Procurement of Hand and Arm Allografts

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Abstract: Upper extremity transplantation has been at the forefront of vascularized composite allotransplantation. There have been more hand and upper extremity transplants than any other kinds of vascularized composite allotransplantation. However, it is a new and evolving field. Reconstructive surgeons are relative newcomers to the field of transplantation, and the procurement of upper extremity allografts has many subtleties that will differ depending on the intended recipient. However, there are certain principles that can be adhered to that this review serves to elucidate.

Key Words: hand transplant, upper extremity transplant, vascularized composit allotransplantation, allograft procurement

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HISTORICAL PERSPECTIVE

Hand and upper extremity transplantation is a field in its infancy. To date, there have been a total of 85 patients who have received upper extremity allotransplants around the world at the time of this writing. The surgical ability to perform an upper extremity transplant has been in existence for some time, but it has been the mistaken notion that the skin is more immunogenic that impaired the early development of vascularized composite allotransplantation (VCA).

It has been said that an upper extremity transplant is "just like a replant." This statement does not take into account the magnitude of the preoperative planning, the vetting of patients through the individual institutions approval process, and the team approach for the execution of the operation, nor the ongoing care for rehabilitation and immunosuppression.

VCA has evolved in conjunction with improvements in immunosuppression. Immunosuppressive agents progressed during the 80s and 90s with the introduction of the calcineurin inhibitors, cyclosporine A, tacrolimus, and mycophenolate mofetil. These new drugs allowed survival of skin-bearing transplants in animals and justified clinical VCA.[1–3]

The first hand transplant utilizing modern immunosuppression was performed in Lyon, France in 1998 by Dubernard et al.[4] A successful hand transplant in the United States performed by the Louisville transplant team soon followed and that patient now represents the longest surviving hand transplant.[5] The field of VCA continues to grow, and we continue to learn about the fate and functional outcomes of upper extremity transplantation as those transplanted are studied over time. With advances in immunosuppression and the quest for the "holy grail" of immunologic tolerance, upper extremity transplantation will continue to evolve and be an accepted means to restore a sense of self, and functional independence to those who have lost upper limbs or hands.

This article will summarize issues pertinent to the donor hand or upper extremity allograft procurement, including logistical, perioperative, and regulatory elements necessary for the donor team to execute a successful transplant.

INDICATIONS/CONTRAINDICATIONS

Approval Processes and Organ Procurement Organization (OPO) Coordination

The donor procurement operation represents a culmination of months, or even years of planning to acquire the necessary approval processes from the Institutional Review Board (IRB), recipient hospital management, financial coordinators, public relations personnel, operating room staff, transplant surgery multidisciplinary staff, supporting surgical and anesthesiology physicians, nursing, and hand therapy to proceed with "listing" a potential hand transplant patient with the local OPO. The regional OPO approval requires significant planning and commitment by the OPO to support a particular program.

The "buy-in" by the regional OPO for a hand transplant program cannot be understated as the OPO will determine how and when a potential hand or arm allograft donor family should be approached. Despite concerns that a paucity of donors would limit the evolution of the field of hand transplantation, these fears have not been borne out as the expertise of the OPOs has led to relatively short waiting times for most hand transplant recipients.[6] For example, the Massachusetts General Hospital patient was listed on September 11, 2012 and after receiving 3 calls for potential donors from the New England Organ Bank, the third call resulted in hand transplantation performed on October 6, 2012. In addition, the University of Pennsylvania worked in close concert with our OPO and had a donor for our bilateral hand transplant within several weeks of listing our recipient. In sum, a strong partnership with the OPO is paramount to success.

Establishing a successful working partnership with the regional OPO and its network of regional coordinators results from understanding the "culture" of the world of transplantation, a tenet not always ingrained in the world of reconstructive surgery. For example, utilizing respectful terminology when referring to the donor procedure ("recovery" or "procurement" in lieu of "harvest") and integrating appropriate measures to show respect for the donor (eg, a moment of respectful silence just before beginning the donor procedure to recognize the donor's gift) go a long way toward developing a successful and fruitful relationship with the OPO and the personnel who drive its mission.

