Original article

Predictive factors determining outcomes in pulseless limb in paediatric supracondylar fractures of humerus

Hemant Chaturvedi^a, Vikram Khanna^{b,*}, Rakesh Bhargava^a, Raju Vaishya^c^a Department of Orthopaedics, National Institute of Medical Sciences, Jaipur, India^b Department of Orthopaedics, Ranjana Hospital, Allahabad, India^c Department of Orthopaedics, Indraprastha Apollo Hospital, New Delhi, India

ARTICLE INFO

Article history:

Received 20 February 2017

Received in revised form 5 May 2017

Accepted 21 October 2017

Available online 31 October 2017

Keywords:

Supracondylar fracture humerus

Mayo elbow performance score

Flynn criteria

Pulseless limb

Gartland classification

ABSTRACT

Introduction: Amongst all the complications associated with paediatric supracondylar humerus fractures, significant vascular injury is reported in only 1% cases, of which, less than 1% develop Volkmann's ischemic contracture. This study evaluates factors, like delay in presentation of the injury, limb perfusion and pulse, in determining functional outcome in a supracondylar humerus fractures with pulseless limb. **Materials & methods:** Twenty-one paediatric patients with a pulseless supracondylar humerus fracture presenting from 2012 to 2014 were included. The patients were divided into 3 groups with Group A (pulse returned post-reduction, n = 13), Group B (pink pulseless hand, n = 7) and Group C (white pulseless hand, n = 1). 11 patients in group A and 4 patients in Group B presented within 6 h. of injury while the remaining patients presented after 6 h. The primary outcome was vascular status as indicated by radial pulse and perfusion, and secondary outcomes included functional parameters assessed with Mayo Elbow Performance Score and Flynn criteria.

Results: Mean peripheral SpO₂ in Group A patients was higher than Group B and Group C had a non-recordable oxygen saturation. Mean capillary refill time was more in Group A than Group B whereas in Group C patient had blanching and no capillary refill was seen. Mean Mayo Elbow Performance Score of Group A patients was highest as compared to Group B and Group C. Patients presenting within 6 h. of injury had a higher mean Mayo Elbow Performance score as compared to the patients presenting after 6 h of injury. Functional outcome as measured by Flynn Criteria was excellent in 13 patients. 6 patients had a good, 2 had fair outcome. A moderate negative correlation ($R = -0.5798$) was seen between the time elapsed from the injury and the Mayo Elbow Performance score.

Conclusion: Duration to presentation since injury, limb perfusion and presence of peripheral pulses seem to be important predictive factors determining the outcomes in pulseless supracondylar fracture humerus.

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1. Introduction

Supracondylar fracture of humerus is the most common elbow fracture in children.^{1,2,3} This fracture pattern is common in the 1st decade of life^{4,5} due to various causes, of which main is ligament laxity and anatomical structure of humerus tube (shaft) to flat transformation at the lower end of humerus. Of all the complications associated with supracondylar fractures, nerve injury ranks highest. Nerve injury in supracondylar fracture humerus occurs in 7% cases and significant vascular injury is seen in 1% cases,⁶ of which less than 1% develop Volkmann's ischemic

contracture. It is necessary to have a high index of suspicion, to avoid missing an impending compartment syndrome, especially in cases with a concomitant median nerve injury or a forearm fracture, as these may mask symptoms of compartment syndrome.

An absent radial pulse is no indication for surgery in the presence of good capillary circulation. Patients with vascular compromise may present with a peripheral pulselessness which often recovers after fracture reduction. Immediate angiography is not indicated for a pulseless limb, as it delays fracture reduction, which usually corrects the vascular problem.⁷ This results in either a return of the pulse or a "pink pulseless hand" with an absent peripheral pulse but good perfusion. Patients in which the pulse doesn't return and have a poor perfusion, result in a "white pulseless hand". Peripheral perfusion of the limb can be assessed

* Corresponding author.

E-mail address: 86.khanna@gmail.com (V. Khanna).

by comparing the hand colour, capillary refill time and peripheral SpO₂, with the normal side.

Patients with the return of the peripheral pulses post-reduction of the fracture, have excellent prognosis and are treated with a standard post-operative protocol as defined for patients with supracondylar humeral fractures without any neurovascular deficit. Patients with a perfused or pink pulseless hand also have a very good prognosis and generally require a strict postoperative monitoring. A white pulseless hand requires an intraoperative duplex ultrasound or a vascular consult or an urgent but not an emergent exploration.

