigations (complete blood count (CBC), international normalization ratio (INR), ABO grouping and serum creatinine) were performed as well as imaging study in the form of plain radiography (anteroposterior and lateral views) to the upper extremity demonstrating the grade of the fracture according to the modified Gartland classification (Fig. 1). The anatomical and hemodynamic data of the limb arterial tree were obtained from preoperative duplex scanning (using

Figure 1



Plain radiography anteroposterior and lateral view, showing supracondylar fracture of the humerus.

Philips Affinity 50 G ultrasound machine with L12–4 MHz linear probe).

The procedures were performed in an operating room containing the duplex machine, and fluoroscopic C Arm (Ziehm vision R, manufactured by Ziehm Imaging, Germany).

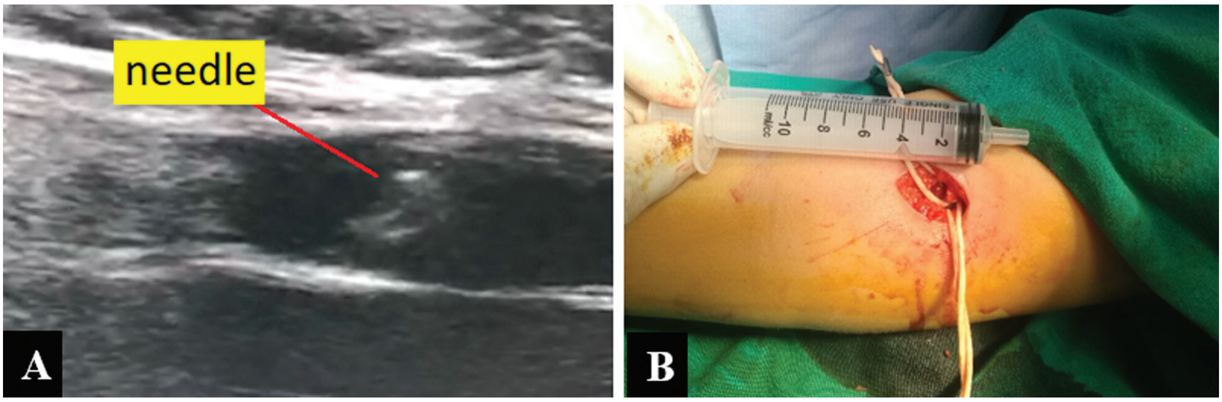
After the patients lie supine and skin preparation and draping, reduction and closed fixation of the fracture using wires was done by orthopedic surgeons. After fixation, clinical assessment of the color of the hand, as well as, the distal (radial and ulnar) pulse was performed by vascular surgeons. In case of absence of distal pulse with preservation of the pink color of the hand, the following was performed.

For group (A)

In situ conventional angiography was performed at the same setting. Arterial access to palpable-pulse brachial arterial segment at higher level than the fracture site was carried out using either percutaneous approach, with the help of duplex, in older children (Fig. 2a) or open approach using small skin incision and with the help of magnifying loops in younger children (Fig. 2b). Arterial access was done by different pore cannula (20, 22, and 24 G) according to the age of the patient and the arterial diameter assessed by duplex.

