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GENERAL REVIEW

Evidence-based postoperative replantation protocols

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Abstract
Postoperative care is essential to upper extremity replantation success and includes careful and frequent monitoring of the replanted part. During this period, pharmacologic agents such as antithrombotic and anticoagulants may prevent complications such as arterial thrombosis and venous congestion. Dressings and therapy can also impact short- and long-term outcomes following replantation. This article reviews the literature to provide guidance for postoperative protocols following upper extremity replantation.

Keywords Amputation · Replantation · Upper extremity · Protocol · Postoperative care

Introduction

Since the advent of digital replantation in 1965, surgical technique and outcomes have improved [1, 2]. Survival rates for digital replantation now range from 57 to 90%, with outcomes potentially influenced by patient comorbidities, mechanism of injury, level of injury, ischemia time, and surgical technique [1, 3–8]. The postoperative management of replanted extremities varies significantly within and between institutions [9–11], yet it is a critical factor in reliably achieving good outcomes [11, 12]. This article summarizes available literature pertaining to the postoperative management of replanted extremities.

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Replant monitoring

Patients require close monitoring to identify any changes in perfusion to the replanted digit; this may be related to arterial insufficiency or venous congestion. As thrombosis risk is the highest within 48 h postoperatively, monitoring during this period is critical [13, 14]. The duration of monitoring following replantation is not specifically addressed in the published literature. As changes in perfusion need to be recognized quickly to avoid partial or complete loss of the part, many centers admit patients to a unit which allows for frequent monitoring postoperatively. Depending on concurrent surgical and medical issues, patients can be admitted to an inpatient ward or an intensive care unit (ICU) [1]. Some authors advocate for hourly monitoring in the first two days [1, 11, 15]. The frequency is typically decreased to every two hours after 48 h following replantation [1, 15].

Clinical monitoring typically includes skin color, edema, temperature, capillary refill, and turgor as well as Doppler for arterial and venous signals [15]. The replanted digit temperature can be closely monitored using a surface temperature probe and a drop of greater than 2 °C from the previous reading or a digit with a temperature below 30 °C should prompt urgent evaluation of the digit [12, 16]. If concerns for arterial insufficiency or venous congestion arise, these should be managed with either return to the operating room if arterial or venous patency is compromised, or with environmental optimization if patency is not compromised (such as limb positioning—dependent positioning if there is concern for arterial insufficiency

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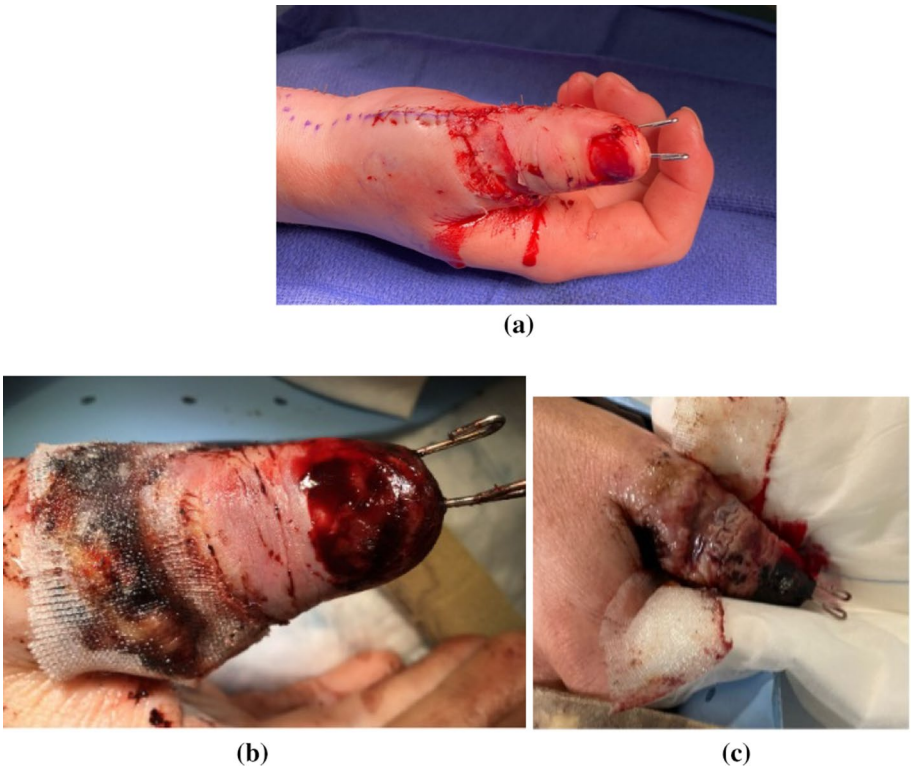

