Treatment of pink pulseless hand following supracondylar fractures of the humerus in children

A. V. Korompilias · M. G. Lykissas · G. I. Mitsionis ·
V. A. Kontogeorgakos · G. Manoudis · A. E. Beris

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Abstract Although acute vascular injury is a common complication in children with severely displaced supracondylar humeral fractures, the management of patients with a pink pulseless hand still remains controversial. Between 1994 and 2006, 66 children with displaced supracondylar fractures of the humerus were treated. Five patients had an absence of the radial pulse with an otherwise well perfused hand. In one patient, radial pulse returned after closed reduction of the fracture. In four patients, open reduction and vascular exploration was required. Three patients had brachial artery occlusion because of thrombus formation. Thrombectomy was performed, which led to the restoration of a palpable radial pulse. In one patient with open fracture, brachial artery contusion and spasm were found, and treated by removal of adventitia. Surgical exploration for the restoration of brachial artery patency should be performed, even in the presence of viable pink hand after an attempt at closed reduction.

Résumé Au cours d'une fracture supra condylienne du coude déplacée, les complications vasculaires sont relativement fréquentes. Le traitement, lui aussi, est largement controversé, notamment lorsqu'il existe une absence de pouls radial après la fracture. Entre 1994 et 2006, 66 enfants présentant une fracture supra condylienne du coude ont été traités. 5 présentaient une complication vasculaire avec absence de pouls radial. Chez un des patients, le pouls radial est réapparu après réduction à foyer fermé. Chez les 4

autres patients, il a été nécessaire de faire une réduction sanglante avec exploration vasculaire. 3 des patients avaient une occlusion de l'artère humérale. La thrombectomie a été réalisée avec restauration du pouls radial. Sur un patient, il s'agissait d'une contusion de l'artère brachiale avec spasme et une réapparition du pouls après endartérectomie. L'exploration vasculaire chirurgicale doit être réalisée même si la main se recoloré après une réduction à foyer fermé.

Keywords Supracondylar humeral fractures · Pink pulseless hand · Vascular compromise · Brachial artery · Neurovascular injuries

Introduction

Supracondylar fracture of the humerus is a common childhood injury, involving 17.9% of all fractures in children [4]. This type of fracture accounts for 55–80% of all fractures around the elbow joint and mostly occurs in children around 7 years of age [13]. They usually result from a fall on an out-stretched arm, forcing the humeral distal metaphysis into extension. These fractures rarely occur from falls with a flexed arm. In such fractures, both primary and secondary iatrogenic neurovascular lesions may occur. Acute vascular injury may be present in approximately 10% of children with supracondylar humeral fractures [22]. Brachial artery lesion may be secondary to various insults, such as entrapment, division, spasm of the vessel, the presence of an intimal tear or thrombus formation. On the other hand, the relative incidence of nerve injuries has been reported as being 12–20% [3, 7] and they mainly (86–100%) consist of neurapraxias, which usually resolve spontaneously [2, 3, 20].

A. V. Korompilias · M. G. Lykissas (✉) · G. I. Mitsionis ·
V. A. Kontogeorgakos · G. Manoudis · A. E. Beris
Department of Orthopaedic Surgery, School of Medicine,
University of Ioannina,
Ioannina 45110, Greece
e-mail: mariolyk@yahoo.com

Although the indications for exploration of the cubital fossa in the case of a pulseless, cool, white hand are clear, the management of patients with a pulseless but otherwise well perfused hand still remains controversial. The aim of this study was to ascertain an appropriate therapeutic approach in children with supracondylar humeral fracture and a pink yet pulseless hand in which a palpable radial pulse does not return after fracture reduction.

Materials and methods

We retrospectively reviewed displaced, supracondylar fractures of the humerus in 66 children with a mean age of 8.5 years (range; 2 to 14 years). Using Gartland's classification system, 35 patients (53%) had type II fractures and 31 patients (47%) had type III fractures (Fig. 1). There was a higher incidence in boys than in girls, with 38 boys and 28 girls treated in our hospital between 1994 and 2006. Of this overall sample, six patients (9%) had primary neurovascular complications diagnosed at the time of hospital admission. The dominant arm was involved in four of the six patients. Five patients (7.6%) had an absent radial pulse with an otherwise well perfused hand. One patient had concomitant median nerve injury and one patient presented with deficit to the radial nerve. All six patients had displaced, extension type III injuries involving five closed and one open fracture.