Several factors are thought to predict and determine the immediate, and long term outcomes in patients with a pulseless limb in supracondylar fracture humerus but with an inconclusive evidence. This study evaluates the predictive factors, like duration to presentation of injury, limb perfusion and peripheral pulselessness in determining outcomes in a pulseless limb in supracondylar fractures of humerus in children.

2. Materials & methods

Twenty-one patients, between the ages of 5–14 years, with a closed pulseless supracondylar humerus fracture presenting to the emergency services and outpatient department of a tertiary care center in Jaipur during the period from January 2012 to January 2015 were included in this study.

Patients coming with closed supracondylar fracture of humerus without any pulse were included in this study. Patients who did not give any consent, open fractures, concomitant injuries, any nerve injury and patients not willing for follow up for the desired period were excluded from the study. After an informed consent all the patients were assessed clinically with special reference to the neurovascular status of the involved limb. Post-traumatic swelling and any visible deformity at the elbow was carefully assessed. All peripheral pulses were palpated, preferably radial pulse. Hand colour, peripheral SpO₂ and capillary refill time, were compared to the normal side to determine the perfusion of the limb. These modalities were assessed by the third author to avoid any bias or any variation. SpO₂ was measured by the pulse oximeter and the capillary filling time was assessed by seeing the blanching of the nail bed and measuring the time. Antero-posterior and lateral view skiagrams of the affected elbow were taken. The X-Rays were assessed regarding the type of fracture and the degree of displacement based on Gartland classification.⁸

Treatment was done according to the following protocol (Fig. 1). An immediate closed reduction and percutaneous cross pinning was done followed by an above elbow slab in 30° less than full extension. Following 20 min' post-reduction, peripheral pulse was

again checked and hand colour, peripheral SpO₂ and capillary refill time, was compared to the normal side, for dividing the patients into 3 groups. Group A (pulse returned post-reduction, n = 13), Group B (pink pulseless hand, n = 7) and Group C (white pulseless hand, n = 1). Group A patients were given standard post-operative care. Group B patients were carefully monitored for the next 48 h in the post-operative ICU while in Group C patient, arterial patency was assessed on duplex ultrasound and surgical exploration was done. On exploration, brachial artery was found entrapped between the fractured ends which was subsequently released and was strictly monitored postoperatively. 11 patients in group A and 4 patients in Group B presented within 6 h. of injury while the remaining patients presented after 6 h. of injury. The reduction, surgery and the assessment of the vascular status was done by the same doctor.

Group A and Group B patients were discharged after 4–5 days and Group C patient was discharged after 7 days, after a post-operative clinical examination for swelling, arterial injury, finger movements and nerve injury and review of the radiographs with instructions on cast care and elevation. The reason for a comparatively longer hospital stay was precautionary as we did not want the children to travel since our hospital was quite far from the city. The child's parents were advised to watch out for any swelling, discoloration of fingers and report immediately, if any, did occur.

Follow Up

2nd week:	2 weeks after the operation, the child was clinically examined for swelling, pulse, peripheral perfusion, infection, loosening of pins, finger movements and status of the nerves.
4th week:	Four weeks after the operation, the above elbow slab and pins were removed and clinical and radiological assessment of the fracture was done. The patients were encouraged to begin with gentle active mobilization of the elbow and strictly advised against any massage, heat or forced passive mobilization. Lifting of heavy weight was not allowed.
6th week:	AP and lateral X-rays were taken to verify progress of union and range of motion of elbow was assessed. Group C patient was subjected to active and assisted physiotherapy to prevent elbow adhesions and fibrosis.
12th week:	Evaluation of range of motion and any deformity.
24th week:	At the final follow-up, clinical assessment of change in carrying angle (Flynn's Criteria) was done along with range of flexion-extension and pronation-supination. AP and lateral view X-Rays of the affected as well as the normal elbow were taken and assessed regarding union, carrying angle, Baumann's angle and Metaphyseal-diaphyseal angle. The Mayo Elbow Performance Score was calculated in all the cases.

The primary outcome was measured in terms of vascular status of the limb both immediate and long term as indicated by radial pulse and perfusion, and secondary outcomes included functional parameters assessed with Mayo Elbow Performance Score⁹ and Flynn criteria¹⁰.