A critical component of this demonstration of respect for the donor is the postprocurement treatment of the donor. Careful, watertight and cosmetic closure of the amputation site is important for 2 reasons: embalming is more successful if the limbs are watertight, preventing the embalming solution from leaking when perfused. Secondly, an adequate soft-tissue taper facilitates prosthetic reconstruction of the limb(s) for the funeral service of the donor.

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Prosthetics can be obtained within a wide range of realism and cost and a number of options should be available to the surgical team. The prosthetic can be placed immediately after procurement, although some teams have suggested providing the funeral home with the prosthetic directly to avoid betadine—or worse, bloodstains—acquired in the OR during the procurement. It is important to realize that "postoperative care" of the donor family may also be required. Communication with the funeral home and regional OPO coordinator is necessary to assure that the donor family is happy with the color, size, and realism of the prosthetic that is brought to the funeral home.

TECHNIQUE

Donor Operation Rehearsal

Almost no procedure in reconstructive surgery affords the opportunity for absolute preparation and run-throughs as the donor operation, which should be rehearsed many times on cadavers before listing the patient, with particular attention to anatomic details relevant to the recipient(s) listed with the OPO for transplant—that is, technical details of the mid-forearm allograft recovery operation should be rehearsed specifically for a recipient with a mid-forearm amputation level.

The rehearsals should be choreographed and videotaped with each team member assigned specific roles in the procedure and the procedure should be timed so that an accurate estimate will be able to be given to the other organ procurement teams at the time of allograft recovery. Sticking to the estimated time goes a long way in building trust and good will among other regional organ transplant teams and will reap benefits in future transplants if the other teams believe your team can accurately predict recovery operation time. The other teams are therefore more apt to allow your team to proceed before recovery of the other organs and complete the procurement with minimal ischemia time. One should realize that reconstructive surgeons are newcomers to this field, and should also respect to the order of procurement in order not to undermine the other teams at the time of harvest.

In addition to dissections before the actual transplant, a "day-of" rehearsal can be an extremely helpful exercise, particularly as specific anatomic details about the donor may be known and the donor operation script modified to account for such details. For example, in the MGH transplant, vascular mapping of the recipient veins revealed a clotted cephalic vein where a peripheral IV had been. This information allowed us to modify the orientation of our donor hand flaps ulnarly to be sure that we captured the basilic vein (which the vein mapping had revealed was patent) instead of the cephalic (Fig. 1). There is usually plenty of time to arrange a cadaver dissection rehearsal between the first call from the OPO regarding a potential donor and the actual transplant, due to the OPO's need to organize many recovery teams and recipients for the various organs to potentially be transplanted. A "day-of" rehearsal also allows the procurement team leader to accurately assess who is available for the recovery and divide tasks accordingly—for example, the MGH transplant took place on a holiday weekend in which some team members who had gone through previous rehearsals were not in town. The day-of rehearsal allowed other team members to step in and fill these roles. The University of Pennsylvania transplant team organized a call schedule so that enough crucial members of the transplant team would be present if the donor became available at all times. This was enacted to avoid the potential situation of not enough team members present to perform the transplant if a donor became available.

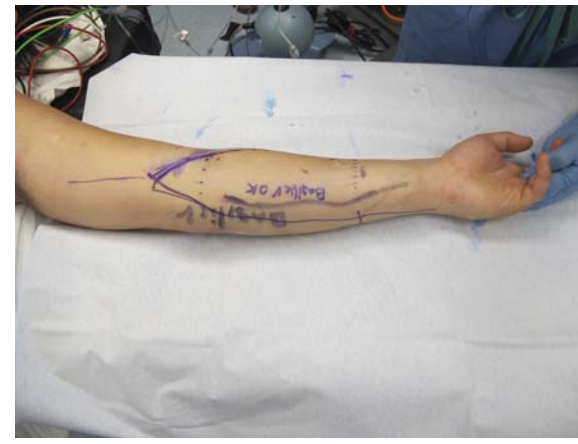

FIGURE 1. Donor forearm with preoperative vein mapping to aid in identification during procurement.