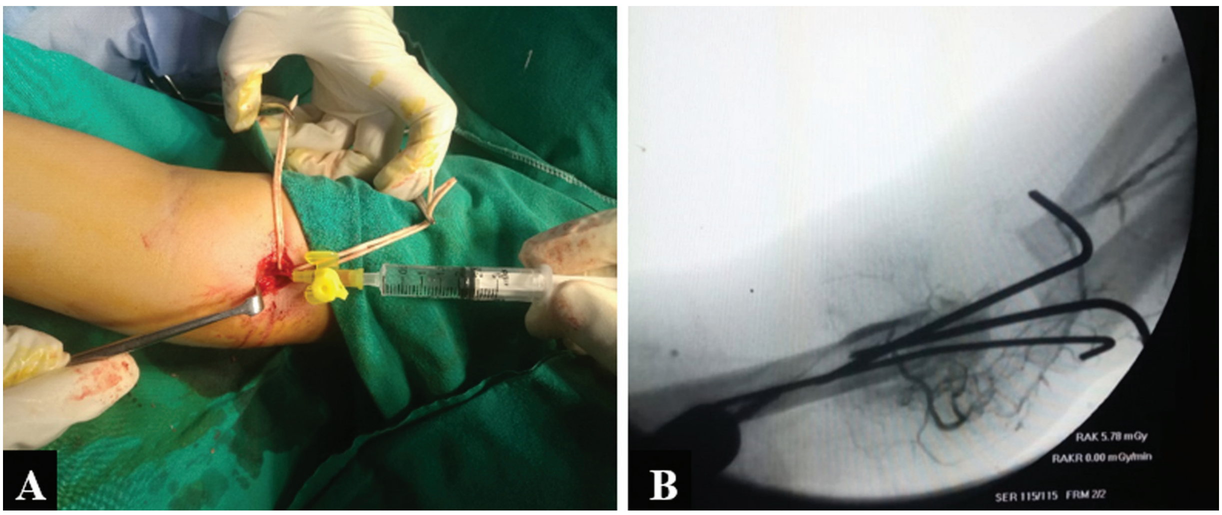
After choosing the suitable pore cannula to access the brachial artery, we performed diagnostic angiogram using low-osmolar iodinated contrast material to assess the condition of the arterial tree (Figs 3 and 4).

Figure 2



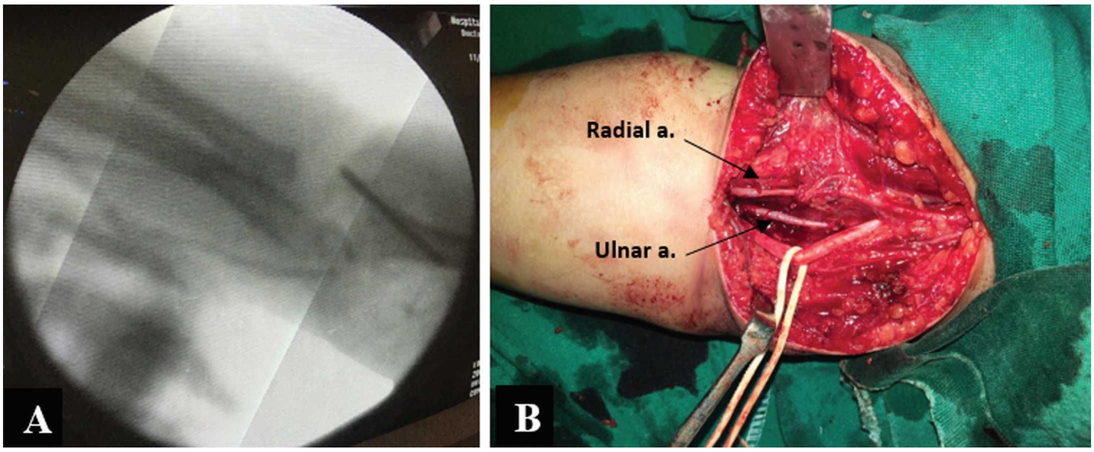
(A): Percutaneous brachial artery access. (B): open brachial artery access.

Figure 3



(A): Injection of contrast material inside the brachial artery. (B): Abrupt interruption of the contrast at the fracture site with reconstruction of distal vasculature through small collaterals.

Figure 4



(A): Diagnostic angiogram is showing filling of ulnar a. separately. (B) Showing high bifurcation of brachial artery upon exploration, which was suspected with pre-exploratory angiogram.