Neurovascular injuries were assessed in the emergency room by physical examination and Doppler sonography. A thorough neurological examination of the extremity was performed, while evidence of a radial pulse was sought regularly by palpation. All five patients with pink pulseless hand were splinted and had emergency surgical treatment for their injuries after an average of 1 h and 30 min (range; 45 min to 2 h and 10 min). These patients were treated

between 3 and 12 h (mean 5 h and 20 min) after the fracture took place.

Surgery was performed under general anaesthesia with the aid of an image intensifier. To obtain restoration of the radial pulse, an initial attempt for closed reduction was performed. The patient was placed close to the edge of the operating table with countertraction around the chest. With the shoulder at 90° abduction, constant traction was applied on the wrist followed by maximum flexion of the elbow. Reduction of the fracture was confirmed by anteroposterior and lateral views.

Once adequate closed reduction was obtained, percutaneous fixation with two Kirschner wires (K-wires) was done in the position of full reduction. However, if the hand remained pulseless, surgical exploration was the treatment of choice. Vascular reconstruction was done using microsurgical techniques with the aid of either the operating microscope or magnifying loops. A standard anterior approach was performed through a "lazy S" incision at the centre of the cubital fossa. A thorough exploration of the brachial artery at a mean distance of 6 to 10 cm above and below the fracture was required in order to rule out entrapment of the artery, thrombus formation or artery spasm. This procedure was followed by exploration of the median, the radial or the ulnar nerve if a neurological deficit had been diagnosed during the initial clinical evaluation. After surgical exploration, the elbow was immobilised with a plaster cast from the hand to just below the shoulder for 4 weeks. In all cases, continuous evaluation of the neurovascular status of the hand was required for the first 72 h after the surgery. Four weeks postoperatively, the cast and the K-wires were removed and the rehabilitation programme was started.

Follow-up was carried out at 4 weeks, 3 months and, subsequently, every 6 months. Mean follow-up was 34 ± 11 months, with a range of 6 months to 5 years.

Fig. 1 A 7-year-old girl with pulseless pink hand following type III supracondylar fracture of the humerus. (a) Anteroposterior and (b) lateral radiographs revealed severe posterior and lateral displacement

Results

In one patient, radial pulse returned after closed reduction of the fracture. However, in four patients, the initial attempt at closed reduction was unsuccessful in restoring the radial pulse. Consequently, they underwent vascular exploration. Three patients had brachial artery occlusion because of thrombus formation (Fig. 2). Thrombectomy was performed, which led to the restoration of a palpable radial pulse. In one patient with an open fracture (Gustilo type II), brachial artery spasm was found (Fig. 3). In addition to the spasm, contusion of the brachial artery with adventitial haematoma formation in a small segment of the artery was revealed. After vascular dissection, removal of the haematoma and adventitia in a long segment of the artery, the spasm was released and the radial pulse was restored as previously. In the same patient, contusion of the median nerve was found. The nerve caused symptoms that persisted for weeks and finally recovered 2 months after surgery. One patient with radial nerve palsy spontaneously recovered within 3 months.

The initial reduction was considered to be adequate in five patients (83.3%) and satisfactory in one patient (16.7%). All fractures united within a mean of 3.8 weeks (range; 3.5 to 5.2 weeks). Cubitus varus deformity of 6° relative to the other side was seen in the patient with the open fracture. Painless full flexion movement was achieved in all of our patients who underwent surgical exploration. Moreover, all patients had the same forearm length and full extension and pronation-supination. During the follow-up, the vascular status of these patients was considered to be satisfactory, as assessed by physical examination and Doppler sonography at the outpatient clinic.

