Composite Vascularized Autograft Elbow Transplant

A Case Report

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Abstract

Case: A 37-year-old man presented with an absent right elbow joint secondary to trauma, subsequent ankylosis, total elbow arthroplasty (TEA), and TEA explantation after infection. The patient also had a contralateral complete brachial plexus injury, but an intact elbow joint. Given that the patient had a functional right hand/wrist, composite vascularized autograft elbow transplant was performed from left to right upper extremity. Four years postoperatively, the patient could independently complete activities of daily living.

Conclusion: This case is the first to report composite vascularized autograft elbow transplant. Although indications are limited, this case illuminates novel uses of standard techniques for a difficult problem.

Allograft transplantation is a potential surgical option for limb salvage surgery. Several past studies have investigated outcomes for this technique in the setting of musculoskeletal tumors and traumatic skeletal defects[1-3].

Specific to the elbow, transplantation of an elbow allograft can be performed after significant bone or joint loss secondary to trauma, tumor resection, or revision total elbow arthroplasty (TEA). However, major and frequent complications such as infection, graft resorption, fracture, instability, and nonunion pose significant challenges[4-6]. In this article, the authors present the first known case of a composite vascularized autograft elbow transplant in a patient who had an absent right elbow joint after failed trauma reconstruction with ankylosis and subsequent infected TEA requiring explantation. The case raises several points regarding novel problem solving, preoperative planning, and unique operative considerations.

The patient was informed that data concerning the case would be submitted for publication, and he provided consent.

Case Report

A 37-year-old man sustained several injuries and a traumatic brain injury in a roll-over motor vehicle accident. His orthopaedic injuries included a right elbow dislocation and a complete left brachial plexus avulsion injury.

Acutely, he underwent primary ligament repair of the right elbow dislocation. After this surgery, he developed severe ankylosis of the elbow and a radioulnar synostosis. Symptomatically, he had loss of motion, with the elbow fixed at approximately 90° of flexion. As his left arm was nonfunctional, he underwent right TEA. The TEA did restore some function, although eventually failed because of infection. After several treatments and reimplantation, he underwent resection arthroplasty. At this time, he was completely dependent on others for activities of daily living (ADLs); on the left, there was no recovery from the brachial plexus injury, and therefore, he had a flaccid left upper extremity (LUE). On the right, he had a flail elbow with functional hand and shoulder motor function.

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Given the patient's activity status, the patient was referred to the senior author 7 years after initial injury (Figs. 1 and 2). The concept of a composite joint transplant from the LUE to the right upper extremity (RUE) was discussed. On physical examination, the patient was able to initiate flexion/extension while braced, but had gross elbow instability in all planes because of massive bone loss. He had a functional hand and wrist with some weakness secondary to partial ulnar nerve palsy.

A surgical team consisting of orthopaedic and plastic surgeons was assembled by the senior author. No previous reports of this procedure were identified in a literature review. Preoperative planning ensued.

The known challenges were the following:

- Mirror image limb;
- Vessel quality and availability (donor and recipient);
- Risk of nerve injury in multiply operated RUE;
- Nerve identification and preservation in scar tissue;
- Bony fixation under timed constraints.

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSCC/B621).

Keywords: middle age, male, total elbow arthroplasty, autograft, elbow transplant, elbow dislocation, motor vehicle collision

Fig. 1

Preoperative right (**Figs. 1-A and 1-B**) and left (**Figs. 1-C and 1-D**) elbow lateral and anteroposterior plain films. In the right upper extremity, a missing elbow joint is noted with significant bone loss in the proximal forearm and distal humerus.

Bilateral upper extremity angiograms were obtained. Bilateral computed tomography scans by Materialise protocol were performed to assist in osteotomies and osteosynthesis of mirror image elbow (Figs. 3 and 4). A left radioulnar synostosis was noted.