Upper extremity transplantation is a complex reconstructive procedure that involves many steps to be performed successfully. The University of Pennsylvania team developed an upper extremity transplant "playbook" that served as a checklist during all stages of the operation (Table 1). This playbook was devised with the specific recipient in mind and delineated the sequential steps of the operation for both recipient and donor. This playbook was used during rehearsals and during cadaver dissections. The team leader made sure that all teams were appropriately completing their assigned tasks and each step was performed in the appropriate order and in a reasonable time to insure timely completion of the operation. At the time of the transplant, there will be some variables that cannot be accounted for, but by in large the sequence of completion of the operation should be well rehearsed. The playbook allows everyone to "stick to the script" with little ad-libbing to avoid potentially costly errors.

Donor Screening: The Importance of Integration Into Transplant Center Policies

Integrating donor recovery screening policies into your institution's Transplant Center policies represents an important feature of the donor screening process, in light of the recent designation of hand allografts as organs by UNOS/OTPN.[6] Although some specific regulations pertinent to hand transplantation are no doubt forthcoming, most of the processes for solid organ procurement are germane to hand allograft procurement. Transplant compliance officers should envelope language for hand allotransplantation into the institutional policies, paperwork, and Web sites of the transplant division.

Donor Identification

Established guidelines for solid organ transplantation are followed by the OPO to begin the process. The OPO representative accesses the profiles of listed transplant candidates to determine the candidacy of the organ donor—these profiles are detailed and provided to the OPO for each potential recipient when he or she is "listed."

If there is a suitable match, the OPO representative will approach the family after they have already given approval for the gift of life for solid organ donation. If informed consent is given and there are no contraindications for donation, the OPO representative will initiate the process of donor evaluation and will organize hand procurement in conjunction with the

TABLE 1. A Page From the University of Pennsylvania Playbook

(*A*) *Procurement*		
Before procurement		
1	Mandatory review and sign-off of donor source documents	GLDP/CTA Team
2	Inspect donor hands before recovery	CTA Team
3	Donor prep and drape up to axilla, arms abducted	CTA Team
4	Secure pneumatic tourniquet cuff to each arm using 1.0 sutures × 2 for each tourniquet	CTA Team
CTA procurement surgery		
5	Inflate tourniquet cuff for each arm	CTA Team
6	Circumferential incision at mid-humeral region	CTA Team
7	Suture ligate brachial artery and vein. Tie around brachial artery at stump and control bleeding (Leave it long, tag it so it can be embalmed)	CTA Team
8	Identify brachial artery and concomitant veins, median nerve, radial nerve, and ulnar nerve	CTA Team
9	Place vessel loop around medial neurovascular bundle	CTA Team
10	Divide biceps muscle, brachioradialis, and all 3 triceps heads with bovie cautery	CTA Team
11	Transect humerus	CTA Team
12	Surgical ligation of neurovascular structures	CTA Team
13	Transport each hand to backtable (see Backtable Preservation Section 12a-12g)	CTA Team
14	Heparin	Anesthesia
15	Aorta and portal vein cannulation	Abd. Team
16	Cross-clamp	Abd. Team
17	UW solution perfusion	Abd. Team
18	Thoracic and abdominal teams complete procurement	CT/Abd Team
19	Release tourniquets and control bleeding	GLDP
20	Skin closure (interrupted subdermal sutures, followed by staples)	GLDP
21	Send prosthetics w/ donor but do not attach	GLDP
Backtable preservation		
13a	Attach catheter to brachial artery	CTA Team
13b	Perfuse manually until clear efflux from brachial vein	CTA Team
13c	Wrap arm in blue towels, followed by triple bag	CTA Team
13d	Label each arm	GLDP
13e	Label each cooler	GLDP
13f	Right arm to right cooler, left arm to left cooler	GLDP
13g	Depart for HUP	CTA Team
(*B*) *Donor Forearm Preparation*		
1	Posterior incision over the triceps and olecranon onto the shaft of the ulna	
2	Anterior incision over the biceps to the antecubital fossa	
3	Raise a medial skin flap down to medial epicondyle. Skin remains attached to muscle	
4	Trace basilic vein down to elbow and MABC	
5	Trace ulnar nerve from proximal to distal and dissected out of the cubital tunnel	
6	Trace median nerve and brachial artery down to antecubital fossa	
7	Elevate flexor/pronator origin from medial epicondyle and tag	
8	Lateral flap, identify and tag cephalic LABC and SN	
9	Raise lateral skin flap down to lateral epicondyle. Skin remains attached to muscle	
10	Trace radial nerve down to elbow	
11	Elevate brachioradialis from humerus	
12	Elevate mobile wad from lateral epicondyle and tag common extensor origin	
13	Measure distance on recipient stump from lateral epicondyle to end of radius and from medial epicondyle to end of ulna. Mark osteotomy sites on donor	
14	Expose ulna and radius from posterior incision	
15	Elevate muscles from proximal radius and ulna	
(*C*) *Recipient Stump Preparation*		
1	Mark basilic and cephalic veins	
2	Inflate tourniquet	
3	Fishmouth skin incision	
4	Elevate anterior and posterior flaps	

