■ CHILDREN'S ORTHOPAEDICS

The value of ultrasonic diagnosis in the management of vascular complications of supracondylar fractures of the humerus in children

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Of 48 consecutive children with Gartland III supracondylar fractures, 11 (23%) had evidence of vascular injury, with an absent radial pulse. The hand was pink and warm in eight and white and cold in the other three patients. They underwent colour-coded duplex scanning (CCDS) and ultrasound velocimetry (UV) to investigate the patency of the brachial artery and arterial blood flow. In seven patients with a pink pulseless hand, CCDS showed a displaced, kinked and spastic brachial artery and a thrombosis was present in the other. In all cases UV showed reduced blood flow in the hand. In three patients with a white pulseless hand, scanning demonstrated a laceration in the brachial artery and /or thrombosis. In all cases, the fracture was reduced under general anaesthesia and fixed with Kirschner wires. Of the seven patients with a pink pulseless hand without thrombosis, the radial pulse returned after reduction in four cases. The remaining three underwent exploration, along with the patients with laceration in the brachial artery and/or thrombosis.

We believe that the traditional strategy of watchful waiting in children, in whom the radial pulse remains absent in spite of good peripheral perfusion should be revisited. Vascular investigation using these non-invasive techniques that are quick and reliable is recommended in the management of these patients.

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In displaced supracondylar fractures of the humerus in children, the incidence of an absent radial pulse, indicating a brachial artery injury, ranges from 2.6% to 20%.[1-4] In those with an arterial injury the fracture is usually a posterolaterally displaced Gartland[5] type III injury,[6-8] with additional involvement of the median nerve or its anterior interosseous branch in 12% to 20% of cases.[4,9-12] In some children with mild symptoms, the level of suspicion for arterial injury is low and many authors suggest that a patient with a pulseless but pink and warm hand should be managed expectantly after reduction of the fracture, assuming that the arterial spasm would resolve and collateral circulation would compensate for the temporary circulatory impairment.[1,12-14] However, others have questioned this approach[2,12,14,15] and Blakey et al[4] reported that 23 of 26 children with a pink, pulseless hand faced ischaemic complications in the long-term.

Early diagnosis of irreversible arterial injury and prompt treatment may help to reduce ischaemic sequelae[16] and in 2007, we adopted a policy of high alert with immediate vascular investigation and close observation for any child presenting with a supracondylar fracture and clinical evidence of arterial injury. We report the results of a prospective study to assess the diagnostic accuracy of non-invasive vascular diagnostic techniques in cases of suspected arterial injury, and the outcome of immediate exploration and treatment.

Patients and Methods

Between January 2007 and December 2010, 48 consecutive children with Gartland type III fractures[5] presented to our hospital. There were 30 boys and 18 girls with a mean age of eight years (4 to 12). The left side was affected in 30 and the right in 18. Each had routine radiographs of the elbow and particular attention was paid to the arterial pulses, the colour and temperature of the forearm and hand, superficial venous filling and neurological assessment. Two vascular surgeons (OM and AL) were on call for any case of suspected arterial injury.

If the radial pulse was absent, colour-coded duplex scanning (CCDS) and ultrasound velocimetry (UV), using Doppler CW equipment (Technos; Esaote, Genoa, Italy), was undertaken for the main arteries of the affected limb. The time to perform these tests was approximately 20 minutes.

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Arterial repair was by a microsurgical technique previously documented by Noaman.[17] CCDS and UV were used intra-operatively to determine the state of the arterial wall, to monitor secondary thrombosis and to assess the velocity of blood flow in the hand. Both were used at the end of every operation and at follow-up. In all the patients who underwent exploration of the brachial artery, low-molecular-weight heparin 4000 IU to 8000 IU were given subcutaneously according to body weight. In patients who had arterial reconstruction, intravenous heparin was also given.

All the children who had exploration and repair were discharged from the hospital after one to four days depending on the type of treatment, then reviewed regularly for the first month post-operatively, every three months during the first year, then annually. The mean follow-up for these patients was 2.85 years (1 to 5).

Results

Of the 48 patients, 37 (77%) had no signs of vascular impairment. The fracture was reduced under general anaesthesia within one to eight hours of admission and fixed percutaneously with two Kirschner (K-) wires. The arm was protected by a posterior plaster splint with the elbow flexed at 90° for four to five weeks.