Fig. 2 Vascular exploration in a patient with pulseless pink hand following type III supracondylar fracture of the humerus showing occlusion of the brachial artery because of thrombus formation (the segment of the artery between the white arrows). Thrombectomy was performed, which led to a patent brachial artery and restoration of a palpable radial pulse

Fig. 3 In a patient with an open fracture and pulseless pink hand, brachial artery spasm was found. In addition, contusion of the brachial artery with haematoma formation on the vascular wall in a small segment of the artery was revealed (white arrow). After vascular dissection, removal of the haematoma and adventitia in a long segment of the artery, the spasm was released and the radial pulse was restored

Discussion

Based on mechanism, supracondylar fractures of the humerus can be classified into extension fractures, which represent 97.5% of all cases, and flexion fractures, representing the remaining 2.5% [25]. According to Gartland's classification, these fractures can be distinguished in three types by displacement. In type I, the fracture is incomplete without displacement; in type II, there is moderate displacement with intact posterior cortex and contact between fragments; while in type III, there is no contact between the fracture ends. While type III fractures are always unstable, type II fractures may be stable or unstable [9, 11]. Supracondylar fractures of the humerus in children should be considered as a surgical emergency, especially Gartland type III fractures associated with vascular compromise. Surgical exploration of the cubital fossa is mandatory in patients with absent radial pulses and a cold, white hand [10, 12]. In such cases, the definition of the vascular discrepancy may vary. However, a delay in order to determine the nature and the extension of the vascular injury with time-consuming imaging studies is probably unnecessary.

It has been demonstrated that there is no correlation between the signs of ischaemia and the type of vascular injury. Because one of the most reliable clinical signs of vascular injury is an absent pulse [6, 8], patients with the absence of a palpable radial pulse, regardless of the lack of other signs of ischaemia, should also be considered as candidates for non-conservative management and be treated as orthopaedic emergencies. In patients with Gartland type III fractures and pulseless yet pink hand, an urgent reduction of the fracture should be attempted, followed by

stabilisation with two K-wires. If the pulse does not return, the authors suggest 30–35 min of close observation. If the hand remains pulseless after 30–35 min, exploration of the injured vessel should follow, regardless of the presence of a pink, warm hand with a good capillary refill. At this point, it should be mentioned that a well perfused pulseless hand may be complicated by severe ischaemia during reduction manoeuvres or due to inadequate reduction of the fracture [14].

According to the literature, however, several options have been proposed for the treatment of a pulseless but otherwise well perfused hand. Observation is the treatment of choice for many authors [10, 16, 21]. If the hand remains pulseless but well perfused after stabilisation, they suggest that the vascular injury should not be treated and instead rely on collateral circulation. A time window ranging from 12 to 24 h is usually given in order to rule out vascular spasm. Absence of the radial pulse at the initial stage of 24 h observation indicates that the brachial artery is unlikely to recover patency. According to the same authors, the rich collateral circulation around the elbow is sufficient for the viability of the arm, whereas early revascularisation procedures are associated with a high rate of asymptomatic reocclusion and residual stenosis of the brachial artery [21]. However, the possibility of limb length discrepancy [21, 24], claudication [18, 24], cold intolerance [17] and thrombus migration [1] should be considered if this method of treatment is selected. Moreover, there are no series available with long follow-up and a significant number of cases to support the superiority of a treatment option that finally leads to an arm that relies only on collateral circulation. Finally, an arm without an original dominant brachial artery may probably be too inefficient to handle a future trauma complicated with an arm-threatening vascular injury or be a donor or recipient of surgical flaps.

Radiographic evaluation of the vascular lesion includes both invasive and non-invasive techniques. Doppler, magnetic resonance angiography and colour-flow duplex scanning are non-invasive techniques that may obtain anatomically and haemodynamically useful information. Angiography is an invasive technique that can be performed either before surgery in the angiography suite or in the operating room, with the aid of a C-arm [15]. Its role in the investigation of an absent radial pulse is still under debate [5, 24]. It is our opinion that angiography should not be performed before surgery in cases of a pink pulseless hand. Pre-operative evaluation based on a thorough clinical examination with the aid of Doppler sonography is considered to be sufficient in evaluating the patency of the brachial artery. Nevertheless, angiography requires general anaesthesia of the patient and takes several minutes to perform, even in the hands of an expert radiologist. Magnetic resonance angiography and colour-flow duplex

are safe and valid techniques that may be used after surgery to assess the patency of the brachial artery.

