Venous Bridge Arterial Grafting for Thumb Replantation

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Abstract

Background: The purpose of this study is to describe a novel technique using an interposition vein graft for thumb replantation in these severe avulsion injuries. **Methods:** From 2002 to 2012, 8 patients underwent interposition venous bridge grafting from the dorsal radial artery at the anatomic snuffbox to the ulnar digital artery of the thumb. All patients had a traumatic thumb amputation with a severe injury to the ulnar digital artery. The technique began with bony stabilization; the radial artery at the anatomic snuffbox is exposed, vein graft harvested, and microsurgical end-to-side (proximally) and end-to-end (distally) anastomoses are carried out. **Results:** The average time to the operating room was 7.4 hours and time to reperfusion was 9.5 hours. At 3.1 years of follow-up, all 8 thumbs remained viable, without any need for revision procedures. The only complication was a metacarpal shaft nonunion treated successfully with iliac crest bone grafting. At last follow-up, all patients reported no or mild pain, with an average metacarpophalangeal (MCP) range of motion of 46.5°, and intact but diminished 2-point discrimination. All patients were able to return to work full-time. **Conclusions:** Due to the challenging nature of thumb avulsion injuries and the pronated position of the thumb, novel salvage alternatives are important. We describe a technique when no proximal vessels are available, using a vein to bridge the dorsal radial artery to the ulnar digital artery of the thumb. This novel arterial reconstruction has shown promise in thumb replantation associated with severe avulsion injuries.

Keywords: thumb replantation, bridge arterial grafting

Introduction

Significant advances in microsurgical techniques within recent years have enabled survival of 80% to 90% of replanted digits.^{3,7} However, replantation is much more difficult in patients with crush or avulsion injuries. Traditionally, these injuries were considered by some to be a contraindication to finger replantation, due in part to the severe damage to the vasculature associated with these injuries. The damage to the small vessels often tracks proximally and distally to the level of amputation, compromising the long-term patency of a primary anastomosis. Furthermore, when replantation is attempted, fingers that suffer avulsion injuries have poor functional outcomes after replantation.^{3,7,11,12}

Interposed or bridging vein grafts have shown promise in salvaging avulsion injuries.^{1,2,5} The thumb is particularly unique in that microsurgical anastomosis of the vessels can be challenging secondary to its pronated position relative to the other digits. In addition, obtaining adequate exposure and positioning of the thumb can be challenging under an operative microscope. When treating avulsion injuries to the thumb, where the proximal digital arteries often have intimal damage, an alternative option is necessary. For thumb

replantation, we present a technique to reconstruct thumb arterial circulation. The purpose of this study was to describe the technique of using an interposition venous bridge grafting from the dorsal radial artery at the anatomic snuffbox to the ulnar digital artery of the thumb as well as to report its outcome.

Methods

Demographics

From January 1, 2002, to December 31, 2012, 8 patients underwent bridge grafting from the dorsal radial artery to the ulnar digital artery of the thumb at our institution. The patients were identified if they had a traumatic thumb amputation with a severe injury to the ulnar digital artery that precluded primary arterial repair. Reconstruction was performed using a vein graft from the volar forearm to

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Figure 1. The proximal and distal stumps are inspected for viability of the ulnar and radial digital arteries, as well as digital nerves and dorsal venous outflow.
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Figure 2. Midaxial incisions on radial and ulnar aspects of thumb are used to expose the radial and ulnar digital arteries, nerves, and dorsal outflow veins that are then inspected for their viability.
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bridge between the dorsal carpal branch of the radial artery in the anatomic snuffbox and the ulnar digital artery of the amputated thumb. Institutional review board approval was obtained prior to beginning the study.

Surgical Technique

The distal amputated digit and proximal stump are prepared in the usual fashion. After a thorough debridement of any contamination remaining in the distal digit, its preparation is then begun by performing midaxial incisions on radial and ulnar aspects of thumb (Figure 1). The radial and ulnar digital arteries, nerves, and dorsal outflow veins are then exposed and inspected for their viability (Figure 2). To perform this flap, the ulnar digital artery on the amputated thumb should be viable without evidence of damage tracking too distally in the stump. To prepare the flexor pollicis longus (FPL) and extensor tendon for later repair, a locked grasping tendon suture is placed into each tendon. Next, the bones are prepared for either K-wire stabilization or tension band compression, depending on the level of the amputation.