Fig. 1 **a** Intraoperative photograph following thumb replantation for avulsion-type injury showing good turgor and restoration of perfusion. **b** Postoperative day 2 image of the thumb with maintained perfusion and nailbed bleeding following leech therapy. **c** Postoperative day 3 image with decreased perfusion and development of arterial insufficiency (white pale color with decreased bleeding) (color figure online)

(Fig. 1), or elevation when concerned for venous insufficiency). Perfusion can also be evaluated with pulse oximetry; saturations above 95% suggesting a well perfused digit, below 85% associated with venous occlusions, and absent oxygen saturation representing arterial occlusion [17]. The use pinprick evaluation may be helpful to determine perfusion as well. During this test, lack of bleeding can suggest arterial insufficiency while brisk dark bleeding may suggest venous congestion.

Environment

Some protocols advocate for a warm environment around the replanted part. Options to achieve this include regional warming (forced-air warming blankets or heating devices) or heated room. Chen reported on three American centers who all use warming pads/forced-air regional warming device rather than hot rooms [10]. Similarly, Yale Medical Center keeps a comfortable room temperature for the patient, and uses heating pads or forced-air warming blankets at the surgical site [1]. Because there is no evidence surrounding these different warming practices, some centers advocate against any method of warming [1, 15]. Surgeons should be cautious when using regional devices as thermal burns have been reported [18].

Postoperative dressings/therapy/mobilization

Bed rest

The duration of bed rest is dependent on surgeon preference. Bed rest is encouraged to minimize rapid changes in patient hemodynamic status and allows for maintenance of a controlled environment for the replanted digit (e.g., warm, constant elevation, and monitoring). Ronkko et al. surveyed five Nordic replantation units (in four countries—Denmark, Norway, Sweden, and Finland) and reported that all centers confined patients to bed for the first postoperative day (POD). Then, during the following two PODs, patients were allowed to mobilize out of bed only for bathroom use. Mobilization was gradually increased over the next three days (POD three to five). One unit was more conservative with bed rest up to 10 days. The Buncke Clinic protocol includes bed rest until POD three, up to chair on POD four, then ambulation on POD five [10].

Dressing

Surgeons have variable practices with regard to dressing changes. The Buncke Clinic changes the surgical dressing

to a hand therapy splint on POD five and encourages dressing changes twice weekly thereafter. In contrast, at Denver Health Medical Center and Duke University Medical Center, the dressing is changed on POD two [19]. Allen and al. from Duke University report leaving the operative dressing in place for seven to ten days following replantation [12]. Ronkko et al. reported dressing change variability in five Nordic units with some centers changing dressings at least once daily to others leaving operative dressing in situ until discharge [11]. One center immobilized the replanted part in a cast for three weeks. Changing the dressing early may prevent constriction of the replanted digit from saturated dressing that has dried (blood cast avoidance). On the other hand, changing the dressing early could alter the digit environment and may lead to complications such as loss of circulation from thrombi or vascular spasm. Early dressing changes can also lead to patient anxiety.

Therapy

Surgeons have variable practices with regard to the initiation of therapy. Duke University reports starting gentle active motion within the confines of the dressing POD two to three. Formal hand therapy is started once the dressing is removed. Ronkko et al. reported variable therapy protocols in five Nordic units [11]. Hand therapy is initiated in most centers four to five days following surgery. One center immobilized the replanted part for three weeks and then re-admitted the patient for 1 week for intensive hand therapy. Silverman et al. developed a post-replantation model of early protected motion in 1996, which focused on motion to be begin as soon as possible (tailored to the specific injury) in addition to edema management with strict elevation, edema wraps, and soft tissue massage when the wounds have adequately healed [20]. Some centers have implemented the Silverman early protected motion protocol [1], but there remains debate on the optimal timing of therapy initiation. Initiation of digit and hand mobilization is also dependent upon the strength of osseous fixation and the confidence of vascular and tendon repair.