5	Tag basilic and cephalic veins
6	Tag brachial artery and brachial vein
7	Tag medial nerve
8	Tag and transpose ulnar nerve
9	Expose the medial epicondyle
10	Tag radial nerve and radial sensory nerve
11	Expose lateral epicondyle
12	Posterior approach to radial and ulnar shaft
13	Reflect supinator off radius
14	Perform radius and ulna osteotomies at same level
15	Deflate tourniquet
16	Measure distance on recipient stump from lateral epicondyle to end of radius and from medial epicondyle to end of ulna, subtract 2.5 cm
17	Screw 6-hole small fragment plate to ulna, dorsomedial side, proximal hole
18	Screw 6-hole small fragment plate to radius, dorsolateral side (safe zone), proximal hole
(*D*) *Forearm Transplant*	
1	Transport donor forearm to recipient. Perform ulna and radius osteotomy
2	Align donor stump and check length of muscles (flexor/pronator and mobile wad)
3	Align plate to donor ulna
4	Align plate to donor radius, posterolateral side
5	Pronate and supinate to confirm range of motion
6	Drill and insert remaining screws 1 compression just distal to osteotomy, then 4 locking
7	Insert 2 Mitek anchors and attach flexors to medial epicondyle
8	Insert 2 Mitek anchors and attach mobile wad to lateral epicondyle. Untangle
9	Anastomose brachial artery/vein
10	Repair median nerve
11	Repair ulnar nerve
12	Repair radial nerve(s)
13	Recipient skin should be maximally closed proximal to distal. At point where native skin closed, interdigitate transplanted flaps
14	Trim skin flaps: anterior with elbow extended, posterior with elbow flexed
15	Anastomose basilic vein
16	Anastomose cephalic vein, additional veins
17	Time out required to check all neurovascular anastomoses
18	Insert Cook Doppler probes
19	Close skin
20	Photograph each transplanted hand to assist with monitoring for rejection

procurement team's criteria for donor retrieval and allocation. Photographs of the donor hand, blood type, and pertinent medical information are sent to the transplant team leader. The OPO ensures that selection of potential hand donors is completely in accordance with the selection criteria determined by the Hand Transplant Team. Upper extremity transplantation differs from solid organ in that the graft is very visible and must be a good match according to sex, size, and skin tone to achieve an esthetically acceptable outcome. Once the donor is determined to be an appropriate match, the OPO will organize transportation options (plane vs. ambulance depending on the distance between donor and recipient hospitals). Once transportation has been arranged, the procurement team is dispatched to procurement hospital. The recipient is notified early in the process and prearranged transportation brings him or her to the recipient hospital. The recipient is transferred to the operating room at a time adjusted to the distance and travel time for the limb(s) to arrive in the recipient hospital.

At the donor hospital, the OPO will arrange:

(1) Plain portable radiographs of both extremities.
(2) Upper extremity vein mapping by portable Doppler.
(3) Removal of arterial catheters [radial A-line(s)] in extremity of interest.
(4) Removal of upper extremity peripheral IVs, in extremity of interest.
(5) Replacement of lines in femoral or IJ, if needed (ie, for bilateral upper extremity case), that is, central line placement per usual thoracic/abdominal organ harvest.
(6) Documentation of recent peripheral IV placement sites per nursing notes.

