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CASE REPORT

Missed Compartment Syndrome of the Forearm: Limb Salvage and Reconstruction

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Introduction

Missed compartment syndrome is extremely rare, particularly in the upper limb, but the consequences can be disastrous [1–4]. Early recognition and treatment may prevent irreversible tissue damage. Established tissue injury, including Volkmann's contracture, can present a major reconstructive surgical challenge. We present a case in which we reconstructed forearm soft tissue and bone defects due to sepsis and missed compartment syndrome after closed treatment of a paediatric Monteggia fracture-dislocation.

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Case Report

A 4-year old female sustained a closed Monteggia fracture-dislocation due to a fall at home. There were no other injuries and she was otherwise well. She lived in a remote highland region and was initially treated at a local village hospital. The injury was reduced closed under local anaesthesia and a circumferential long-arm cast applied. The cast was changed 5 days post-operatively, when dorsal forearm skin necrosis and blistering were noted and she was transferred to our Hospital for ongoing care.

We diagnosed soft tissue necrosis, forearm infection and missed compartment syndrome. Sepsis and progressive necrosis were difficult to control despite serial radical debridement. At the third procedure, osteomyelitis necessitated proximal radial shaft excision. A dorsal forearm soft tissue defect was closed with a pedicled abdominal flap (Fig. 1). The flap healed well and the pedicle was divided 3 weeks later. At that stage we noted early signs of Volkmann's ischaemic muscle contracture.

Three months later, we diagnosed ulna shaft osteomyelitis, also difficult to control despite serial debridement. Midshaft ulna excision was eventually required, creating substantial proximal radial and ulnar mid-shaft defects. A forearm splint was applied and the patient discharged home.

One year later, clinical and laboratory assessment (Fig. 2) indicated that the infection had settled. We elected to reconstruct a one-bone forearm using free vascularized fibular transfer with a skin paddle. The 8 cm forearm defect was bridged with a 12 cm fibular graft, fixed proximally to the ulna and distally to the radius (Fig. 3). Graft vessels were anastomosed to the ulnar artery and venae commitantes with 10/0 Nylon under magnification (Fig. 4). Bony union occurred at 3 months and the fixation wires were removed at 6 months.

Clinical assessment 2 years later showed a Volkmann's-type extrinsic finger and thumb flexion deformity, with no active flexion. Passive joint mobility

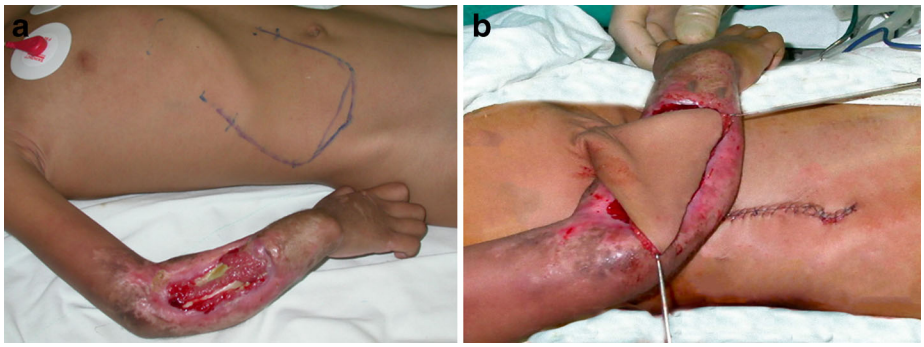

Fig. 1 Soft tissue defect at the forearm after the third debridement (**a**); Coverage the soft tissue defect by pedicle abdominal flap (**b**)

Fig. 2 The forearm 1 year after the accident. Wound healing with a pedicle abdominal flap (**a**, **b**), both radius and ulna bones defects in X-ray (**c**)

Fig. 3 Schema of a one-bone forearm reconstruction using free fibular graft

was preserved. Sensation had recovered. The right forearm was shorter than the left.

To address the Volkmann's contracture and paralysis, we planned flexor muscle scar debridement and free functional muscle transfer. The fibular graft was clinically stable and hypertrophic on X ray. Arteriography showed that the radial artery was dominant (Fig. 5). We explored the anterior interosseous nerve in the forearm and confirmed it was functional using a nerve stimulator. Then the gracilis muscle was harvested from the right thigh with its vascular pedicle and motor nerve. The harvested gracilis was fixed to the medial epicondyle proximally and sutured to the thumb and finger flexor tendons distally. Graft vessels were sutured end-to-side to the radial forearm vessels using 10/0/ Nylon under magnification. The gracilis motor nerve was sutured to the anterior interosseous using 11/0 Nylon, also under magnification (Fig. 6). Post-operative recovery was uneventful. Our patient continued a special rehabilitation program and was followed-up every 3 months in the first year and every 6 months from 1 year to 3 years.