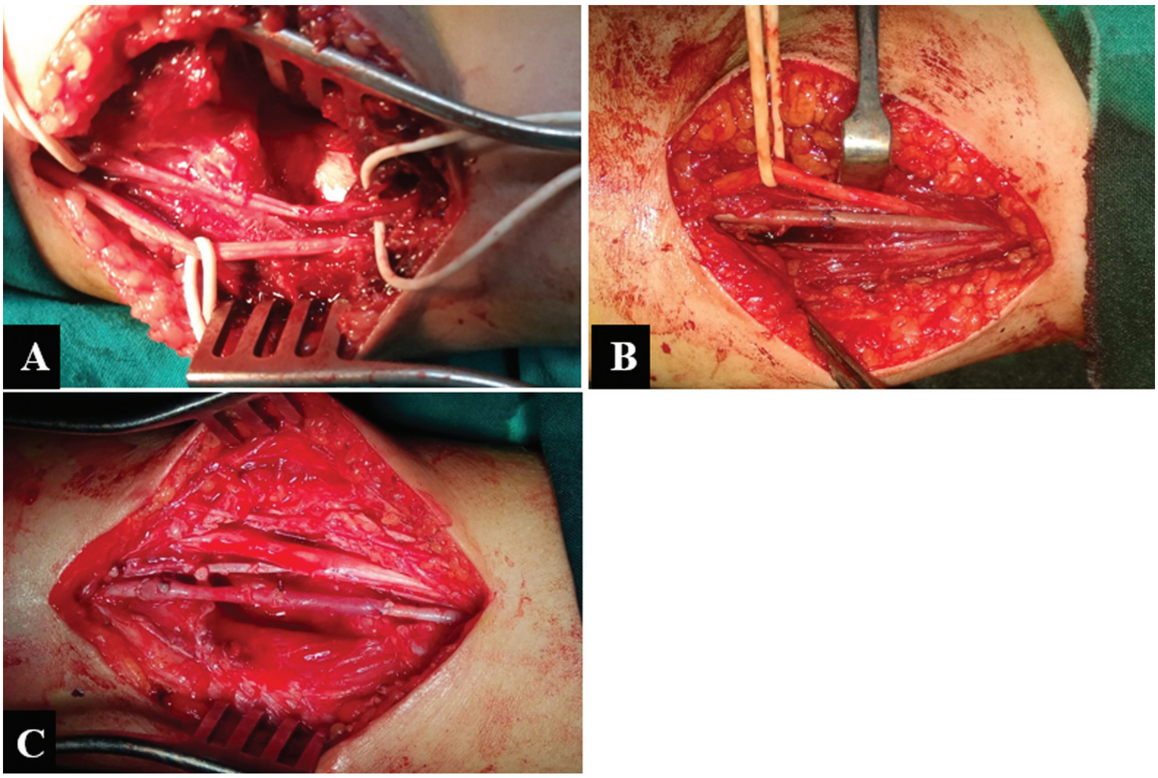
In case of established diagnosis for arterial insult (entrapment, transection or intimal contusion and thrombosis); exploration of the artery at the level of arterial injury and repair was done either by release (Fig. 5a), primary repair (Fig. 5b) or using interposition vein graft harvested from the ipsilateral basilic vein (Fig. 5c), respectively.

In case of intact spastic arterial tree, intra-arterial papaverine was injected with a dosage of 1 ml, 0.12 mg/ml.

Completion angiogram was done to assess the arterial repair or spasm relief (Fig. 6).

Clinical assessment of the distal (radial and ulnar) pulse was done after arterial repair or few minutes later after papaverine injection. In cases with open arterial access or extension of the incision for arterial repair, the wound was closed in layers with no drain. In cases with percutaneous arterial access with no need for arterial exploration, duplex guided compression was done.

Figure 5



(A): Brachial artery entrapment in the fracture site. (B): Resection of contused arterial segment and primary repair. (C): Repair using interposition vein graft.

Figure 6

Completion angiogram demonstrating intact arterial tree after repair.

For group (B)

Patients were conservatively followed-up for the return of radial and ulnar pulses within 12 h postoperatively. In cases with failure to regain distal pulse, arterial exploration of the brachial artery was performed after performing CTA to confirm the diagnosis of arterial injury (Fig. 7).

For group (A) and (B)

The limb was then supported by above elbow slab in semiflexion position.

Repeated checking for the distal pulse, early postoperatively, was done. The patients who have undergone arterial repair were discharged on prophylactic antiplatelets (aspirin 75 mg/day) for 2 weeks.

Follow-up visits

Visits were scheduled in the outpatient clinic within 2 weeks after the procedure and every one month thereafter for a period of 3 months. Patients underwent clinical assessment for the distal pulse and any signs of ischemic contracture. Also duplex scan for assessment of the patency of repaired arteries, as well as, the peak systolic velocity (PSV) in radial and ulnar arteries.