The proximal stump is then prepared after a thorough debridement of any nonviable tissue and gross contamination. The remaining stump is shortened with a saw or rongeur. A modified Bruner incision is made over the first web space, raising radial and ulnar flaps to identify the digital arteries, nerves, and potential venous outflow. The FPL tendon is then identified, tracing it back to the flexor carpi radialis (FCR) subsheath if needed. After identifying the proximal vasculature, FPL, and extensor tendons, the bone ends are then approximated and secured in place prior to the arterial anastomosis.

After bony stabilization, revascularization is then begun. If the proximal ulnar and radial arteries are not available,

the radial artery at the snuffbox is then exposed using a dorsal incision proximally. Once the snuffbox has been exposed, the arm is supinated to allow a volar vein to be harvested. Beginning proximally at the wrist crease, a volar vein is exposed and harvested for the graft (Figure 3). The vein is then reversed and prepared for the anastomosis (Figure 4). Either the proximal or distal anastomosis can be done initially, depending on position and technical difficulty. The anastomosis typically is begun at the radial artery in the anatomic snuffbox. Using a microscope, an end-to-side anastomosis of the vein graft to the radial artery is performed using a 9-0 nylon suture. A subcutaneous tunnel is then made to bring the other end of the vein graft in proximity to the ulnar digital artery. The ulnar digital vessel is identified and freed up distally. It is resected until there is no evidence of intimal damage. An end-to-end anastomosis of the bridging vein graft to the ulnar digital artery is then performed. A sponge soaked in papaverine is then placed in the thumb and inflow reestablished.

The dorsal veins are then anastomosed, using vein graft if needed. The FPL and extensor tendons are repaired or grafted, and skin is closed in the usual fashion. The thumb is placed in thumb spica postoperatively.

Statistical Analysis

Descriptive statistics will be used to summarize the data, including percentages and counts for categorical and ordinal data and medians and interquartile ranges (IQRs) for continuous data. The association between surgical outcomes and microsurgical replantations will be tested using the Spearman correlation. As there are significant confounders in patient

Figure 3. A volar vein is exposed around the proximal wrist crease and harvested for the graft. The vein is then reversed and prepared for the anastomosis.

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outcomes, we will also analyze the outcome measures using univariate regression analysis. All analyses will be carried out using the JMP statistical software package (Version 8; SAS Institute Inc, Cary, North Carolina). A *P* value of less than .05 will be considered statistically significant.

Results

Among the 8 patients who underwent the ulnar digital artery to radial artery thumb replantation, all 8 were males, with

Figure 4. The microsurgical end-to-side (proximally) and end-to-end (distally) anastomoses are carried out using a 9-0 nylon suture.

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an average age of 42 years (range, 21-60). There were 2 smokers, 7 laborers, and 1 patient with diabetes mellitus. The mechanism of injury was an avulsion-type injury in all 8 patients. The location of injury was metacarpal shaft in 2 patients, metacarpophalangeal (MCP) joint in 5 patients and interphalangeal (IP) joint in 1 patient. All cases were performed in the emergent setting. The average time to the operating room was 7.4 hours (range, 4-14) and the average time to reperfusion was 9.5 hours (range, 6-16). After the arterial anastomosis, 7 patients had an anastomosis of 2 veins, while 1 patient had 1 dorsal vein anastomosed. Concomitant thumb procedures included MCP joint fusion in 2 patients, IP joint fusion in 1 patient, and radial collateral ligament repair in 2 patients.

At an average of 3.1 years of follow-up (range, 0.1-9.3), all 8 thumbs remained viable, without any revision procedures performed for the original anastomosis. There was only 1 complication in the follow-up period: a metacarpal shaft nonunion treated with iliac crest bone grafting 3 months post-operatively. The nonunion went on to heal without complication. Two patients required a full thickness skin graft and 1 patient required a free rectus abdominis and eventual split thickness skin graft for additional injuries to the hand.

Of the 5 patients with greater than 1 year of follow-up, all patients were able to return to work full-time. All patients reported no or mild pain at the last follow-up. The average MCP range of motion was 46.5° when not fused. All patients had intact, but diminished 2-point static discrimination compared with the other thumb.