Donor Selection Criteria

Brain-dead donors who have met the criteria for Determination of Death are selected by the hand transplant team in conjunction with the OPO. Mandatory requirements are family consent for limb donation, a stable donor (ie, a donor who does not require excessive vasopressors to maintain blood pressure), age between 18 to 60 years, the same blood type as recipient, a negative cross-match, and skin tone within the range deemed acceptable by the listed recipient.

Inclusion

(1) Any potential brain-dead donor considered for solid organ transplant 18 to 60 years of age, either sex.
(2) ABO compatibility.

Exclusion

(1) Unresolved sepsis.
(2) Active CMV, EBV, or TB infections.
(3) HBV+, HCV+.
(4) HIV/AIDS.
(5) Meets CDC high risk criteria.

Donor Workup

(1) Standard serologies for a potential solid organ donor.
(2) Digital picture of skin color.
(3) Upper extremity vein mapping.
(4) Plain portable radiographs of both extremities.
(5) Removal of arterial catheters [radial A-line(s)] in extremity of interest.
(6) Removal of upper extremity peripheral IVs in extremity of interest.
(7) Placement of central lines in femoral or IJ, if needed, per usual thoracic/abdominal organ harvest (that is, for bilateral upper extremity case).
(8) Documentation of recent peripheral IV placement sites per nursing notes.

Technical Details of the Procurement

When arriving at the donor hospital, the team arranges the timing of hand allograft recovery relevant to the other organ procurement teams. Two methods are described below and illustrate 2 different, but acceptable approaches to the donor operation. They differ essentially in where the detailed dissection of structures requiring coaptation is performed—either in situ on the donor, which allows for reperfusion of the allograft before transport to the recipient hospital (the first described approach, MGH team), versus a "cut and run" approach, which has the advantage of flexibility with regard to the other organ procurement teams, and depends on the stability of the donor (the second described approach, University of Pennsylvania team).

With either approach, the best option is to arrange to go first, relative to the solid organ procurement teams. This order is best accomplished with an accurate prediction of time (eg, "we will be exactly 2 h and 20 min total," for instance). The extremity of interest is prepped, a surgical time-out initiated, and a moment of silence is undertaken to acknowledge the donor's gift of life. At this time, a 5000 U IV heparin bolus is given systemically and after 3 minutes the tourniquet inflated to the extremity.

The MGH performed the extremity allograft procurement under tourniquet control, which included isolation of 5 cm of antecubital vein and brachial artery proximal to the elbow crease. The artery and vein are not yet cut, as reperfusion after the tourniquet run will be performed before the official beginning of ischemia time. All pertinent structures are dissected out and tagged with a color-coded titanium tags with hole punches that are etched with the structures to be labeled (ie, all nerves are gold tags, "median nerve"–etched tag is tagged to donor median nerve). Knots are tied down to the each structure so long tails of suture that can become tangled are avoided.

Once all structures are dissected out and tagged, the tourniquet is let down and reperfusion appropriate to the length of time the extremity was under tourniquet occurs (eg, 20 min for 2 h of dissection and tagging).

This reperfusion period represents a good time to assess the progress of the recipient operation, which should be proceeding concurrently at the recipient hospital with the recipient transplant team. Reperfusion is then followed by sharp disarticulation at the elbow joint. This time point marks the official beginning of ischemia time for the entire case.

The extremity is then flushed on the backtable, first with heparin through the brachial artery with heparin (100 U/mL) and then with a preservative solution. University of Wisconsin (UW) solution or HTK are used for preservation—some teams prefer HTK because it is less viscous than UW, but has the disadvantage of being not readily available, expensive, and stocks need to be frequently replaced. OPOs do not commonly provide HTK, so the donor team would need to bring their own. In contrast, UW is commonly provided by the OPO.

The allograft is then placed on ice in standard replant fashion inside a sealed bag that will prevent maceration or frostbite from the melting ice (ie, wrapped in moist sterile gauze and placed in a sealed polyurethane bag) and transported in a sterile container with iced water at 4 to 6°C. While the backtable work occurs, other teammates close the suture at the elbow disarticulation site in watertight fashion.

The thoracic team can then give the standard 30,000 U of heparin and proceed with cross-clamp and organ recovery. The prosthesis to be attached to the elbow disarticulation site is provided at this time unless arrangements are to be made to deliver the prosthesis directly to the funeral home.