The use of these radiographic procedures in the estimation of the vascular status in children with a pulseless but otherwise well perfused hand raises questions and controversy. Sabharwal et al. [21] supported the view that the combination of segmental pressure monitoring, colour-flow duplex ultrasound and magnetic resonance angiography are sufficient evaluation tools for the patency of the brachial artery. On the contrary, some authors believe that these techniques do not have the specificity and sensitivity of angiography [23]. The latter is sufficient to define the extension and localisation of the vascular injury and provide the necessary information for the surgical plan [15]. Copley et al. [6] reported that a formal angiography should be performed before surgery if either the pulseless limb has no clinical signs of severe ischaemia and the essence or location of the vascular injury remains unknown due to previous vascular pathology or combined limb trauma, or when a surgical exploration is being debated. Furthermore, intra-operative arteriography with the aid of a C-arm is a useful tool in cases in which the radial pulse is not palpable after an attempt of fracture reduction [15]. The same authors hold that the only contraindications for intra-operative arteriography are Gustilo type I and II open fractures, as well as severe ischaemia of the limb [15].

In a series of 190 children with displaced supracondylar fracture of the humerus, six patients had vascular impairment diagnosed by physical examination and Doppler sonography [12]. Nerve injury was present in all of these patients. Four other patients presented with a pulseless pink hand. In these four patients, careful observation was the treatment of choice. According to the authors, pulses returned spontaneously. However, no vascular follow-up examination was carried out.

In a recent study, Luria et al. [15] analysed the vascular complications of 24 children with supracondylar fractures of the humerus. In their series, reduction of the fracture was followed by a return of the pulse in 58% of the cases. They concluded that, in the rest of the cases in which the radial pulse was not returned after reduction of the fracture, exploration of the cubital fossa was indicated only if intra-operative angiographic evaluation revealed a brachial artery injury. As they noted, angiography is a helpful procedure that may prevent unnecessary exploration of the brachial artery, as in the case of arterial spasm. However, angiography may not be sufficient to distinguish arterial spasm from an intimal tear (e.g. in the case of coexistence), which necessitates surgical intervention. Moreover, a persistent arterial spasm may require removal of the adventitia, as in one of our patients.

Nerve injuries associated with supracondylar fractures in children occur primarily due to tenting or entrapment of the

nerve within the humeral fragments [19]. These injuries usually recover spontaneously and have a good prognosis and surgical exploration should be retained for selected cases. Nerve injury with coexisting ischaemia is considered as an indication for nerve exploration [19]. Other indications include a complete nerve lesion or a lesion that deepens progressively, a nerve injury during reduction or stabilisation of the fracture, and the presence of persistent neuropathic pain [19]. Luria et al. [15] found a statistically significant correlation between the median nerve injury and the brachial artery lesion. However, they did not notice a correlation between the type of vascular lesion and nerve injury. In our series, 33% of the patients with vascular injury (two of the six cases) had nerve injury. Palsy of the median and the radial nerve recovered spontaneously within 6 and 3 months, respectively.

The current literature is imprecise regarding the optimal management of an absent radial pulse in an otherwise well perfused hand associated with supracondylar fractures in children. Although the rich collateral circulation around the elbow is thought to sustain the viability of the extremity in a pulseless but otherwise well perfused hand, there are no series available indicating that a collateral circulated arm has the same potential as a normal hand after trauma. In addition, an arm without an original dominant brachial artery may greatly compromise the final outcome in the case of an arm-threatening vascular injury.

Conclusion

The absence of the radial pulse should not always be attributed to a spontaneously resolved vascular spasm. The authors' preferred method is surgical exploration for the restoration of brachial artery patency, even in the presence of viable pink hand after an attempt at closed reduction.