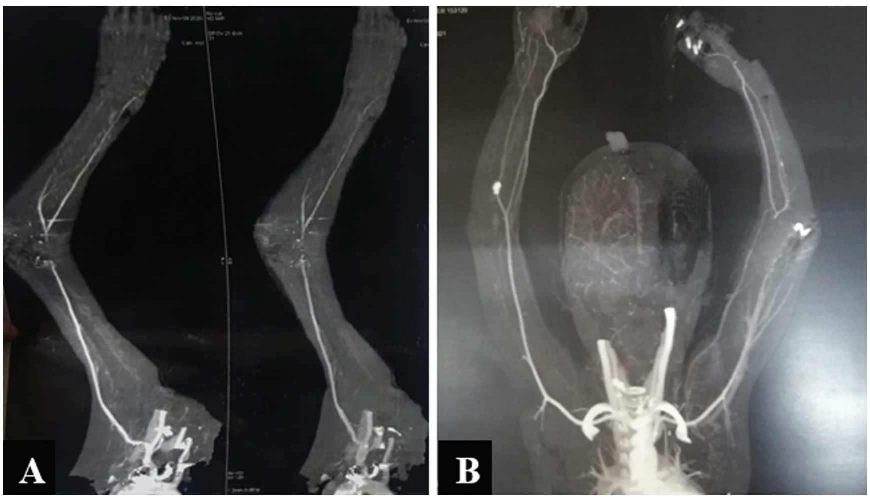
Statistical analysis

The collected data were organized, tabulated and statistically analyzed using Statistical Package for The Social Sciences (SPSS) version 26 manufactured by SPSS, international Business Machines (IBM) company, United States of America. Quantitative variable were present as mean and standard deviation (SD) and compared between the two groups utilizing unpaired Student's *t*- test. Qualitative variables were presented as frequency and percentage (%) and were analyzed utilizing the χ^2 test or Fisher's exact test when appropriate. A two tailed *P* value less than 0.05 was considered statistically significant.

Results

During the study periods, a total number of 80 children (30 for group A and 50 for group B) (52 males) with mean age 6.4 years ±2.73 (ranged between 3 and 14 years). All fractures were closed, isolated SFH with no associated ipsilateral fractures. The demographic data

Figure 7



(A and B): multiple computed tomography angiography demonstrating interruption of the contrast in the brachial artery at the level of the fracture site.

were insignificantly different between both groups as illustrated in Table 1.

As shown in Table 2 the mean total operative time of the procedure was significantly different between both groups in the favor of group (A) (P value <0.001). The number of anesthesia session in group (B) was significantly higher than that of group (A). In group (B), 10 (20%) cases had single session of anesthesia for reduction and fixation of SFH and regained pulse within 12 h postoperatively, 13 (26%) cases older than 8 years could perform CTA without anesthesia, however, they were submitted to second session of anesthesia for vascular reconstruction. Twenty seven (54%) cases under the age of 8 had second session of anesthesia to perform CTA and another third session

Table 1 Demographic data

Demographic data	Group (A) *n* ~30	Group (B) *n* ~50	*P* value
Age (years)	6.47±2.76	6.74±2.73	0.667
Sex			
Male	18 (60%)	34 (68%)	0.468
female	12 (40%)	16 (32%)	
Mode of trauma:			
Falling to the ground on outstretched hand	14 (47%)	27 (54%)	0.27
Falling from height	7 (23%)	5 (10%)	
Road traffic accident	9 (30%)	18 (36%)	
Time of presentation (hours)	3.7±1.8	4.2±1.9	0.106
Distal capillary refill (seconds)	3.4±1	3.7±1	0.277
Grade of fracture			
Grade III	17 (57%)	22 (44%)	0.273
Grade IV	13 (43%)	28 (56%)	