In contrast to the MGH approach, the University of Pennsylvania procurement team arranged for a very rapid procurement at a higher level of the extremities in the donor in order to not impede the additional teams for organ recovery. This was done under tourniquet control and took a total of 20 minutes for identification of the key structures in the mid-upper arm. The proximal aspect of these structures were ligated and then divided. The tourniquet was then deflated and hemostasis was insured. The skin was then closed with a running nylon suture. The donor arms were then flushed with University of Washington solution and placed on ice. The final preparation and tagging of key structures of the donor arms was prepared on a backtable in the operating room with the recipient where there are less time constraints. Preetched, sterilized tags for all the vital structures of interest were vital in the operating room to avoid the need to reidentify structures repeatedly and greatly facilitated the anastomoses and coaptations (Fig. 2).

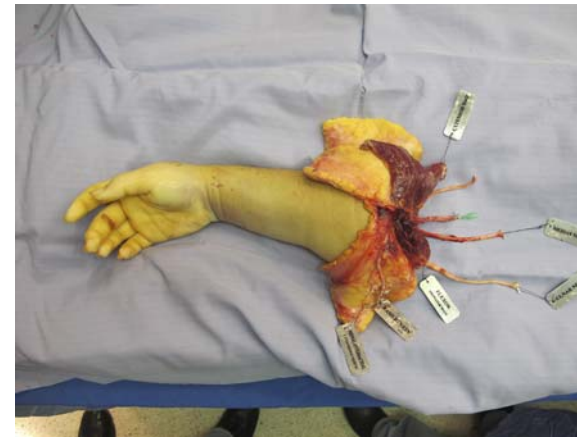

FIGURE 2. The procured forearm allograft with the preprepared anatomic tags in place.

Upon arrival at the recipient hospital, the transplant then ensues. On the basis of the preoperative assessment of the recipient, tissue requirements from the donor will be known. The recipient team will know exactly what measurements are necessary for the donor team to proceed. The recipient team will need to clearly identify the amount of nerve, artery, and veins required for transplantation and communicate any game-time adjustments to the donor team. A portable donor recovery team kit with a battery-powered saw, the anatomic tags, and a hand surgical kit are helpful to account for any equipment shortcomings of the donor hospital as smaller hospitals may not have all the necessary tools. We developed a University of Pennsylvania travel kit that included a cooler large enough to facilitate placement of both arms, UW solution, bags large enough to accommodate the arm, and a Gigli saw if needed.

COMPLICATIONS

Complications after upper extremity transplantation can be divided into early and late. The early complications are ones that hopefully can be avoided with judicious rehearsals and meticulous procurement and preparation. Ensuring a reasonable allograft of appropriate size, length, and match through donor selection will limit the opportunity of size mismatch of bone, vessels, or nerves. One must have adequate inflow of the donor arm and outflow. Many donors will have had peripheral IV catheters and arterial lines for invasive monitoring. This may limit perfusion of the hand distal to the wrist crease if the radial artery is thrombosed from excessive attempts at radial artery cannulation (Fig. 3). The superficial peripheral veins may be thrombosed secondary to IV access and must be assessed at the time of procurement to make sure that the donor arms remain a viable organ. Our patient at the University of Pennsylvania, unknown to us at the time of surgery, had a prior brachial artery cutdown during her previous surgeries and resuscitation. This resulted in a significantly narrowed luminal diameter of the patient's right brachial artery requiring resection of the brachial artery back to a very proximal level. Despite harvesting the donor arm with a very long segment of artery, we had to utilize a reversed interposition cephalic vein graft from the donor arm and noted to maximize the inflow to the transplanted arm. This segment was not visualized on the patient's preoperative imaging.

The most dreaded late complication after upper extremity allotransplantation is that of rejection and poor functional outcome. We had a very specific protocol for biopsies of the transplanted arms at specific time points to monitor her for signs of rejection that were not clinically apparent.