3. Results

In this study, of all the 21 patients presenting with paediatric supracondylar fracture humerus, 16 were males and 5 were females. The mean age at presentation was 7.6 years. 66.7% patients presenting with pulseless limb had fractured their non-dominant extremity. The most common mode of trauma was fall from height accounting for 81% of the patients. Group C patient suffered a road traffic accident. Post-reduction of the fracture, a return of peripheral pulse was seen in 13 patients. 7 patients presented with a perfused pulseless hand and only 1 patient presented with a white pulseless hand. All the patients suffered from Gartland Type III supracondylar fracture extension type.

Fig. 1. Treatment protocol followed in the management of pulseless supracondylar fracture.¹⁹

71.4% patients presented within 6 h. of injury. 11 patients in group A and 4 patients in Group B presented within 6 h. of injury while the remaining patients presented after 6 h. of injury. Pulse returned in 61.9% patients post reduction. Post-reduction pink colour hand was seen in 95.2% cases while white hand was seen in 4.8% cases.

Post-reduction all patients in Group A and Group B had a pink hand. Mean peripheral SpO₂ after fracture reduction in Group A patients was 97.0% and in Group B patients was 94.7%. Group C patient had a non-recordable peripheral oxygen saturation even after reduction. Mean peripheral oxygen saturation in patients presenting within 6 h of injury 97.0% while the patients presenting after 6 h. of injury had a mean peripheral oxygen saturation of 78.2%. 11 patients presenting in group A in less than 6 h of injury had a mean peripheral oxygen saturation of 97.4% seconds and the remaining 2 patients who presented after 6 h of injury had a mean peripheral oxygen saturation of 95.0%. 4 patients in Group B presenting within 6 h of injury had a mean peripheral oxygen saturation of 96.0% and remaining Group B patients had a mean peripheral oxygen saturation of 93.0%.

Mean capillary refill time in Group A patients was 1.5 s while the mean capillary refill time in Group B patients was 1.9 s. Group C patient had blanching and no capillary refill was seen. Patients presenting within 6 h of injury had a mean capillary refill time of 1.4 s while the patients presenting after 6 h. of injury had a mean capillary refill time of 2.4 s. 11 patients presenting in group A in less than 6 h of injury had a mean capillary refill time of 1.4 s and the remaining 2 patients who presented after 6 h of injury had a mean capillary refill time of 2.5 s. 4 patients in Group B presenting within 6 h of injury had a mean capillary refill time of 1.5 s and remaining Group B patients had a mean capillary refill time of 2.5 s.

The final functional outcome was measured by Mayo Elbow Performance Score and Flynn criteria. Mean Mayo Elbow Performance Score of Group A patients is 96.2. Patients in Group B had a mean Mayo Elbow Performance Score of 94.3 while the Group C patient had a mean Mayo Elbow Performance score of 80. Patients presenting within 6 h. of injury had a mean Mayo Elbow Performance score of 96.3 as compared to the patients presenting after 6 h of injury who had a mean score of 90.8. Group A patients presenting within 6 h. of injury had a mean Mayo Elbow Performance Score of 96.8 while those presenting after 6 h. had a mean score of 92.5. Patients in Group B presenting within 6 h. of injury had a mean Mayo Elbow Performance score of 95.0 while those presenting after 6 h. had a mean score of 93.3. No patient in Group C presented within 6 h. of injury. Group C patient presenting after 6 h. of injury had a mean Mayo Elbow Performance Score of 80 [Table 1].

Table 1
Comparison of final functional outcome and limb perfusion among different study groups.

	No. of patients	Mean SPO ₂	Mean CPT	Mean Mayo Elbow Performance Score
<6 h	15	97	1.4	96.3
>6 h	6	78.2	2.4	90.8
Group A	13			
<6 h	11	97.4	1.4	96.8
>6 h	2	95	2.5	92.5
Group B	7			
<6 h	4	96	1.5	95.0
>6 h	3	93	2.5	93.3
Group C	1			
<6 h	0			
>6 h	1	Not Detectable	Not Detectable	80
Total Pts.	21	91.6	1.65	94.8