Brachial plexus blockade

Replantation can be performed under regional and/or general anesthesia. Regardless of anesthesia type provided during the surgery, most advocate for continuous postoperative brachial plexus anesthesia for a period of 4–9 days [11]. Brachial plexus blockade improves flow volume, flow velocity, extremity temperature, and oxygen saturation [10, 21]. A prospective randomized trial comparing single-dose to continuous infraclavicular brachial plexus blockade in 47 patients following digital replantation found a higher survival rate at 95.6% in patients with continuous plexus blocks compared to 79.1% in the single-dose group [22]. At Denver Health, all patients received a regional block, while none received blockade at the Buncke Clinic [10], demonstrating variability in practices.

Postoperative antiplatelet and anticoagulation therapy

Replantation failures result from arterial thrombosis, venous insufficiency, hematoma, and/or infection. Ninety percent of microvascular anastomotic arterial thrombi occur within 24 h postoperatively and are thought to be related to platelet aggregation [13, 14]. Forty-two percent of venous thrombi in microvascular surgery occur after the first 24 h [13]. Thrombosis risk is the highest (80%) within 48 h postoperatively but may occur as late as two weeks. Thus, antiplatelet and anticoagulation treatments can be initiated postoperatively and are aimed at preserving vascular integrity by targeting platelet aggregation and coagulation.

Antiplatelet therapy: aspirin

Aspirin (ASA) antiplatelet therapy is commonly used to prevent thrombus formation following replantation. Common postoperative doses range from 81 to 600 mg and for a duration of 3 days to 6 weeks [11]. Because of limited evidence specific to upper extremity replantation, evidence in patients undergoing free-flap procedures has been applied to digital replantation. Ashjian et al. compared ASA (325 mg for 5 days) against low molecular weight heparin (LMWH, 5000 units daily until ambulation) in a retrospective analysis and found no significant differences in incidence of free-flap complications [23]. In contrast, other studies have demonstrated increased rates of adverse events with ASA [24]. A systematic review and meta-analysis of 12 studies consisting of 4984 free flaps found that ASA administration did not significantly affect the rate of flap loss, but was associated with a two-fold increase in the rate of hematoma formation [25]. Despite this evidence, ASA is routinely used following digital replantation. A survey of four Nordic countries found that most centers administer it from ten days to four weeks post-replantation [11]. Prsic et al. reported adherence to the recommendations of Buckley and Hammert and administered 325 mg of ASA daily [1]. The Buncke Clinic also prescribed ASA 325 mg daily for 30 days post-replantation [10]. Denver Health prescribed 81 mg of ASA for 6 weeks post-replantation [10]. Duke University prescribed 325 mg of ASA daily postoperatively in 2002, but decreased to 81 mg in recent years [10, 12]. Yale School of Medicine prescribed 325 mg of ASA daily unless contraindicated [1].

Anticoagulant therapy

Unfractionated heparin

Unfractionated heparin (UFH) administration typically begins during surgery, but duration of therapy postoperatively is variable. Cigna et al. reported on 16-microreplantations performed at their center in Italy; their replant protocol included dextran and UFH for five days postoperatively for all patients [7]. At Duke University, UFH was provided to complex or difficult replants and to patients sustaining crush or avulsion injuries [10, 12]. At Denver Health Medical Center, UFH was given to artery-only replants [10]. Finally, at the Buncke Clinic, UFH was given to avulsion or complex procedure (e.g., vein graft) or artery-only replants [10].

A retrospective review of 108 patients undergoing digital replantation found no difference in survival rate for variable infusion rates and treatment durations of UFH [19]. Continuous intravenous UFH may improve rates of successful digital replantation in patients with artery-only anastomoses [26]. Despite encouraging findings, routine UFH prophylaxis is controversial owing to adverse events that include hematoma, hemorrhage, and heparin induced thrombocytopenia (HIT) [9, 25–28]. Nikolis et al. reported that UFH use following digital replantation was associated with a 3.6-fold increase in complications (hematoma and venous congestion) and was not associated with a higher success rate [9]. The authors concluded that the addition of intravenous UFH with ASA was not warranted, compared to ASA alone or ASA with subcutaneous UFH [9]. Similarly, another study compared three different postoperative protocols: (1) continuous intravenous UFH infusion and PGE1, (2) intravenous UFH alone, and (3) neither medication [28]. While there were no differences in vascular occlusion or spasm, postoperative bleeding was higher in groups using UFH [28]. Systemic heparinization may thus be appropriate only in select situations such as cases with poor venous outflow, artery-only repairs, vascular anastomoses in traumatized vessels, situations utilizing vein grafts, postoperative thrombosis, and atherosclerotic vessels.

