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ORIGINAL ARTICLE

Elbow vascularized composite allotransplantation—surgical anatomy and technique

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Background: Elbow reconstruction with vascularized composite allotransplantation (VCA) may hold promise in treating end-stage arthritis as no current treatment is both functional and durable. We describe the vascular and gross anatomy of the elbow in the context of VCA procurement and propose a step-by-step surgical technique for human elbow VCA.

Methods: We injected latex in the arterial tree of 16 fresh adult cadaveric upper extremities. We identified and measured arteries and nerves and their branch points relative to the medial epicondyle. Based on our determination of the dominant blood supply to osseous and capsular elbow structures, we derived a cadaveric model of elbow VCA by performing donor preparation on 2 fresh cadaveric upper extremities by elevating a lateral arm flap in conjunction with the vascularized elbow joint. We prepared and transplanted 2 size-matched recipient specimens to refine the surgical technique.

Results: The elbow arterial supply was composed of consistent branches contributing to medial, lateral, and posterior arcades. Preservation of the elbow arterial network requires sectioning of the brachial, radial, and ulnar arteries 12 cm proximal, 1 cm distal, and 6 cm distal to the ulnar artery takeoff, respectively. The supinator, anconeus, distal brachialis, proximal aspects of the flexor digitorum profundus, and flexor carpi ulnaris must be preserved to protect osseous perforators. Articular innervation was most commonly derived from ulnar and median nerve branches. We refined our proposed surgical technique after performing 2 cadaveric elbow VCAs.

Conclusions: Elbow VCA may be technically feasible on the basis of its consistent vascular anatomy and our proposed surgical technique.

Level of evidence: Basic Science Study; Anatomy and Surgical Technique using Cadaver Specimens

Institutional Review Board or Ethical Committee approval is not applicable. This study was approved by the anatomical gifts oversight committee.

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End-stage elbow arthritis is a challenging clinical entity, particularly among young patients for whom activity modification, oral anti-inflammatory medications, bracing, injection, and arthroscopic capsular releases have failed to satisfactorily relieve pain and provide function. Nonsurgical treatment options are of limited efficacy for this population of patients, and surgical treatments have significant drawbacks for active patients. After total elbow arthroplasty (TEA), lifelong limitations on weight bearing are often recommended, ranging from 5-15 pounds.[21] TEA is also associated with a complication rate as high as 44%,[15] and reoperation is frequently indicated.[11] Relatively low 10-year TEA survival rates are a concern, ranging from 53%-81% in the nonrheumatoid population, even with newer generation implants.[16,17] After interpositional arthroplasty, elbow instability[12] and need for surgical revision rates of approximately 10% are known complications.[8,9] Arthroscopic débridement and osteophyte excision may afford increased range of motion and short- to intermediate-term pain relief. However, durability of the procedure and associated long-term outcomes are less clear.[14] Elbow arthrodesis is durable; however, the resulting loss of flexion and extension could compromise function and preclude patients from engaging in certain activities or occupations. As such, arthrodesis is most often reserved for salvage in the setting of prior failed surgical treatments. In addition, nonunion and a high rate of secondary surgery are known complications.[18] Nonvascularized, total elbow osteoarticular allografts have been used to replace the elbow for post-traumatic reconstruction or to address massive bone loss. However, half of the patients suffered a complication, and the total arc of motion was limited to 100°.[4] Clearly, available surgical procedures to address end-stage elbow arthritis are limited, especially for young patients who want to remain active.

Vascularized composite allotransplantation (VCA) has been successful in the context of "reconstructive transplantation" for upper extremity transradial[5,19,20] and transhumeral[1,20] amputees and for patients requiring facial reconstruction.[7] Nonetheless, to the best of our knowledge, reconstructive transplantation of the isolated human elbow has not been reported in the medical literature. Although previous reports described the vascular and neural anatomy of the elbow after intra-arterial injection,[23,24] studies attempting to elucidate a comprehensive surgical protocol to enable human elbow VCA are lacking. Such a protocol must focus on preserving the osseous and neural arterial supply. As such, reports have delineated the techniques and surgical steps needed to procure and to transplant a vascularized composite elbow allograft in a rat model.[22] However, proposed techniques for elbow VCA in humans have not been reported.

This paper describes the arterial and neural anatomy of the elbow in the context of procuring a vascularized composite allograft, preparing the recipient, and transplantation. Based on preserving the arterial anatomy and bone and neural perforators, we propose a step-by-step surgical protocol for human elbow VCA.

Materials and methods

Cadaveric preparation for anatomic studies

This paper describes a step-by-step surgical protocol for human elbow VCA. We obtained frozen upper extremities from fresh adult human cadavers with no known history of traumatic injury or congenital abnormalities. The specimens were allowed to thaw for 24 hours at room temperature before dissection. We used 16 adult elbows to elucidate the arterial and neural anatomy of the elbow. The brachial artery was cannulated using a 16F Foley catheter, and the arterial network was injected with latex rubber (Carolina Biological Supply Company, Burlington, NC, USA) under mechanical pressure using a peristaltic electrical pump (Masterflex, L/S Economy Pump System; Metrohm Nederland, Schiedam, The Netherlands) until the dye was visualized through a minimal longitudinal incision in the long finger pulp. To allow the latex to solidify, we placed the specimens in a cold room (4°C -6°C) for 48 hours before dissection.

We dissected the brachial, radial, and ulnar arteries proximal to distal to identify all branches terminating within the elbow joint capsule and surrounding osseous structures (humerus, radius, and ulna). We measured the number and location of osseous perforators with a ruler. The central portion of the medial epicondyle served as an anatomic reference point for all distance measurements. Similarly, we dissected the median, radial, and ulnar nerves proximal to distal and recorded the number and location of branches from each that penetrated the joint capsule relative to the medial epicondyle. We recorded the origin of each arterial and neural branch.

Deriving a step-by-step surgical technique for elbow VCA

Using 4 additional cadaveric specimens, we performed sequential cadaveric elbow VCA procedures by procuring the donor, preparing the recipient extremity, and transplanting with osteosynthesis. The goals of the procedure were to preserve the recipient forearm, wrist, hand, and neurovascular structures while removing only the elbow joint. We used the detailed arterial and neural anatomic findings from the latex injection and dissection studies to develop a donor elbow procurement protocol that preserves the osseous perforators to the joint capsule, humerus, radius, and ulna. Furthermore, we elevated a lateral arm flap, based on the posterior radial collateral artery, along with the vascularized elbow allograft at the level of the brachial artery proximal to the posterior radial collateral artery takeoff.