Functional outcome as measured by Flynn Criteria was excellent in 13 of the total 21 patients. 6 patients had a good, 2 had fair while none of the patients had a poor outcome. 77% of Group A patients had an excellent outcome while 23% had a good outcome with none of the Group A patient having a fair or poor outcome. 42.9% of the Group B patients had an excellent and good functional outcome each and 14.2% patients had a fair functional outcome while none of the patient had a poor outcome. The Group C patient had fair functional outcome. 73% of the total patients presenting within 6 h of injury had an excellent functional outcome while the remaining 23% patients had a good functional outcome. Of the 6 patients presenting 6 h. after injury, 33% patients presented with excellent, 33% with good and the remaining with a fair functional outcome. 81.9% of the Group A patients presenting within 6 h. of injury had an excellent functional outcome while only 50% of the Group A patients presenting after 6 h of injury had an excellent functional outcome. In Group B patients, excellent outcome was seen in 50% of the patients presenting within 6 h of injury with remaining patients having a good outcome while only 33% of the patients presenting after 6 h of injury had an excellent functional outcome with 33% patients present with a good and fair outcome each. Group C had only 1 patient which presented 6 h. after injury and had a fair functional outcome [Table 2].

On calculating the degree of correlation between the time elapsed from the injury and the Mayo Elbow Performance score, using the Pearson's coefficient of correlation it was seen that there was moderate negative correlation (-0.5798). A moderate negative correlation (-0.5962) between time elapsed and Mayo Elbow

Table 2
Functional Outcome Based On Flynn Criteria.

	No. of patients	Excellent	Good	Fair	Poor
Total Pts.	21	13	6	2	0
<6 h	15	11	4	0	0
>6 h	6	2	2	2	0
Group A	13	10	3	0	0
<6 h	11	9	2	0	0
>6 h	2	1	1	0	0
Group B	7	3	3	1	0
<6 h	4	2	2	0	0
>6 h	3	1	1	1	0
Group C	1	0	0	1	0
<6 h	0	0	0	0	0
>6 h	1	0	0	1	0

Performance score was seen in group A as compared to the moderate negative correlation (-0.6535) found in Group B. In group C there was only 1 case hence, there was no means of calculating the correlation coefficient.

On finding the association between the functional outcome as devised by Flynn scoring and the Mayo Elbow Performance score it was seen that there was no significant difference in between the two.

4. Discussion

This study shows the outcome of the vascularly compromised supracondylar fracture of humerus in paediatric patients. Supracondylar fracture of the humerus commonly occurs in the age group of 1–15 years with greatest frequency between 3 and 8 years (Mitchell and Adams).¹¹ Wilkins,¹² reviewing data from 61 major series comprising a total of 7212 fractures around the elbow, found the mean age of incidence to be 6.7 years. In this study the mean age of presentation was found to be 7.6 years.

Supracondylar fracture of humerus occurs more commonly in males. Edmann and Lohr¹³ in their series of 161 fractures reported that 71% were males. Even in this study the majority of the cases (16 out of 21) were found to be males.

Supracondylar fracture more commonly involves the non-dominant side (usually left). Edmann and Lohr¹³ found that the reason for this is that the left arm is more often used for protective movements, used less skilfully, and is weaker muscularly in right handed persons. About 66.67% cases in this study consisted of fracture of the non-dominant side.

Brian P. Scannel¹⁴, evaluated paediatric patients who sustained a perfused, pulseless supracondylar humeral fracture and who had at least six months of clinical follow-up. Follow-up data were obtained for 20 of 36 patients with a Gartland type-III fracture who had been managed with closed reduction and percutaneous pinning. Five patients had a return of a palpable pulse in the operating room after closed reduction and percutaneous pinning. All twenty had a palpable radial pulse at the time of the latest follow-up, and all nerve palsies resolved. This study concluded that after an average of twenty months of follow-up, children with a perfused, pulseless supracondylar humeral fracture that had been treated with closed reduction, percutaneous pinning, and observation demonstrated a palpable distal radial pulse, normal growth of the arm, and good/excellent functional outcomes, although 5 of the 20 patients had an occluded brachial artery.

Wegmann¹⁵, studied 40 of 499 patients sustaining a supracondylar humeral fracture presenting with peripheral pulselessness and concluded that blood flow often recovers following reduction of supracondylar fractures with impaired peripheral vascularisation. In cases of a “pink pulseless hand” (absent peripheral pulse and good peripheral capillary refill time), “watchful waiting” instead of immediate surgical exploration might be a treatment option.

Soh¹⁶ & Ramesh P¹⁷ found that waveform using pulse oximeter was very sensitive and was an easily available modality to determine the vascularity and proved to be very helpful in deciding whether or not to go for brachial artery exploration or not. In this study it was seen that SpO₂ measured by the pulse oximeter was helpful in the post reduction period to decide whether or not to go for brachial artery exploration.