Discussion

There have been tremendous advances in microvascular anastomosis techniques in recent years. Although a recent review of 2273 replantations demonstrated an 86%

survival rate, the survival rate dropped down to 66% in another systemic review of 442 replantations associated with severe finger and thumb avulsions injuries.^{4,9} These severe crush or avulsion injuries of the thumb are very challenging when primary microvascular anastomosis is not available. Due to the critical role the thumb plays in hand function; microsurgical replantation of the severed thumb should be attempted if at all possible. Traditionally, avulsion injuries were associated with poor outcomes.^{3,4,7,11,12} Successful restoration of perfusion to the amputated digit relies on resection of the damaged vessel proximally and distally. Without an adequate debridement of the injured vessel, it is much more difficult to restore and maintain blood flow through the artery. To achieve this, bridge venous grafting enables the surgeon to resect a large amount of the injured vasculature. These interposed veins for arterial repair have shown promise in salvaging avulsion injuries.^{1,2,5,8,10,13} However, when there is significant proximal vessel damage preventing end-to-end anastomosis, the reconstruction options are limited. Especially in thumb injuries, it is important to consider all possible reconstructive options to salvage the digit, including vein grafting and even adjacent digital arterial interposition.

We describe an arterial bridging technique in cases when the proximal digital vessels have intimal damage tracing back to their origin. To reconstruct these thumb avulsion injuries, a venous graft is performed from the dorsal radial artery to the ulnar digital artery of the thumb. The direct line of anastomosis from the ulnar digital artery of the thumb to the radial artery in the anatomic snuffbox allows the hand to be easily positioned under the operative microscope, and the lesser digits are no longer impeding the visualization. This technique was performed in 8 thumbs over a 10-year period for traumatic avulsion injuries. The ulnar digital arterial bridge grafting to the radial artery was performed using volar forearm veins. Seven patients had 2 veins reconstructed, whereas 1 patient had only 1 vein anastomosed. All 8 thumbs survived, without any need for anastomosis revisions. Patients did very well overall, with minimal pain and reasonable function at the last follow-up. There was 1 complication in the follow-up period, including a patient who required bone grafting for metacarpal shaft nonunion at 3 months postoperatively.

This technique should be considered when patients suffer an avulsion injury of their thumbs with significantly limited arterial reconstruction options. If the radial digital artery and proximal ulnar digital artery is severely damaged, there should be consideration for this technique. It does require the distal ulnar digital artery to be patent. In our experience, it is critical to carefully evaluate the damage to the arterial intima in the proximal and distal stumps of the radial and digital vessels. It is very important to be aggressive in resecting all damaged vessels before beginning the anastomosis.

Of note, there was 1 patient who was not included in our series who underwent distal ulnar digital artery to proximal radial digital artery anastomosis. Although initially successful, this patient's anastomosis failed within 10 days of the operation and required a revision amputation. Although a comparison group of patients who did not undergo bridge grafting is lacking, we believe it highlights that if the need for an aggressive resection of damaged vessels without hesitation to use a vein graft if needed.

Although it is difficult to compare the results of replantation for avulsion injuries secondary to the heterogeneity of the injury patterns and reconstruction techniques, recently, there have been acceptable results with vein grafting in avulsion injuries.^{1,2,5,8,10,13} In a study by Hyza et al of 6 cases of Urbaniak type III ring avulsion injuries, radical resection of the damaged vessels and interposition vein grafting led to 100% survival and reasonable functional outcomes.⁵ In another study examining 9 type II ring avulsion injuries, Van der Host et al demonstrated successful grafting on the 7 fingers when vein grafts were used, whereas the 2 where vein grafts were not used did not survive.¹³ Akyurek et al used a similar technique involving long vein grafts to reconstruct type III ring avulsion injuries in 7 patients.² Although there were 2 cases of late arterial failure, the authors reported an 85% success rate.

Although there are few studies examining similar reconstructive options solely for the thumb, our results are comparable with these prior reports. We agree with the principle of resecting proximally enough to avoid any damaged vessel to restore blood flow through healthy vascular endothelium. Jin et al described a similar arterial bridge grafting technique to the one reported in our study.⁶ In that series, 13 patients underwent bridge grafting as part of thumb replantation. At an average of 11-month follow-up, all 13 thumbs had survived, with an average 2-point discrimination of 6.5 mm with good or excellent results in 12 of 13 fingers. The arterial bridge grafting technique in this study enables surgeons to use the dorsal radial artery as an alternative proximal blood supply for the ulnar digital artery of the thumb.

In conclusion, avulsion or crush injuries to the thumb are very challenging to salvage. However, given the critical role of the thumb, it is important to consider every possible replantation option in these injuries. Bridge grafting using a vein to bridge the dorsal radial artery to the ulnar digital artery of the thumb represents a promising technique for surgeons to consider. This novel arterial reconstruction has shown promise in thumb replantation associated with severe avulsion injuries.

Authors' Note

Investigation was performed at the Mayo Clinic, Rochester, Minnesota.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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