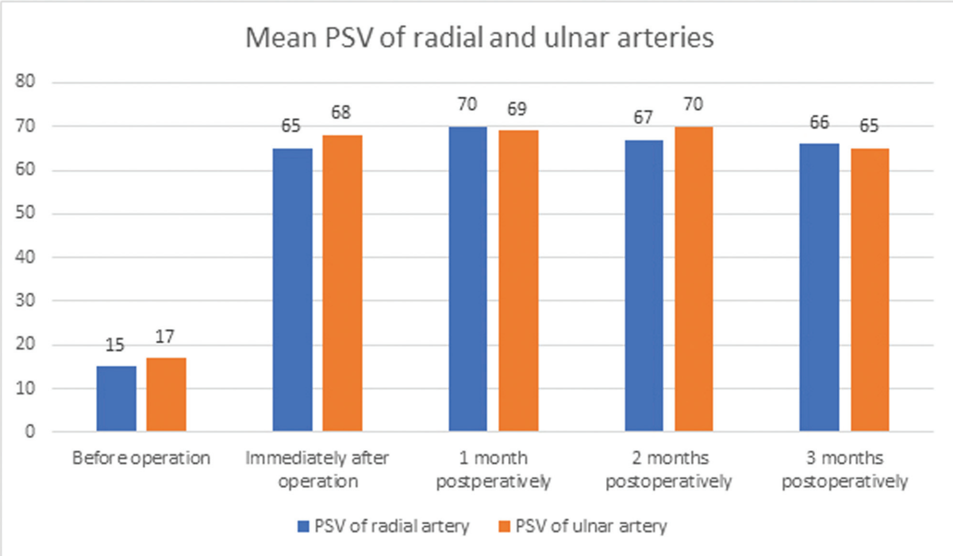
Data are presented as mean±SD or frequency.

Table 2 Operative results

Operative data	Group (A) *n*~30	Group (B) *n*~50	*P* value
Operative time (min)			
First procedure	88.5±36.1	42.3±6.4	<0.001*
Second procedure	–	84±32.32	
Total operative time (min)	88.5±36.1	126.28±38.7	
Diagnostic CTA	–	40 (80%)	<0.001*
In situ conventional angiography	30 (100%)	–	
Percutaneous access	6 (20%)	–	<0.001*
Open access	24 (80%)	–	
Number of anesthesia session	1±0	2.34±0.79	<0.001*
Type of arterial injury:			
Brachial artery entrapment	8 (27%)	9 (18%)	0.936
Complete transection	2 (7%)	3 (6%)	0.714
Intimal contusion and thrombosis	13 (43%)	28 (56%)	0.396
Arterial spasm	7 (23%)	10 (20%)	0.517
Management:			
Conservative	0	10 (20%)	<0.001*
Papaverine injection	7 (23%)	0	<0.001*
Release from entrapment site	8 (27%)	9 (18%)	0.936
Primary arterial repair	5 (17%)	11 (22%)	0.482
Using of interposition vein graft	10 (33%)	20 (40%)	0.577
Postoperative complications:			
Mortality	0	0	–
Post ICU admission	2 (7%)	3 (6%)	0.905
Wound dehiscence	1 (3%)	2 (4%)	0.857
Associated median nerve injury	0	9 (18%)	<0.001*
Hospital stay (days)	2.5±1	6±2	<0.001*
Limb salvage	30 (100%)	50 (100%)	–

Data are presented as mean±SD or frequency. Significant as P value less than or equal to 0.05. CTA, Computed tomography angiography; ICU, intensive care unit.

Figure 8



Mean peak systolic velocity of radial and ulnar arteries.

for arterial repair. The duration of hospital stay was significantly lower in group (A), while the associated median nerve injury was significantly higher in group (B).

Follow-up visits showed primary patency rate of 100% at the end of the 3 months follow-up. PSV was estimated for both radial and ulnar arteries before, immediately after the procedure and during follow-up visits (Fig. 8). Results show statistically significant difference between values before and after the procedure (*P* value was 0.003). However, there was no statistically significant difference between values during follow-up visits.

Discussion

Up to date, there is no consensus has been established regarding the management of pink, warm, pulseless hand in pediatric SFH. The surgical vascular exploration in such cases is controversial.

Some authors believe that vascular vasospasm in pediatrics is intense and may take up to 24–48 h to resolve [4]. Moreover, the chances of developing thrombosis in a kinked vessel in children are relatively lower than those in adults [8]. In addition, surgical exploration may damage the collaterals that may be crucial for a viable extremity [9]. Also, postoperative re-occlusion following arterial repair in children is common [5]. According to the previously mentioned factors, some studies have reported that open surgical exploration of the brachial artery is not required for cases of pink, pulseless hand [4,5,10,11]; reserving vascular exploration to those with evident signs of ischemia (pale or cyanotic pulseless hand) [12,13].