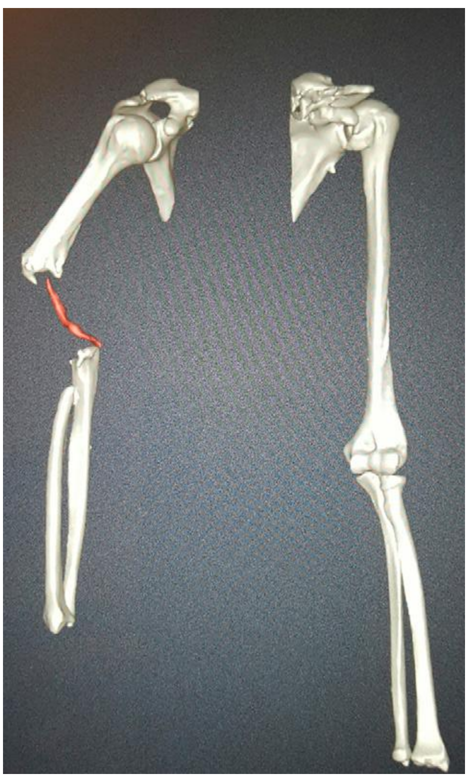

Fig. 2

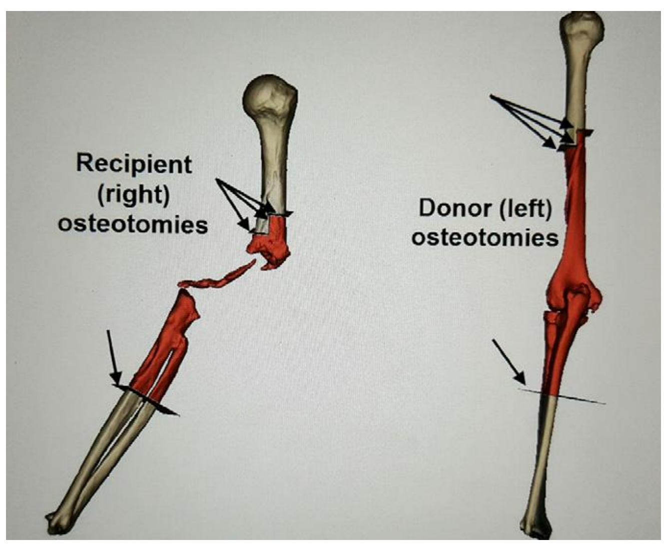

Fig. 3

Fig. 2 The patient's left upper extremity and right upper extremity are shown. In the right upper extremity, there was normal motor and sensory function, although no elbow joint. In the left upper extremity, there was no motor function, but viable bone and joint function present. **Fig. 3**Preoperative planning with Materialise software allowed for estimation of osteotomy cuts. During preoperative planning, a defect of 19.1 cm was measured for the distal humerus in the right upper extremity. However, intraoperatively, a defect of only 9.4 cm was noted. This difference was believed to be attributed from soft-tissue contracture over time.

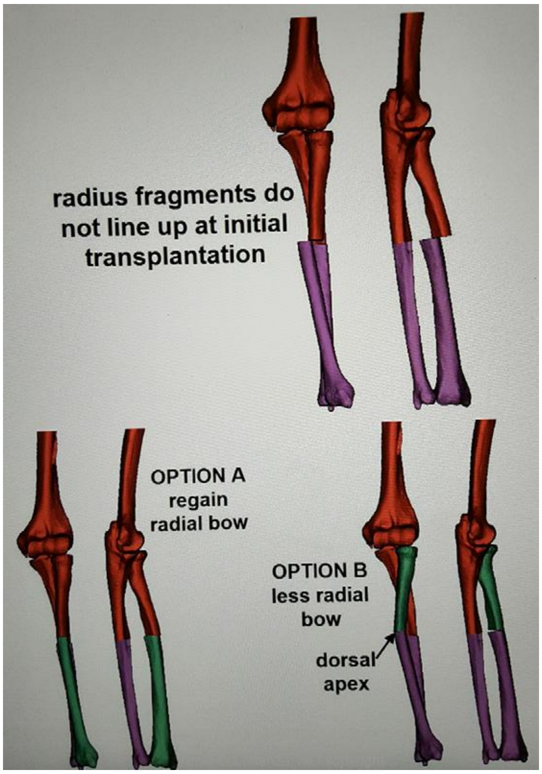

Fig. 4

Fig. 5

Fig. 6

Fig. 4 Preoperative planning with Materialise software allowed for planning for rotational correction. **Fig. 5** Preoperative inspection of patient's right upper extremity on the day of surgery. **Fig. 6** Postoperative plain film radiograph of patient's right upper extremity, after composite autograft elbow transplant. Humeral fixation was completed through intramedullary rod and forearm fixation involved plating.

