Use of an Intra-Arterial Catheter as a Provisional Conduit for Regulated Outflow Management in the Setting of Artery-Only Digital Replantation

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Abstract

Keywords

- arterial catheterization
- artery-only replantation
- artificial conduit
- digital replantation
- fingertip amputation

Successful replantation of distal digital segments necessitates the establishment of sufficient outflow to minimize congestion and progressive tissue necrosis. In cases where only arterial anastomosis is feasible, an artificial outlet must be provided to maintain physiological requirements until microvenous circulation regenerates. This can be accomplished using any number of “exsanguination techniques” designed to facilitate egress through ongoing passive blood loss. Although reportedly effective, these measures are imprecise and carry a substantial risk of infection, scarring, and/or uncontrolled hemorrhage. Herein, we describe a preemptive alternative for provisional venous drainage, whereby direct catheterization of a distal arterial branch is used to enhance the precision of outflow management following artery-only digital replantation. The establishment of intravascular access, using the technique described, permits remote manipulation of the microcirculatory environment through timed administration of heparinized saline and regulated removal of controlled volumes of blood.

Technical Point

Replantation of digits distal to the insertion of the flexor digitorum superficialis (i.e., Sebestin zone I) is not commonly performed in the United States. This operation is technically challenging, and the perceived functional loss caused by a missing fingertip is considered negligible in most cases. Nevertheless, high rates of survival (80–90%) and return to work (98%), improved digital motion, and reduced pain and disability scores have been reported following replantation of distal digital segments.¹ Success in this scenario is intimately dependent on the establishment of sufficient outflow to minimize congestion and the onset of progressive tissue necrosis. In the posttraumatic state, however, extensive crush and/or avulsion injury, prolonged ischemia time, and poor vessel quality can limit the availability of distal veins that are suitable for anastomosis.

In cases of artery-only replantation, provisional venous drainage is required to maintain minimal nutritive flow until microvenous circulation regenerates (i.e., 4 to 5 days).² This can be accomplished using any number of “exsanguination” techniques designed to facilitate egress through ongoing passive blood loss. Medicinal leech therapy, in particular, has proven effective for surgically uncorrectable venous insufficiency, with salvage rates as high as 60 to 80% in the setting of compromised replants/flaps.³ Due to the high prevalence of associated complications (21.8%), however, leeches are not advocated as routine prophylactic therapy for impending venous congestion.³ Other reactionary measures including controlled surgical wounding, nail plate removal, and direct subcutaneous heparinization demonstrate variable therapeutic effect and carry a substantial risk of infection, scarring, and/or uncontrolled hemorrhage.

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As a preemptive alternative, Kim et al described the use of an externalized intravascular stent to promote passive drainage from distal fingertip replants.⁴ Although effective (salvage rate: 87.5%), blood loss with this approach is unregulated and may be insufficient for more proximal replants and/or those complicated by worsening venous stasis. Herein, we describe a modified technique for Sebastin zone 1 artery-only replants, whereby direct microcirculatory access is established using a digital arterial catheter with a stopcock valve to regulate passive outflow, local heparin administration, and interval decompression of stagnated blood.

Following debridement and operative fixation, the amputated part is incised longitudinally along the length of its volar surface to facilitate exposure of both neurovascular bundles (► **Fig. 1**). Careful dissection and anastomosis of the proper digital arteries is performed under microscopic guidance using standard microvascular technique with 10–0 nylon suture. Limited undermining throughout this process is key to the preservation of arborized nutrient vessels that perfuse the surrounding compromised soft tissues. In the absence of reliable venous targets, the arteries are traced distal to the insertion of the profundus tendon, where the central artery originates from the distal transverse arch in the pulp (► **Fig. 2**).^{4,5} Meticulous dissection along the central artery often reveals one or more branches of sufficient caliber (0.4–0.5 mm) to permit direct cannulation with a 24- to 26-gauge pediatric angiocatheter. Once identified, the distal arterial branch is ligated and divided with an oblique cut to maximize the luminal cross-section available for anastomosis. The catheter is then inserted tangentially through the proximal volar skin flap and anastomosed to the cut end of the distal artery using paired 10–0 nylon sutures, positioned 180 degrees apart (► **Fig. 3**). Care must be

Fig. 1 Proximal Sebastin zone I amputation involving the left middle finger. A 24-year-old male presented with an oblique amputation through the middle phalanx of the left long finger, distal to the insertion of the flexor digitorum superficialis tendon.

Fig. 2 Intraoperative dissection along the digital arterial network. Exposure of the neurovascular bundles is facilitated by a midline longitudinal incision along the volar surface of the amputated part. The proper digital arteries are identified and traced distal to the insertion of the flexor digitorum profundus tendon, where they give rise to the distal transverse arch (arrows) in the pulp. A solitary central artery (asterisk) with multiple branches can be seen originating from the distal arch.

taken to anticipate the approximate angle of anastomosis with the recipient vessel to avoid kinking the venous conduit on attempted skin closure.

