



The First Bilateral Pediatric Hand Transplant



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Since the first successful hand transplantation performed in France in 1998, the field of vascularized composite allotransplantation (VCA) has gained widespread acceptance as a means of reconstruction in upper extremity amputees. Until recently, hand transplants had only been performed on adult patients with 72 patients having received a total of 107 transplanted hand or arms over the past 17 years.¹ Under the guidance of Drs. L. Scott Levin and Benjamin Chang, the CHOP Hand Transplant Team was formed in the fall of 2013 in conjunction with the Shriners Hospital for Children to pursue the first ever hand transplant in a pediatric patient. After one and a half years of planning and just under 11 hours in the operating room, this goal became a reality. On July 7, 2015, Zion Harvey became the first child to receive a double hand transplant.

At the age of two, Zion was hospitalized with staph aureus bacteremia and sepsis resulting in fulminant renal failure and bilateral below knee amputations, left upper extremity transcarpal amputation and right transradial amputation. He underwent a successful renal transplant from his mother two years later. Zion, now 8, adapted well to his lower extremity prostheses, but unfortunately failed a trial of passive hand prostheses. After initial consultation with Dr. Kozin and Dr. Zlotolow at the Shriners Hospital, Zion was referred to CHOP to determine his eligibility for a vascularized composite allotransplant.

Hand transplantation in a child carries significant ethical considerations. In addition to opportunistic infections, lifelong immunosuppression puts patients at significant risk of *de novo* malignancy compared to the general public (SIR = 1.4-3.6), with younger recipients even higher risk than their adult counterparts (SIR = 2.2-2.4).^{2,3} This risk has thus tempered much enthusiasm about VCA in pediatric patients. By virtue of his history of renal transplant, however, Zion was a uniquely qualified candidate, as the procedure and postoperative immunosuppressive regimen would not put him at increased risk for malignancy.

A multidisciplinary team was formed, including physicians from orthopedic surgery, plastic surgery, transplant surgery, pediatrics, cardiology, infectious disease, nephrology, anesthesia and psychology, as well as members from social work and physical and occupational therapy. Zion was evaluated by each member of the team prior to being listed for the transplant. Several rehearsals of the surgical procedure were held in the fresh tissue laboratory to achieve an efficient surgical protocol. CTs of his forearms were used to create 3D printed models and cutting guides which would be used intraoperatively to improve efficiency through precise osteotomies of the radius and ulna and accurate plate

placement. 3D models of an upper extremity for a child of Zion's weight and stature were made to allow for appropriate size match at the time of procurement. After detailed informed consent, Zion was listed and to the surprise of many, a donor was found in a matter of 10 short weeks.

The procedure was divided into four parts with three surgeons on each team: one team to prepare each donor hand (2) and one team to prepare each recipient forearm (2). The patient was brought to the operating room and dissection of the recipient forearms was begun while the donor hands were simultaneously dissected with all of the neurovascular structures and tendons meticulously labeled. The 3D printed cutting guides were then used to make precise osteotomies and drill holes prior to plating. The donor hands were plated first and then brought to the patient where they were fixated to the recipient radius and ulna bilaterally. Ulnar arteries were anastomosed and the donor hands were reperfused to end ischemia time and to allow for venous egress to flush preservative solution prior to continuing with the reconstruction. Next, radial arteries were anastomosed along with the venae comitantes of both arteries, followed by repair of the median and ulnar nerves and the volar tendons. The hands were then pronated and the dorsal tendons and radial nerve branches were repaired. After closing skin, Drs. Levin and Chang notified Zion's family of a successful operation as the patient was brought to the intensive care unit to recover.

Revision of the right arterial and venous anastomoses was required on the first postoperative day due to an acute arterial thrombus. Zion's recovery was closely monitored by a multidisciplinary team, with weekly skin biopsies to monitor for signs of rejection during the first 12 weeks after his surgery.^{2,3} Despite low grade rejections (grade 1-2), Zion responded well with modifications to his immunosuppression regimen. Six weeks after his transplant, there was evidence of bone formation at his osteotomy sites. A protocol of intensive physical and occupational therapy was started early in his postoperative course to allow for tendon and nerve gliding. Zion continues to engage in intensive physical and occupational therapy with continually improving function and sensation of his new hands. He can now perform activities of daily living with his hands including eating and writing.

This marks an exciting milestone in the field of reconstructive surgery. This goal could never have been realized without important contributions from many people, including the tireless work of the entire CHOP team and the diligent leadership of Dr. Chang and Dr. Levin. We must also thank the family of the donor who, despite their tragedy, found a way to help others. But most importantly, we owe the greatest gratitude to the unrelenting courage and exquisite character

of Zion and his family for trusting us with his care. We look forward to watching Zion grow into an amazing young man and learning from his experience as more children stand to benefit from vascularized composite allotransplantation.

References

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