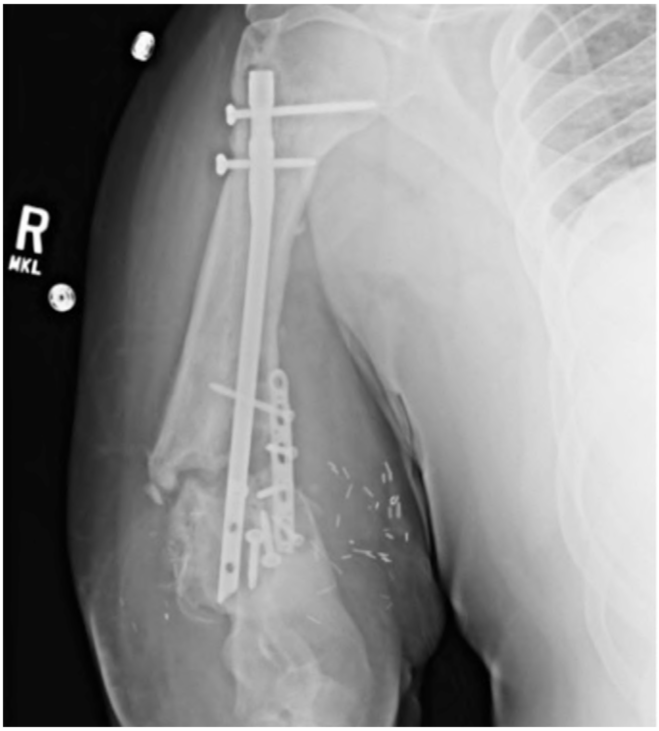

Fig. 7

Fig. 8

Fig. 9

Fig. 7 Plain film radiograph taken 16 months after the index surgery, indicating a diagnosis of right humeral hypertrophic nonunion. **Fig. 8** Plain film radiograph taken after the operation was performed to treat the humeral nonunion. **Fig. 9** Four-year follow-up plain film radiograph.

Humerus fixation was planned using a humeral rod for ease of insertion and to limit periosteal stripping. Standard plating technique was planned for the forearm.

The entire surgery was then rehearsed in a cadaver laboratory to work through potential unforeseen obstacles.

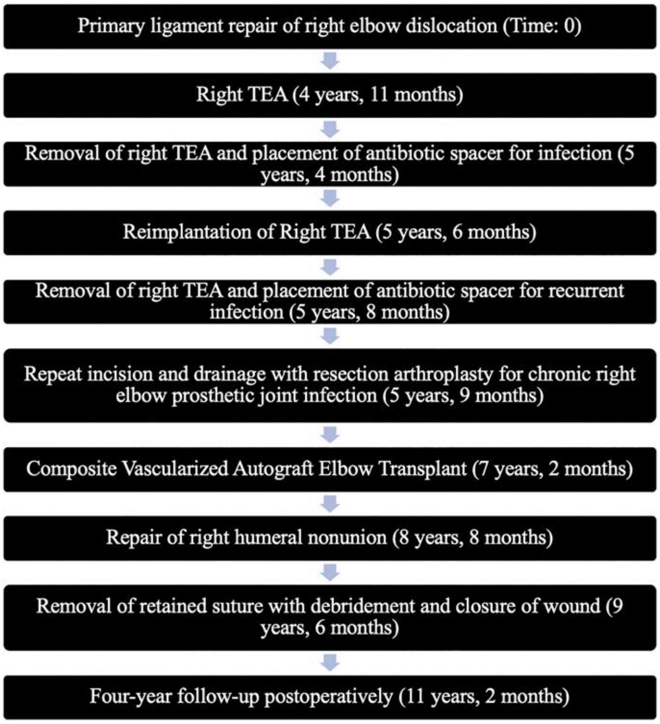

Fig. 10

Timeline illustration of key events. Surgeries/events are listed as time from the initial roll-over motor vehicle accident.

On the day of surgery (Fig. 5), 2 teams worked simultaneously. The plastic surgery team worked on excising the donor left elbow, while the orthopaedic team prepared the recipient RUE. Of note, multiple frozen sections, Gram stains, and cultures were taken at the onset of surgery to rule out infection. A nerve stimulator was used on the RUE to trace and protect all nerves. 3D-printed bony templates were used intraoperatively to determine appropriate cuts for the donor left elbow to ensure proper length and tension in the recipient side. Once dissections were complete, the donor left elbow was excised with its ligaments, biceps/triceps tendons, vessels, and skin paddle intact. The composite vascularized autograft left elbow was then quickly attached to the recipient right humerus and forearm. A humeral rod was used for osteosynthesis proximally. Although the need to correct rotational differences was anticipated preoperatively (Fig. 4), it was decided to preserve the radioulnar synostosis, given the complexity of the surgery; therefore, the planned rotational osteotomy was not necessary. The forearm was instead plated ulna to ulna leaving the forearm in a 40° pronated position. The teams then switched sides; the orthopaedic team completed and closed the above the elbow amputation on the LUE, while the plastic surgery team performed the RUE vessel anastomosis. The anastomosis involved retrograde flow through the radial artery and antegrade flow through the veins. A successful anastomosis was achieved despite friable donor vessels, likely secondary to upper extremity disuse over the previous 7 years.