After appropriate orientation has been confirmed, the skin is reapproximated with 5–0 chromic interrupted suture. The catheter tip is connected to a 25-cm extension of narrow bore (internal diameter of 1.6 mm) intravenous (IV) tubing with a remote stopcock valve and sutured to the palmar digital skin to prevent traction and/or accidental avulsion. Once assembled, the entire system (i.e., catheter and extension tubing) is secured either beneath the splint or to its external surface, depending on the ideal trajectory of catheter insertion, to optimize hemodynamic flow within the conduit (► **Fig. 4**).

The splint itself is typically maintained for the duration of catheterization (i.e., 4 to 5 days), with incisional care provided through the daily application of petroleum-based gauze and gentle removal of surface clots during routine clinical assessments.

Postoperatively, patients are maintained on daily aspirin (162 mg) and a fixed-rate heparin drip (500 U/hour) while the catheter is in place. The stopcock valve is kept open during the first 48 hours to promote continuous passive outflow (2–3 mL per hour) through the conduit into a remote basin. Both the replant and conduit are assessed hourly and flushed with dilute heparinized saline (500 U/mL) to

Fig. 3 Direct cannulation of a distal branch of the central artery using a pediatric angiocatheter. Left: a 26-gauge angiocatheter is directed obliquely (~30 degrees) through the proximal volar skin and anastomosed to the cut end of the recipient artery using 10-0 nylon suture. Right: it is important to anticipate the appropriate angle of catheter insertion, prior to skin closure, to facilitate streamline flow and prevent obstructive kinking at the catheter-skin interface.

Fig. 4 Immediate postoperative view. The angiocatheter tip is connected to narrow bore (internal diameter of 1.6 mm) intravenous tubing with a remote stopcock valve, which provides a conduit to regulate passive outflow, local heparin administration, and interval withdrawal of stagnated blood as needed. The conduit is secured either beneath the splint or to its external surface to prevent traction and/or accidental dislodgement.

Fig. 5 Removal of the angiocatheter on postoperative day 5. The replanted fingertip is viable with stable color, capillary refill, and bright-red bleeding from the suture lines.

optimize bleeding and prevent the formation of obstructive clots. For a 25-cm conduit composed of narrow bore IV tubing, the total volume of irrigation approximates 1.5 mL and is determined by the sum of the catheter's priming volume (i.e., 0.5 mL) and the desired volume of replant instillation (i.e., 1 mL). If early signs of venous congestion predominate, active withdrawal of stagnated blood is achieved by connecting a 10-mL syringe to the IV tubing. The volume and frequency of decompression are dictated by the clinical response of the replant (i.e., color and capillary refill) as well as the presence of bright-red blood within the catheter lumen. Beginning postoperative day 3, the stopcock valve is closed over progressively longer intervals, permitting intermittent drainage of blood every 2 to 4 hours as the clinical exam stabilizes. In most cases, the catheter is removed at bedside on day 4 or 5, once vascular stability has been confirmed by the presence of normal capillary refill and lack of venous congestion with closed circuit tubing (→Fig. 5).

Provision of an artificial venous conduit, using the technique described, offers a safe and effective alternative to enhance the precision of outflow management for artery-only digital replants. The establishment of intravascular access permits direct manipulation of the microcirculatory environment through timed administration of heparinized saline and regulated removal of controlled volumes of blood. This process is aided by the addition of narrow bore IV tubing, which reduces the rate of egress (i.e., through increased internal resistance) and provides remote access to the catheter site to minimize the risk of dislodgement during routine intervention. Furthermore, the incorporation of a stopcock valve represents an improvement over open-ended stent designs and/or other external bleeding techniques that promote unrestricted blood loss. In contrast to these methods, use of the valve enables outflow to be titrated to the clinical appearance of the replant, thereby limiting congestion as well as excessive hemorrhage with subsequent need for transfusion.

In our experience, direct arterial catheterization is reliable and bypasses the need for more complex microvascular arrangements, autologous vein grafting, and/or secondary

surgical procedures. Compared with zone 1 venous recipients, branches of the distal arterial network are more elastic and possess the structural integrity to support cannulation.^{4,5} Although described in the context of distal artery-only replants, this technique can be modified according to the level of amputation and availability of vascular targets (i.e., proper digital arteries and proximal/distal cruciate anastomoses) and can be used to augment outflow in the setting of tenuous venous anastomoses.

Note

There are no financial disclosures, commercial associations, or any other conditions posing a conflict of interest to report for any of the authors. Informed consent was obtained from the individual whose photographs were used in the preparation of this manuscript.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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