Low molecular weight heparin (LMWH)

Compared to UFH, LMWH anticoagulation is less researched in the setting of hand and digit replantation. The available evidence is mixed regarding the efficacy of LMWH as compared to UFH in preventing arterial thrombosis [7]. A systematic review based on two randomized trials comparing LMWH to UFH found no difference in digit replantation survival [29].

LMWH is commonly used for patients with limited mobility to prevent deep vein thrombosis (DVT) which may have a role in the hospitalized patient following replantation during mobility restrictions. Ronkko et al. reported starting all patients on a prophylactic dose of LMWH during the hospital stay [11]. Similarly, Prsic et al. administered subcutaneous UFH or LMWH as DVT prophylaxis [1].

Postoperative antibiotic therapy

Prophylactic antibiotic therapy following replantation varies significantly within and between institutions. Some provide antibiotics only during the surgical procedure and stop them immediately postoperatively, while others continue antibiotics for the first postoperative day, and others continue antibiotics for up to two weeks postoperatively or until the wounds are healed [11]. Other surgeons advocate for antibiotic prophylaxis for all replantation for a period of 48 h, and up to seven days in cases of heavy contamination [1, 10].

Antibiotic therapy is indicated if/when leech therapy is performed. Antibiotic prophylaxis against *Aeromonas hydrophila* infection should be initiated at the time of leeching with trimethoprim-sulfamethoxazole or ciprofloxacin, though antibiotic coverage may need to be altered to address resistant strains [30, 31].

Leech therapy and controlled bleeding

Venous congestion can be addressed non-surgically with leech therapy or controlled bleeding [32]. These methods provide venous drainage while angiogenesis reestablishes an outflow network [33], and the duration of therapy depends on rate of neovascularization and volume of the amputated part (range 5–9 days) [10, 34–36]. Leech therapy and controlled bleeding can also be used as decongestive techniques following artery-only replantation [37]. In this circumstance, these methods are useful to establish a reliable drainage which maintains a physiologic pressure gradient across capillary beds.

Medicinal leeching

Medicinal leeches (*Hirudo medicinalis*—Fig. 2) address venous congestion by: (1) establishing temporary mechanical venous outflow, and (2) secreting hirudin, a natural anticoagulant, and hyaluronidase, an enzyme which promotes local vasodilation [10, 38].

Leeches are effective at treating postoperative venous congestion and for venous decompression in artery-only replantation [33, 37]. Leeches are useful in artery-only replantation as they augment external bleeding [37]. Leeches may be less effective in proximal finger—compared to distal finger replantation due to higher volume of congested tissue [39]. In cases of proximal amputations,

Fig. 2 Development of congestion postoperatively with bluish discoloration and leech in place (color figure online)

earlier initiation and longer duration of leech therapy may improve survival. At the Buncke Clinic, leeching was performed every two hours for artery-only replants, in addition to heparin scrubs hourly [10]. Leeches are weaned on POD7. At Denver Health, leeches were used hourly for artery-only replant or with venous insufficiency; then were weaned [10]. Leeching is associated with complications such as bleeding requiring blood transfusion, anaphylaxis, increased length of hospital stay, infection, and scarring [33, 35, 38].

Controlled bleeding

External bleeding can be achieved through a variety of methods including the removal of the nail plate, serial stab incisions, and fishmouth incisions [37]. With the removal of the nail plate at the time of surgery, some will create additional bleeding via mechanically scrubbing the nail bed with a heparin/saline gauze [36]. Using this technique, one study reported 88% survival in artery-only fingertip replantations [36]. Another retrospective review of 228 artery-only distal finger replantations compared two methods of controlled bleeding: nail matrix or hyponychial area bleeding with pulp skin area bleeding, termed the "crater method" [40]. Authors concluded that the method of external bleeding did not have an impact on survival, with 84% survival in the traditional nail bed incision and 77% in the crater bleeding group [40]. Controlled bleeding can also be performed through the injection of subcutaneous UFH at an open wound on the fingertip [10, 36, 41]. Using this technique, the authors reported a 93% survival rate [41]. Controlled bleeding can alleviate venous congestion and decongest artery-only replants leading to replantation success, but is associated with complications such as bleeding requiring blood transfusion, partial finger necrosis, and prolonged hospital stay [35, 41, 42].