The biceps tendon and triceps tendons were attached from the donor to the recipient at the appropriate length and tension. The elbow was stable to testing, and there was adequate blood flow to the new elbow and skin paddle. The wounds were irrigated and carefully closed. Final intraoperative x-rays (Fig. 6) were taken, and both the LUE and RUE were appropriately dressed.

The surgery was completed in 12 hours. Postoperatively, the right hand function did not change from preop, and his hand was functional. The partial ulnar nerve palsy (present preop) continued to manifest as mild weakness in grasping and pinching. He was able to fully flex/extend and abduct/adduct digits. Mild varus/valgus elbow instability was also seen.

The forearm osteotomy and LUE stump site healed uneventfully. The right humerus went on to nonunion despite the use of a bone stimulator. There was failure of distal interlocking screws (Fig. 7). This was revised to a double plating of the humerus (Fig. 8), which healed. Of note, the patient did have 1 subsequent surgery for a localized infection with removal of some suture from the triceps repair; this also healed uneventfully. The previously noted ligamentous laxity stabilized over time.

At 4-year follow-up, there has been no clinical or radiographic sign of reinfection (Fig. 9). He is now living independently, is independent with all ADLs, and can ambulate with a cane in his right hand. He has no residual pain. The forearm is fixed at about 40° pronation, and active elbow ROM is approximately 30/120°. Figure 10 represents a timeline of events.

Discussion

Devastating injuries of the elbow are an unsolved problem in the young patient. Although TEA offers a solution, loosening and need for revisions makes this a poor choice.

Total elbow allografts have been used rarely to treat severe elbow injury or loss after tumor resection, trauma, or TEAs[1,4]. However, complications such as nonunion, infection, and resorption remain a challenge[4,5,7]. In this case, the authors present the first composite vascularized autograft elbow transplant from a flail upper extremity to the contralateral upper extremity, which had suffered elbow joint loss secondary to trauma and subsequent TEA with multiple infections.

The use of vascularized bone grafts in large reconstructions has several advantages over nonvascularized bone grafts, such as delivery of growth factors to deeper parts of the graft and reduced risk of graft resorption and infection[8,9].

As this case did not have a precedent, extensive planning was involved. First, a team-based approach was applied. Past literature shows that the addition of a surgeon to an operating team has a favorable impact on hospital length of stay and wound complications[10]. For this complex surgery, the operating team consisted of 3 orthopaedic hand/upper extremity surgeons and 3 plastic microvascular surgeons. In addition, this case emphasizes the importance of using 3-dimensional virtual planning, which enabled the team to make more precise osteotomy cuts (saving valuable operating room time) and plan for rotational correction of the donor radius/ulna.

Postoperatively, it was hypothesized that the patient's instability was due to poor ligament tensile strength in the donor LUE because they had not seen normal stresses for 7 years since the initial injury[11]. Future modifications of this surgery may include reconstruction of the ligaments. However, in this instance, increased use of the arm postoperatively led to greater ligament stability over time.

The patient developed a nonunion of the humerus postoperatively. However, his nonunion was hypertrophic, indicating a failure of fixation and not blood flow. In retrospect, given that the humeral canal was larger distally, it may have been better to use standard compression plating or tension band plating during the first operation rather than using the intramedullary rod. However, in the extensive preoperative planning, we sought expert opinion from surgeons with experience in limb transplantation. Given the extensive scarring, previous endosteal stripping, and the need for speed of fixation with timing limitations for vessel anastomosis, expert opinion favored intramedullary rod fixation.

There have been no recurrent infections in the 4 years since the last surgery. One of the main reasons for attempting this operation over other choices was that better blood flow is associated with increased local delivery of immunologic markers[12] and, therefore, a decreased risk of infection. Although the indication for this surgery is rare, this surgery can be considered in similar trauma cases. This case highlights the importance of a team-based approach and meticulous preoperative planning. ■

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