MGH Case Example—Distal Hand Allotransplantation

Patients with a history of circumferential extremity burns may have a paucity of cutaneous veins due to their initial injury or prior surgical intervention, which commonly entails debridement and skin grafting. A volar forearm extension can serve to increase the vessel caliber for anastomosis and improve the soft-tissue pliability for gliding of tendons.

The MGH patient is a 44-year-old, left hand–dominant male who sustained 50% total body surface area burns in a nightclub fire in 2003. His injury resulted in a metacarpal level amputation of his left hand with a truncated thumb, contracture of the first webspace, and a 45-degree fixed flexion contracture of his wrist. In prior operations, the patient's forearm was extensively debrided and circumferentially covered with skin graft.

Preoperative ultrasound studies demonstrated the absence of cutaneous veins for use during transplantation. After comprehensive preoperative consideration, the patient underwent unilateral left hand transplantation with a volar forearm extension in October of 2012. The radial artery and basilic vein anastomoses were performed in the proximal forearm 4 cm distal to the antecubital fossa, with inflow through the volar forearm skin into the hand with reciprocal outflow. The ulnar artery and vena comitans anastomoses were performed in the distal forearm immediately proximal to the wrist crease. Single weave tenorrhaphy was performed using the "Brown" technique for all tendons. Osteosynthesis was performed 3 cm proximal to the radiocarpal joint, and median and ulnar neurorrhaphies were performed distally at the palmar crease (Fig. 4). Total cold ischemia time was 5.5 hours. The patient began protected active motion therapy on postoperative day 1, and tacrolimus levels have been maintained at 8 to 12 ng/mL to maximize nerve regeneration. Currently, at 1-year postoperatively, the patient has sensibility to the level of his fingertips and has had return of both extrinsic and intrinsic hand function. No rejection episodes have been observed to date clinically or histologically.

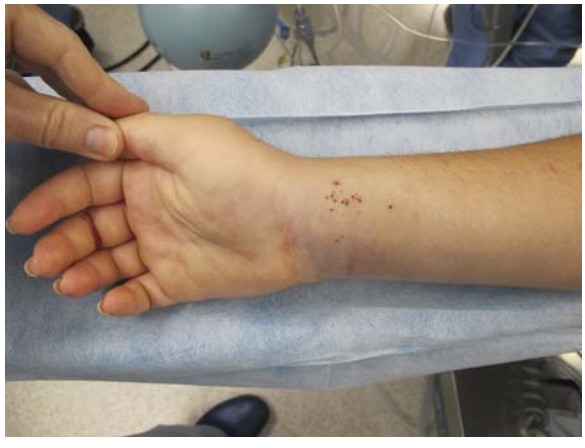

FIGURE 3. The donor forearm with evidence of multiple cannulations of radial artery.

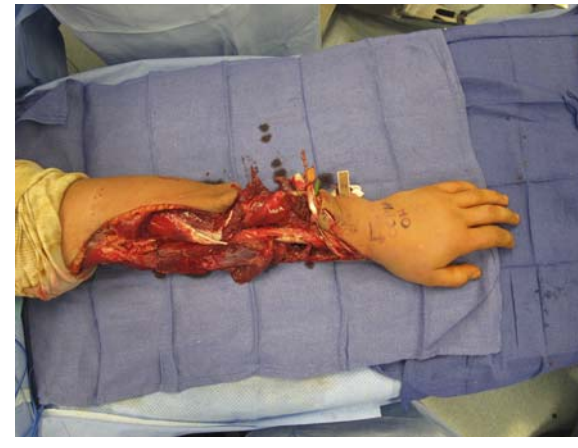

FIGURE 4. Donor allograft with osteosyntheses performed with tenorrhaphies and coaptations to be performed at wrist level.