Weller et al.¹⁸ in their retrospective study assessing the necessity of operating in all cases of vascular compromise found that it was not necessary for all patients with absent radial pulse to undergo arterial exploration if other factors like Doppler signal and capillary filling time was normal. In the present study we have used the help of pulse oximeter along with capillary filling time and we have found them to be useful in assessing the requirement

of vascular exploration as well as clinical outcome. We also see that the clinical outcome depends also on the time elapsed between the fracture and treatment.

Vascular insufficiency may be one of the most devastating complications of supracondylar fracture humerus if not managed or intervened in the correct manner. These complications arise in case of mismanagement or neglect in vascular insufficiency in cases of supracondylar fractures. This may manifest as decrease in the functional outcome or may manifest in some cases as VIC or may in severely neglected cases may undergo necrosis. An algorithmic approach was used for management of all the cases included in this study.¹⁹ The treatment and the rehabilitation protocol followed was similar in all the cases. All the observations and interventions were done by a single surgeon to avoid any inter-observer variation.

The functional outcome was assessed using the Mayo Elbow Performance score and the Flynn criteria at the end of 6 months after the patient followed strict physiotherapy and regular follow-up which was done to observe the progress of the recovery. The Flynn criteria is based on the change in the carrying angle and also the degree of loss of range of motion of the elbow joint. Since the vascular insufficiency is associated with decrease in the muscle function due to muscle ischaemia and subsequent fibrosis, the outcome was assessed using functional outcome. The outcome was also judged clinically using the Flynn criteria which takes into account the change in the carrying angle and loss of degree of motion and hence gives an idea regarding the accuracy of reduction and the functional impairment due to any degree of malunion.

The degree of correlation calculated between the time elapsed from the injury and the Mayo Elbow Performance score in group A showed that there was a moderate negative correlation between the two suggesting that with the increase in the time elapsed after injury the functional outcome may decrease, suggesting that there might be a significance of the time elapsed from injury on the final functional outcome.

The degree of correlation calculated in group B also showed a slightly stronger moderate negative correlation than what was seen in group A which may indicate that in cases when the pulse returns after reduction of the fracture, delay in the treatment was less devastating, than that seen in cases when the pulse did not return. These findings may be significant but due to the small sample size the results may not be very conclusive. Furthermore, as the Mayo Elbow Performance score is also affected by the accuracy of reduction along with the degree of comminution and stability, this correlation might not be accurate. Further studies with a larger data are required to find the actual association between the time elapsed and the outcome.

This study also proves that the capillary filling time and the oxygen saturation are a better prognostic marker than the pulse. In both group B and C, the pulse was absent but the outcome was better in group B where the capillary filling and the oxygen saturation was relatively normal. This might be due to the uninterrupted vascular supply to the muscles from collaterals causing the muscles not to atrophy and hence giving a good functional outcome in the end. In group C where the capillary filling was impaired, the functional outcome was decreased even after open reduction and vascular intervention showing that there was certain degree of muscle death followed by fibrosis resulting in mild functional impairment.

The degree of functional outcome not only depends upon the muscle function but also the degree of malunion and the variation in terms of the amount of physiotherapy done by the patient. This study tried to rule out the confounding factor of the malunion with the help of the Flynn scoring system and the association found between Mayo Elbow Performance scoring and Flynn scoring was

not significant. All the patients were given a regular supervised physiotherapy to eliminate it as an important confounding factor in this study.

The only limitation of this study was the small sample size especially of Group C. However, only 1 patient came with the specifications required for Group C. Hence, further studies maybe required to assess the importance of the predictive factors for the outcome of supracondylar humerus fractures with vascular compromise.

5. Conclusion

This study has briefed with important predicting factors determining the successful management and the functional outcomes of the paediatric supracondylar fracture of the humerus presenting with pulseless limb, despite of a small sample size. Perfusion of the limb has proved to be a superior predicting factor in determining the outcome in patients with pulseless limbs. Peripheral pulses and time elapse between the injury and the treatment are other important factors, with peripheral pulses having lower significance as compared to the other perfusion markers like hand colour, peripheral SpO2 and capillary refill time. Functional impact of time lapse requires its inclusion in deciding the treatment algorithm for the management of pulseless limb in paediatric supracondylar fracture humerus. All these predicting factors need further evaluation with a large sample size to determine the significance of these factors.

Conflict of interest

None.

Source(s) of support

Nil.

Presentation at a meeting

Nil.

Acknowledgement

None.

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