Diet and lifestyle

Diet

Postoperative nutrition protocols vary between institutions. Some patients are kept fasting for a certain period following a replantation to minimize anesthetic risks in the event of the need for urgent return to the operating room. At institutions in Nordic countries, most surgeons allow patients to eat freely immediately after the operation, though one center restricts patient diet for 12 h postoperatively [11]. Chen et al. described replant protocols at two American institutions and reported fasting guidelines for the day of the replantation with a regular diet initiated on POD one [28].

Caffeine

Replantation protocols typically restrict caffeinated products (such as coffee, tea, and chocolate) in the postoperative period for up to 3 weeks because of concerns for peripheral vasoconstriction [1, 43]. No studies have specifically evaluated the effect of caffeine on digital replantation. A study reported that surgeons in two Nordic centers restricted the intake of caffeine during the first 3 or 7 days following replantation [11]. In contrast, several authors report not enforcing a strict caffeine-free diet post-replantation [1, 4]. The Buncke Clinic did not have a specific caffeine restriction protocol although patients are counseled to minimize caffeine intake [10]. Per Prsic et al. as there is only anecdotal evidence that caffeine leads to peripheral vasoconstriction, decreased tissue perfusion, and subsequent loss of replanted digits, the authors do not enforce a strict caffeine-free diet at Yale School of Medicine [1].

Nicotine

Smoking and nicotine-containing products are restricted following digit replantation. Van Adrichem et al. studied the effects of smoking in patients undergoing replantation, and observed acutely decreased Doppler blood flow immediately after cigarette smoking [44]. Based on this evidence, the authors recommended restricting the use of nicotine-containing products following digital replantation. Ronkko et al. surveyed five Nordic units and found that all centers prohibited smoking for at least 1 month postoperatively, and one unit restricted all other nicotine-containing products for at least 1 month [11]. Two American centers, the Buncke Clinic and Denver Heath, both restrict nicotine [10].

Institutional preferences [10]

At our institution, patients are provided with a continuous preoperative regional block to prevent vasospasm, improve perfusion, and manage pain. We prefer continuous blockade with an indwelling catheter as some data supports a survival benefit with this. Following replantation, patients are admitted to the intensive care unit for hourly digit monitoring. The digit is monitored clinically (color, turgor, capillary refill, and skin temperature) hourly and then transitioned to every two hours the following day, and then less frequently as appropriate. During this period, the digit is carefully monitored for signs of arterial or venous insufficiency. If the digit demonstrates signs of arterial insufficiency, return to the operating room may be indicated following local and systemic optimization. In the event of venous congestion, leeching and/or controlled bleeding are initiated. The limb is placed in a forced-air regional warming device (Bair hugger) for the duration of hospitalization and hot rooms are not used. The patient is placed on bed rest for two days to minimize stress and provided a regular diet without nicotine or caffeine POD one. All patients are prescribed aspirin 81 mg daily for 6 weeks. For revascularization injuries where venous outflow is intact and only the artery is repaired, patients are typically discharged on POD two. For replantations that achieve good artery and vein anastomosis, enoxaparin 40 mg daily is used for a duration of two weeks and heparin is not used. Injuries where venous anastomosis cannot be achieved (artery-only repairs), heparin is administered titrating to an activated partial thromboplastin time of 40–60 for the duration of controlled bleeding or leeching, and then transitioned to enoxaparin 40 mg daily for two weeks once leeching is weaned. During the admission, the patient's hemoglobin is checked daily, and transfusions are given for a hemoglobin below 9 mg/dL. The operating room dressing is removed on POD two and transitioned to an occupational therapy custom thermoplastic splint to allow ease of monitoring and prevent constriction from saturated dressings. Mobilization of the digit typically begins following discharge from the hospital with gentle early active motion in an outpatient therapy setting once the digit does not require controlled bleeding/leeching.