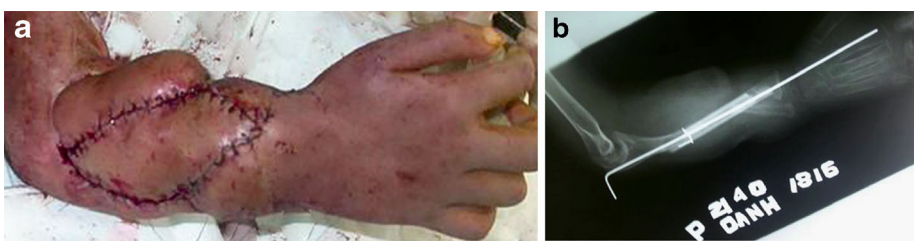

Fig. 4 Free vascularized fibular transfer for one-bone forearm reconstruction: Fibular graft inset at the end of operation (**a**), bone stabilization in post-op X-ray: fibula inserted between proximal ulna and distal radius (**b**)

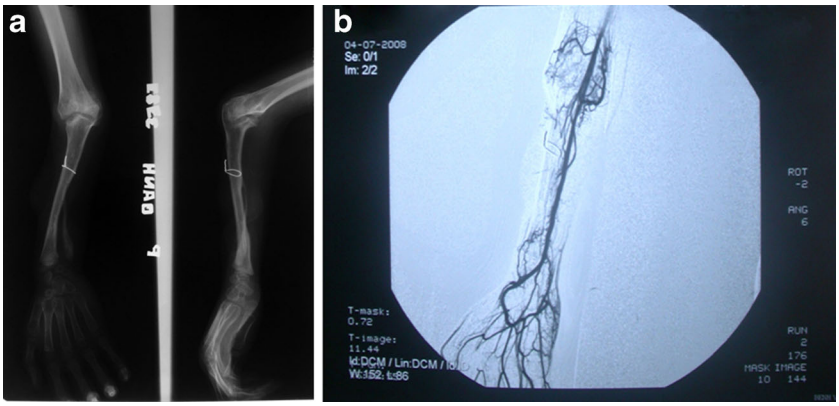

Fig. 5 The forearm after 2 years of the bone reconstruction in X-ray (**a**), only radial artery at the forearm in Arteriogram (**b**)

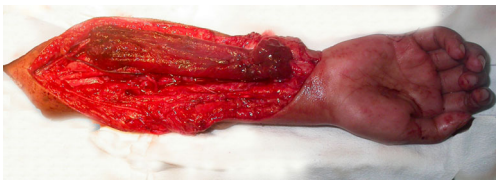

Fig. 6 Free functional Gracilis transplantation for restoration of hand function

Three years post-operatively, the finger and thumb extrinsic contractures had resolved and the transferred gracilis graft was functional. The forearm was 8 cm shorter than the contralateral side. Elbow range was from 10 to 110°. The forearm was fixed at neutral position. Wrist extension was 60 and flexion 50. Active finger and thumb flexion were intact. Pinch grip and grasp were possible and the patient was able to make a full fist. She reported good function, including riding her bicycle to school and writing with the operated hand. The Disabilities of Arm, Shoulder and Hand (DASH) score was 40, compared with 85 pre-operatively. The patient and her family were satisfied with the functionally result (Fig. 7).

Discussion

Missed forearm compartment syndrome can have serious long-term functional consequences. Our patient's necrotic forearm muscles became a nidus for severe deep infection, due to direct spread from the infected skin ulcer. Despite skin closure with an abdominal flap, deep infection continued, causing osteomyelitis and bone loss, consistent with the pathophysiological mechanism described by Delasobera [1], Gulgonen [3] and Hawkins [5].

Due to bone loss, the forearm was short and unstable. Associated soft tissue injury included flexor muscle Volkmann's contracture and soft tissue scarring. Wrist and hand tissues were relatively unaffected. Hand sensation was

Fig. 7 Follow-up 3 years after free functional Gracilis transplantation for the forearm, complete normal muscle volume (**a**) and bony union in X-ray (**b**)

intact and the patient was systemically well. We were faced with a difficult decision. Do we reconstruct the complex forearm bone and soft tissue defects, thereby committing this young girl to several large reconstructive procedures and the associated rehabilitation program? After lengthy discussion with the patient and her family, we elected to proceed with the reconstructions [6, 7].

The anatomy of a vascularized fibular graft is predictable. The graft provides adequate length, mechanical strength and potential for hypertrophy. Vascularized fibula was therefore a suitable donor for her complex bone defects, creating a one-bone forearm in neutral rotation. The proximal ulna and distal radial growth plates were preserved, allowing further growth. The fibrotic and contracted forearm soft tissues were excised and reconstructed with an associated skin paddle [7–13]. Our goal was to achieve skeletal stability and supple soft tissue cover.

Free innervated muscle transfer was indicated for restoration of active finger and thumb flexion. This patient met the requirements:

- A viable recipient nerve (the most important predictor of eventual function)
- Supple distal joints and functional extensors
- Supple, mobile distal flexor tendons
- Intact hand sensation
- The patient and her family consented to the procedure and associated rehabilitation.

Other functional muscle flap options include latissimus dorsi, pectoralis major and rectus abdominus. Gracilis is the preferred forearm option [14], due to its length, width, dominant pedicle and single nerve.

The result may have been improved by shorter time intervals between reconstructions and by planning a two-stage bone reconstruction using an external fixator and cement spacers at the first procedure, followed by the definitive fibula graft at the second. Treatment was largely determined by geographic, economic and family circumstances. They lived in a remote region, were very poor and usually attended follow-up appointments late.

Conclusion

This case report demonstrates that the complex forearm soft tissue and bone defects due to missed compartment syndrome can be reconstructed using microsurgical techniques. Basic hand function can be restored. Despite the large surgical procedures and long rehabilitation time involved, this treatment is an acceptable salvage option to improve upper limb function and return the patient to normal life.

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