References

1. Broudy S, Jupiter J, May JW Jr (1979) Management of supracondylar fracture with brachial artery thrombosis in a child: case report and literature review. *J Orthop Trauma* 19:540–554
2. Brown IC, Zinar DM (1995) Traumatic and iatrogenic neurological complications after supracondylar humerus fractures in children. *J Pediatr Orthop* 15:440–443
3. Campbell CC, Waters PM, Emans JB, Kasser JR, Millis MB (1995) Neurovascular injury and displacement in type III supracondylar humerus fractures. *J Pediatr Orthop* 15:47–52
4. Cheng JC, Ng BK, Ying SY, Lam PK (1999) A 10-year study of the changes in the pattern and treatment of 6,493 fractures. *J Pediatr Orthop* 19:344–350
5. Clement DA (1990) Assessment of a treatment plan for managing acute vascular complications associated with supracondylar fractures of the humerus in children. *J Pediatr Orthop* 10: 97–100
6. Copley LA, Dormans JP, Davidson RS (1996) Vascular injuries and their sequelae in pediatric supracondylar humeral fractures: toward a goal of prevention. *J Pediatr Orthop* 16:99–103
7. Culp RW, Osterman AL, Davidson RS, Skirven T, Bora FW Jr (1990) Neural injuries associated with supracondylar fractures of the humerus in children. *J Bone Joint Surg Am* 72:1211–1215
8. Endean ED, Veldenz HC, Schwarcz TH, Hyde GL (1992) Recognition of arterial injury in elbow dislocation. *J Vasc Surg* 16:402–406
9. Felsenreich F (1931) Kindliche suprakondylare frakturen und posttraumatische deformitäten des ellebogengelenk. *Arch Orthop Unfallschir* 29:555
10. Garbuz DS, Leitch K, Wright LG (1996) The treatment of supracondylar fractures in children with an absent radial pulse. *J Pediatr Orthop* 16:594–596
11. Gartland JJ (1959) Management of supracondylar fractures of the humerus in children. *Surg Gynecol Obstet* 109:145–154
12. Gosens T, Bongers KJ (2003) Neurovascular complications and functional outcome in displaced supracondylar fractures of the humerus in children. *Injury* 34:267–273
13. Landin L, Danielsson L (1986) Elbow fractures in children. An epidemiological analysis of 589 cases. *Acta Orthop Scand* 57:309–312
14. Louahem DM, Nebunescu A, Canavese F, Dimeglio A (2006) Neurovascular complications and severe displacement in supracondylar humerus fractures in children: defensive or offensive strategy? *J Pediatr Orthop B* 15:51–57
15. Luria S, Sucar A, Eylon S, Pinchas-Mizrachi R, Berlatzky Y, Anner H, Liebergall M, Porat S (2007) Vascular complications of supracondylar humeral fractures in children. *J Pediatr Orthop B* 16:133–143
16. Malviya A, Simmons D, Vallamshetla R, Bache CE (2006) Pink pulseless hand following supra-condylar fractures: an audit of British practice. *J Pediatr Orthop B* 15:62–64
17. Marck KW, Kooiman AM, Binnendijk B (1986) Brachial artery rupture following supracondylar fracture of the humerus. *Neth J Surg* 38:81–84
18. Pirone AM, Graham HK, Krajbich JI (1988) Management of displaced extension-type supracondylar fractures of the humerus in children. *J Bone Joint Surg Am* 70:641–650
19. Ramachandran M, Birch R, Eastwood DM (2006) Clinical outcome of nerve injuries associated with supracondylar fractures of the humerus in children: the experience of a specialist referral centre. *J Bone Joint Surg Br* 88:90–94
20. Ristic S, Strauch RJ, Rosenwasser MP (2000) The assessment and treatment of nerve dysfunction after trauma around the elbow. *Clin Orthop Relat Res* 370:138–153
21. Sabharwal S, Tredwell SJ, Beauchamp RD, Mackenzie WG, Jakubec DM, Cairns J, LeBlanc JG (1997) Management of pulseless pink hand in pediatric supracondylar fractures of humerus. *J Pediatr Orthop* 17:303–310
22. Schoenecker PL, Delgado E, Rotman M, Sicard GA, Capelli AM (1996) Pulseless arm in association with totally displaced supracondylar fracture. *J Orthop Trauma* 10:410–415
23. Schuler JJ, Flanigan DP, Meyer JP (1992) Combined vascular and orthopedic injuries. In: Flanigan DP (ed) *Civilian vascular trauma*. Lea & Febiger, Pennsylvania, pp 265–267
24. Shaw BA, Kasser JR, Emans JB, Rand FF (1990) Management of vascular injuries in displaced supracondylar humerus fractures without arteriography. *J Orthop Trauma* 4:25–29
25. Wilkins KE (1996) Fractures and dislocations of the elbow region. In: Rockwood CA, Wilkins KE, King RE (eds) *Fractures in children*, vol 3, 4th edn. Lippincott-Raven, Philadelphia, pp 363–575