In total, 11 patients (23%) presented with signs of vascular impairment. Eight had a pink pulseless hand without other signs of ischaemia, whereas three had severe pain and a white pulseless hand that was cold with areas of paraesthesia and/or anaesthesia, and impaired movement. In four of the children with a pink pulseless hand, CCDS showed a displaced brachial artery with kinking, compression and mild spasm but without occlusion or thrombosis. The velocity of the blood in the hand as measured by UV was moderately reduced. The radial pulse reappeared after reduction and fixation of the fracture with two K-wires and the artery regained its normal position and calibre. No vascular abnormality was observed thereafter.

In the other four patients with a pink pulseless hand (Cases 1 to 4, Fig. 1, Table I) there was moderate to severe swelling of the hand. In three, CCDS showed severe spasm and displacement of the brachial artery and the other had intimal-media disruption with thrombosis. UV showed much reduced flow in the hand and, in two, none in some digital arteries. In the three patients with spasm and displacement, the radial pulse did not return after closed reduction and fixation and immediate exploration of the brachial artery was undertaken. In the fourth, immediate open reduction and K-wire fixation was undertaken. The operative treatment of the vascular injury in the four cases is shown in Table I. The swelling of the hand resolved in between one and four months.

In the three patients with a white and cold pulseless hand (cases 5 to 7, Table I), CCDS and UV examination confirmed severe arterial injury with absence of peripheral blood flow. One child was pale and hypotensive, with a large pulsating mass in the cubital fossa. All three patients underwent immediate exploration after reduction and percutaneous K-wire fixation and the findings, treatment and outcome are also shown in Table I.

In all seven patients who underwent vascular surgery, the elbow was immobilised in 60° of flexion to avoid compression of the brachial artery.

There were no complications related to the vascular surgery, vein harvesting or heparin administration.

Discussion

In this series of 48 Gartland III closed fractures, 11 children (23%) had local vascular complication with an absent radial pulse and reduced arterial perfusion of the hand. This is a slightly higher incidence than the 2.6% to 20% hitherto reported for a pulseless hand with this fracture.[1-4]

There is general agreement that the initial treatment for a patient with a displaced supracondylar fracture with a pulseless but well-perfused hand is prompt closed reduction under general anaesthesia and percutaneous K-wire fixation.[18] This treatment allows recovery of the radial pulse in about 55% of cases.[4] However, opinions differ about the management of those who do not recover a radial pulse but have good peripheral perfusion as judged by a pink and warm hand.[1,3,12,19,20] Whereas Choi et al[18] considered that reduction of the fracture alone is usually sufficient, White et al[12] considered that absence of the pulse indicates arterial injury even if the hand appears pink and warm, and recommended further vascular investigations in such cases.

From the current literature, it is apparent that the diagnosis of arterial injury has been mainly based on physical examination and, with some exceptions,[12,21] little importance has been attached to supplementary vascular diagnostic techniques that during the last few years have become noninvasive and allow a precise diagnosis of the type of arterial injury.[22-25]

In four of the eight pink pulseless hands in our study, CCDS and UV on admission showed compression and displacement of the brachial artery with mild spasm and decreased blood flow. There was full recovery of the calibre and anatomical position of the artery after reduction of the fracture. In the other four patients, in whom the radial pulse did not return after reduction, CCDS before reduction showed severe spasm, displacement and compression and, in one case, intimal–media disruption with thrombosis.

In the three patients with a pulseless pink hand in whom CCDS showed severe spasm and displacement of the brachial artery, closed reduction and K-wire fixation not only failed to improve circulation but in two CCDS showed complete occlusion of the brachial artery at the level of the fracture. Although the hand remained fairly well perfused after reduction, these two patients might have had a poor long-term outcome if the artery had not been explored,[4] as also might the other two children in whom CCDS and UV had shown irreversible arterial damage. The operative findings justified intervention in these four patients. CCDS correctly identified arterial lesions and normal patency of