On the contrary, other studies reported that the absence of distal pulse in SFH is a strong indicator for arterial injury [6]. The collaterals around the elbow in pediatrics are variable, and the success rates of brachial artery exploration are encouraging. Long-term sequelae of prolonged relative ischemia such as Volkmann's ischemic contracture is considered catastrophic [7]. Therefore, early surgical exploration of the brachial artery is recommended by those studies.

In our study male sex represented 65% of cases, however it was of no statistically significance. The mean age in the study was 6.4 years±2.73.

There was no statistically significant difference between group (A) and group (B) regarding the mode of trauma. Half of our patients (51%) had injury while falling on the outstretched hand during a sporting activity, bicycle accident or even slipping at home. In 34%, the fracture was caused by road traffic accidents, while falling from height caused 15% of cases.

Grade III fracture was relatively more in group A (57%) than group B (44%). On the contrary, grade IV fracture was present in group B (56%) more than group A (43%). However, there was no statistically significance between both groups. There was no vascular injury with grade I or II SFH in either groups. Correspondingly, Usman R. *et al.* [14] reported vascular injury was caused by grade III (18%) and IV (82%) fractures. Perez JM. *et al.* [15] reported vascular injuries with grade II and III fractures.

In our belief, we agree with Vu. TN. *et al.* [16] that observation of such cases of pink, pulseless hand in SFH will cause prolonged hospital stay and increase the implementation of different diagnostic modalities (Doppler ultrasound and multi-slice computed tomography angiography (CTA)); of which application is not easy for pediatrics. Anesthesia should be used to ensure safety and efficacy of these measures, hence increasing the risk of complications from repeated anesthesia. In group (B) in our study, 27 (54%) cases under the age of 8 required second session of anesthesia to perform CTA. Also, we do not believe in routine vascular exploration for these cases. The fear from wound complications, moreover the complications from vascular exploration especially when it comes to negative exploration (due to vascular spasm), enforces the surgeon to think twice before proceeding.

In this study, we applied same session, intraoperative, in situ conventional angiogram in group (A) patients to minimize the duration of the treatment, the required sessions of anesthesia and their possible complications, and to avoid consumption of medical resources (by repeated duplex scanning or performing CTA). Angiogram could provide an absolute, precise intraoperative diagnosis of presence of arterial injury, which would provide the optimum decision for arterial exploration in the same setting of fracture fixation and thus avoiding the need for repeated anesthesia required for separate procedures. Also, it could provide intraoperative evidence of presence of arterial spasm with no anatomical disruption of the arterial tree, as well as the modality to manage it by intra-arterial injection of papaverine, unless this was associated with another lesion such as arterial entrapment. This would help to avoid negative vascular exploration with the possible complications.

In group (A) with performing in situ conventional angiography in the same setting of fracture fixation; arterial spasm was found in 7 (23%) cases. Exploration could be avoided and the treatment was intra-arterial injection of papaverine via the same brachial access used for performing the angiogram; a few minutes later, they all regained distal pulse on table. The angiogram of the other 23 (77%) cases showed brachial artery injuries as follow, entrapment in the fracture site was found in 8 (27%) cases that required dissection and release with no further arterial repair. Two (7%) cases suffered complete brachial artery transection in road traffic accidents that required repair with interposition vein graft. Thirteen (43%) cases had intimal contusion and thrombosis, 5 (17%) of them underwent resection and primary repair while 8 (27%) cases required interposition vein graft due to long segment of contusion. In group (B), after fracture fixation and still no radial or ulnar pulses, follow up of the patients with conservative prophylactic IV anticoagulants and vasodilators was done up to 12 h. Ten (20%) patients regained distal pulse denoting arterial spasm to cause the vascular pathology. Forty (80%) patients failed to regain distal pulse, so diagnostic CTA was performed and showed brachial artery injury. Upon exploration to the 40 cases, 9 (18%) cases showed brachial artery entrapment and underwent release from the fracture site. Three (6%) case had complete transection of the brachial artery and required repair with interposition vein graft, while 28 (56%) cases had intimal contusion and thrombosis; of which 11 (22%) cases were managed by resection and primary repair, while 17 (34%) cases required repair with interposition vein graft.