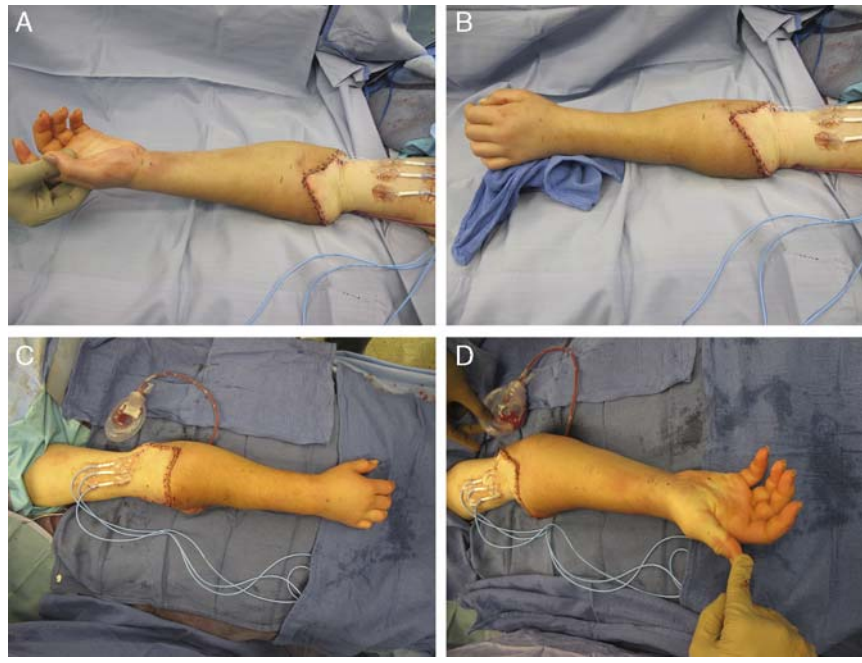

FIGURE 5. A–D, The completed transplant with interdigitating ulnar and radial skin flaps.

University of Pennsylvania Case Example—Bilateral Below Elbow Transplantation

Our patient at the University of Pennsylvania was a 27-year-old, right hand–dominant female who developed intra-abdominal sepsis from a bowel resection. The patient required resuscitation and high-dose pressors which resulted in the loss of her bilateral legs below the knees, and her bilateral arms below the elbows in 2007, rendering her a quadrimembral amputee. The patient was evaluated at the University of Pennsylvania in our hand transplant program in 2010. She ultimately became a candidate for bilateral upper extremity transplantation and was listed on June 13, 2011. On September 21, 2011, a suitable donor was located by our OPO. The donor arms were noted to be of appropriate size, color match, and matched for transplant according to our protocol.

The procurement team was dispatched to an outside hospital where the donor arms were harvested under tourniquet control at the level of the mid humerus. The arms were then flushed with University of Washington solution, placed in a bag and on ice. The arms were then transported to the University of Pennsylvania where the remaining critical structures were dissected and tagged and the redundant intervening soft tissue was resected and preserved if needed. The ulnar and radial shafts were then measured from a fixed point on the donor and recipient to facilitate appropriate length. The team at the University of Pennsylvania had simultaneously prepared the bilateral recipient forearms. Both ulnar and radial skin flaps were designed to interdigitate with each other from both the donor and recipient arms (Figs. 5 A–D). Osteosynthesis was performed first, followed by fixing the flexor pronator mass to the medial epicondyle, and the extensor mass to the lateral epicondyle. End to end of brachial artery anastomoses were then performed bilaterally with interrupted 8-0 nylon. The venous anastomoses of the brachial artery comitantes were performed with the Synovis venous coupler (Synovis, Birmingham, AL) followed by end-to-end anastomoses of the basilic, and cephalic veins also with the venous coupler. As noted previously, the right brachial artery anastomosis required revision with an interposition, reverse cephalic vein graft from the donor arm secondary to a stenotic segment of the native brachial artery of the recipient. There were no tenorrhaphies required as we fixed the flexor pronator mass and extensor mass as units without individual tenorrhaphies. The skin flaps were then interdigitated so as to provide for unrestricted range of motion (Figs. 5 A–D). The implantable Cook Dopplers (Cook, Bloomington, IN), visual examination, and distal pulse checks were used for postoperative monitoring. The patient was maintained on our predetermined immunosuppressive regimen, including tacrolimus, which has been maintained within the therapeutic range since the time of transplantation.

In the intervening 2 years postoperatively, the patient has had 3 episodes of rejection, (grade I, II, II) managed with topical tacrolimus and intravenous steroids, and has excellent extrinsic and intrinsic function of her transplanted arms and hands. She has undergone revision of the interdigitating skin flaps secondary to redundant soft tissue and a desire for improved cosmesis.

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