Fig. 1a

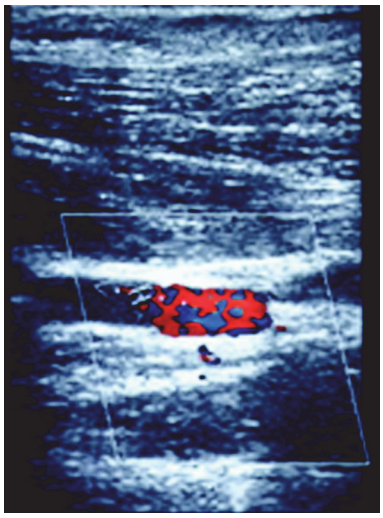

Fig. 1b

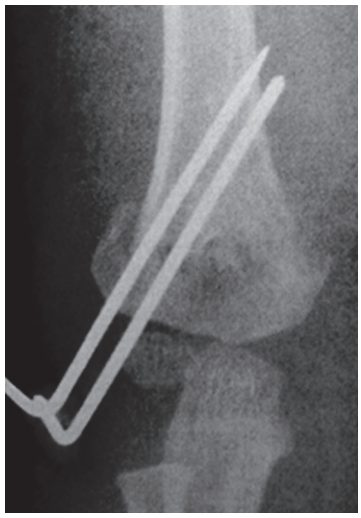

Fig. 1c

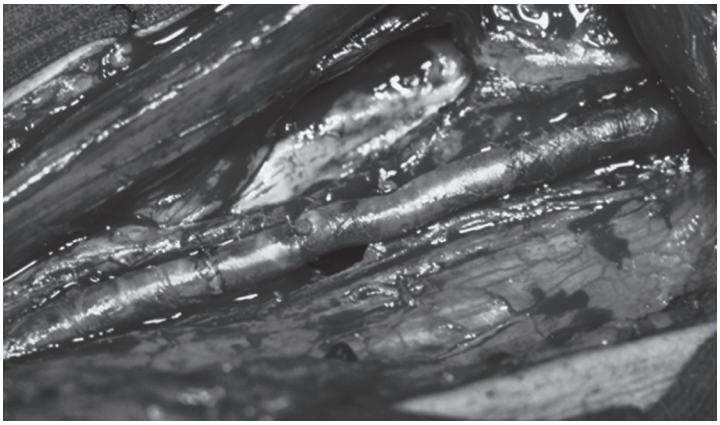

Fig. 1d

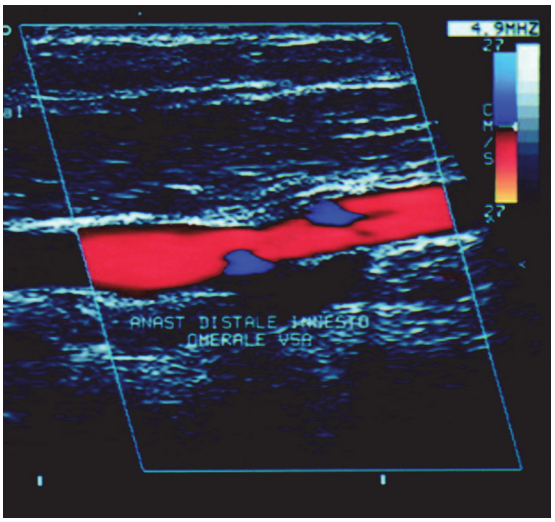

Fig. 1e

Images of a six-year-old boy (case 4, Table I) with a Gartland type III fracture and a pink pulseless hand. Pre-operative radiograph (a) showing the fracture and colour-coded duplex scanning (CCDS) image (b) showing ascending thrombosis of the brachial artery. The fracture was fixed with two Kirschner wires (c). Photograph (d) showing the thrombotic segment resected and replaced with an autologous great saphenous vein graft, and CCDS image (e) showing a patent brachial artery.

the brachial artery was restored. Along with others,[4,12,14,17,26] we emphasise that in those cases, a satisfactory temporary collateral circulation could not have guaranteed a good long-term outcome. Cold intolerance, sometimes with Raynaud's phenomenon, dysaesthesia, claudication of the forearm, delayed development and growth arrest of the involved limb and complete loss of function have been reported following arterial damage associated with a supracondylar fracture.[4,7,9,12,17]

In Blakey et al's[4] series of 26 patients with a pink pulseless hand after reduction of the fracture with a mean follow-up of 15.5 years, only four had undergone an exploration, three immediately, when an arterial repair was possible and one 48 hours after the injury, which was unsuccessful. Thus, 23 patients developed an ischaemic contracture of the forearm and hand and they concluded that a pink pulseless limb is ischaemic and recommended urgent exploration under these circumstances.[4] Towler et al[14] described five patients out of 25 with a pulseless but well-perfused hand after reduction of the fracture; four underwent immediate exploration and all needed an arterial repair, in addition to a median nerve release in two. The fifth was managed conservatively and developed an ischaemic contracture with significant disability.[14]