There was no perioperative mortality in either group (A) or group (B). Two cases from group (A) and 3 cases from group (B), after road traffic accident, were admitted to ICU postoperatively. The limb salvage rate was 100% in both groups. Nine (18%) cases in group (B) suffered median nerve injury (sensory) due to delay in the diagnosis of neurovascular entrapment at the fracture site, however they showed improvement of the limb function later in the follow-up visits. These results were corresponding to the limb salvage rate reported by Usman R. *et al.* [14] (100% limb salvage). Similar results were also reported by Vu TN. *et al.* [16], although they reported 1 case of immediately postoperative embolism, 2 cases of superficial infection and 2 cases of temporary loss of sensation around the incision 1 month after the surgery. Also, Luria S. *et al.* [17] reported 5 out of 24 cases (21%) had signs of median nerve deficit.

In our study, group (A) had single procedure with one-time anesthesia exposure; while in group (B) 40 (80%) cases had 2 separate procedures with, at least, double exposure to risk of anesthesia [27 (54%) cases under the age of 8 required sedation while performing CTA, hence they were subjected to three sessions of anesthesia]. Also, there was significant difference between both groups regarding hospital stay in the favor of group (A).

Some studies [15,17–19] reported conventional angiography as an important tool in accurate diagnosis of vascular lesion regarding nature and extend of the lesion, assisting the surgeon in planning the arterial reconstruction. Other authors [20–22] believe that angiogram is not necessary not only because the arterial lesion is located at the fracture site, but also due to the adverse effect to the contrast material as well as the access site complications.

In group (A) we performed conventional angiography through direct brachial arterial access that is just proximal to the fracture site with suitable pore cannula to minimize access site complications. In 6 (20%) cases aged between 10 and 14 years percutaneous arterial access was able to be performed with the help of duplex machine, while in 24 (80%) cases aged between 3 and 8 years open access was performed through small skin incision with the help of magnifying loops. In cases of vascular spasm, even with open access to perform an angiogram, exploration of the arterial segment at the fracture site was avoided. Thus minimizing wound complications increased by the fracture hematoma, bone osteomyelitis, furthermore complications from arterial exploration (destructing surrounding collaterals and possible arterial thrombosis).

Perez JM. *et al.* [15] had performed traditional conventional angiogram in 5 out of 11 patients in their study. Only one of them had pink, pulseless hand that went ischemic after fracture fixation; while the remaining 4 cases had ischemic, pulseless hand. They managed a case with spasm following entrapment by exploration, release from entrapment site and papaverine injection; while 3 cases with spasm and 1 case with intimal dissection were all managed by bypass with saphenous vein.

Luria S. *et al.* [17] also recommended intraoperative angiography as a simple and rapid procedure that may aid in the planning of the vascular surgical procedure and may prevent un-necessary exploration of the brachial artery in cases of arterial spasm. However, they performed a limited number of conventional angiography (only 6 out of 11 patients with 5 cases underwent vascular exploration without angiogram). Two of the six cases underwent a formal angiography in the angiography suite, using a port inserted at the femoral artery (although they recommended against formal angiography as it would cause a delay even when performed efficiently). The remaining 4 (out of six) angiographies were performed intraoperatively with limited exploration of the brachial artery in the distal arm. They also, reported a case (out of the 5 nonangiogram performed cases) with arterial spasm that went negative exploration which could have been diagnosed with conventional angiography and exploration could have been avoided. Another case with intact artery that went exploration without conventional angiography based on Doppler misdiagnosis of arterial tear was complicated postoperatively with wound infection and osteomyelitis in distal humerus.

Conclusion

We believe that in situ conventional angiography is the most appropriate, accurate and rapid diagnostic tool to define the lesion and plan the procedure in pediatrics with pink, warm, well perfused pulseless hand associated with SFH. It has many advantages over the traditional wait and see strategy (less frequency of anesthesia, avoiding negative exploration, less operative time and hospital stay, better functional activity of the limb in follow-up)

Limitation of the study

The number of cases in the current study was smaller than those in other studies because of the focus on the cases with pink, pulseless hand only as we excluded cases who regained peripheral pulse after reduction and fixation of the fracture. Also we excluded the evidently ischemia cases that were included in other studies.

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Nil.

Conflicts of interest

No potential conflict of interest was reported by the authors.

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