The time taken for the radial pulse to return after reduction is also an important consideration. The use of CCDS and UV can reduce that time by making a precise assessment of the arterial status. It is also noteworthy that two patients have been described in whom the radial pulse returned after closed reduction but disappeared during the

Table I. Brachial artery (BA) injuries and their treatment in seven patients

Case/Gender/ Age (yrs)	Clinical status of the hand and type of BA and nerve injury	Type of vascular surgery	Follow-up (yrs)	Clinical status of the hand and BA patency at follow-up
1 / M / 9	Pink pulseless hand. BA entrapment in the fracture	BA release	1	Clinically normal. Normal BA calibre
2 / F / 6	Pink pulseless hand. BA entrapment in the fracture	BA release	3	Clinically normal. Normal BA calibre
3 / F / 4	Pink pulseless hand. BA long-lasting severe spasm	BA exploration, adventitial resection, papaverine soaking	2	Clinically normal. Normal BA calibre
4 / M / 6	Pink pulseless hand. BA intimal-media disruption and thrombosis	BA segmental resection, thrombectomy, and end-to-end replacement by cephalic vein	2	Clinically normal. BA patent
5 / M / 8	White pulseless hand. BA intimal-media disruption and thrombosis	BA segmental resection, thrombectomy, and end-to-end anastomosis. Fasciotomy	4	Clinically normal. BA patent
6 / M / 5	White pulseless hand. BA intimal-media disruption, ascending thrombosis	Partial resection of BA and a utologous great saphenous vein interposition graft. Fasciotomy. Release of median nerve	3	Mild paraesthesia in hand. Patent by-pass
7 / F / 9	White pulseless hand. Laceration of distal BA at its bifurcation and large haematoma. Median nerve entrapment. Anterior interosseous nerve tear	Partial resection of BA and brachial-ulnar bypass with autologous long saphenous vein graft. Release of median nerve. Anterior interosseous nerve irreparable. Fasciotomy	5	Partial impairment of thumb and finger flexion. Subjective hypothermia. Palmar paraesthesia. Patent by-pass but higher than normal peripheral resistance, confirmed by UV

following 36 hours.[17] Thrombosis had complicated an underlying arterial wall injury that was clinically unrecognised, and both patients needed vascular repair. This is important since any vascular injury may cause occlusion by thrombosis in spite of regained patency.[21] We believe that a post-reduction pink, even warm, but pulseless hand is not necessarily well-perfused nor a benign condition.[18] One must suspect that 'pink' is equivalent to borderline or delayed ischaemia with the risk of deterioration. Although we performed CCDS and UV at presentation in all our patients with a pink pulseless hand, we believe these tests should be essential only in cases where the condition persists after reduction.

In cases of frank ischaemia, we believe that CCDS, UV and exploration are essential, even before any attempt at closed reduction and K-wire fixation. In our three patients with a pulseless pale and cold hand, CCDS and UV were highly diagnostic and, even in the patient with a large pulsating haematoma, the exact location of the arterial injury was detected. In those cases, an attempt at closed reduction might have been harmful, useless or time-consuming. However, it is reported that 29% of patients with a cold, pulseless hand recovered the pulse and perfusion after reduction and stabilisation of the fracture.[18] Notwithstanding these findings, we consider that such a policy might not be appropriate in a hospital with diagnostic facilities for vascular disorders.

Our results with early exploration and arterial repair were favourable in all the patients, albeit to a varying degree clinically. All arterial reconstructions were successful. There was no recurrence of thrombosis or stenosis in the segment repaired directly in case 4 or in any of the grafts in cases 5 to 7, which remained patent with good function, in spite of high peripheral vascular resistance in case 7. Similar good results with arterial microsurgical repair have also been reported.[2,9,12,17,24,25]

In conclusion, we believe that following successful reduction of a supracondylar fracture, the traditional strategy of watchful waiting in children with a pink pulseless hand should be revisited. In some cases there may be severe injury to the brachial artery in spite of a compensatory collateral circulation. Therefore, in such patients we advise CCDS complemented by UV to improve the diagnosis. These techniques are non-invasive and quick, have no contraindications and have high diagnostic accuracy.[22-25]

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