Conclusions

This review summarizes the most recent literature pertaining to the postoperative care of upper extremity replantations and highlights the variability in the published postoperative protocols for these patients. Because of the lack of high-quality comparative studies, this review cannot provide clear guidelines on the most appropriate care of replant patients. Instead, it highlights the available evidence around postoperative practices. Based on this, surgeons can adopt their own patient centered postoperative protocols to optimize replantation survival

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Declarations

Conflict of interest The author(s) declare that they have no conflicts of interest.

Ethical approval Not needed.

References

1. Prsic A, Friedrich JB (2019) Postoperative management and rehabilitation of the replanted or revascularized digit. Hand Clin 35(2):221–229
2. Solaja O, Retrouvey H, Baltzer H (2021) Trends in digital replantation: 10 years of experience at a large Canadian tertiary care center: les tendances de la replantation digitale : dix ans d'experience d'un grand centre canadien de soins tertiaires. Plast Surg (Oakv) 29(1):21–29
3. Florczynski M et al (2022) Factors associated with early and late digital revascularization and replantation failure: a retrospective cohort study. J Hand Surg Eur 47(5):446–452
4. Retrouvey H et al (2020) Effect of vasopressor use on digit survival after replantation and revascularization—a large retrospective cohort study. Microsurgery 40(1):5–11
5. Retrouvey H, Solaja O, Baltzer HL (2019) The effect of increasing age on outcomes of digital revascularization or replantation. Plast Reconstr Surg 143(2):495–502
6. Retrouvey H, Solaja O, Baltzer HL (2019) Role of postoperative anticoagulation in predicting digit replantation and revascularization failure: a propensity-matched cohort study. Ann Plast Surg 83(5):542–547
7. Cigna E et al (2015) Postoperative care in finger replantation: our case-load and review of the literature. Eur Rev Med Pharmacol Sci 19(14):2552–2561
8. Ma Z et al (2016) Effects of non-surgical factors on digital replantation survival rate: a meta-analysis. J Hand Surg Eur 41(2):157–163
9. Nikolis A et al (2011) Intravenous heparin use in digital replantation and revascularization: the Quebec provincial replantation program experience. Microsurgery 31(6):421–427
10. Chen C et al (2021) Postoperative digit and hand replantation protocols: a review of the literature. J Am Acad Orthop Surg 29(15):e732–e742
11. Ronkko H et al (2023) Indications, anaesthesia and postoperative protocol for replantation and revascularization in the hand in Nordic countries. J Hand Surg Eur 48(1):46–51
12. Allen DM, Levin LS (2002) Digital replantation including postoperative care. Tech Hand Up Extrem Surg 6(4):171–177
13. Ichinose A et al (2003) Short-term postoperative flow changes after free radial forearm flap transfer: possible cause of vascular occlusion. Ann Plast Surg 50(2):160–164

14. Li X, Cooley BC (1995) Effect of anticoagulation and inhibition of platelet aggregation on arterial versus venous microvascular thrombosis. Ann Plast Surg 35(2):165–170 (**Discussion**)
15. Barbato B, Salsac AV (2020) Finger and thumb replantation: from biomechanics to practical surgical applications. Hand Surg Rehabil 39(2):77–91
16. Stirrat CR et al (1978) Temperature monitoring in digital replantation. J Hand Surg Am 3(4):342–347
17. Graham B, Paulus DA, Caffee HH (1986) Pulse oximetry for vascular monitoring in upper extremity replantation surgery. J Hand Surg Am 11(5):687–692
18. Zukowski ML, Lord JL, Ash K (1998) Precautions in warming light therapy as an adjuvant to postoperative flap care. Burns 24(4):374–377
19. Efanov JI et al (2018) Duration and cessation characteristics of heparinization after finger replantation: a retrospective analysis of outcomes. Microsurgery 38(3):251–258
20. Silverman PM, Gordon L (1996) Early motion after replantation. Hand Clin 12(1):97–107
21. Wenger A et al (2017) Skin perfusion changes within 12 h after axillary plexus block. Eur Surg Res 58(5–6):227–234
22. Sahin MS, Cakmak G, Birtay T (2019) Comparison of single-dose infraclavicular brachial plexus block and continuous infraclavicular brachial plexus block applications in the treatment of finger amputations. J Hand Microsurg 11(3):134–139
23. Ashjian P et al (2007) The effect of postoperative anticoagulation on microvascular thrombosis. Ann Plast Surg 59(1):36–40 (**Discussion**)
24. Lighthall JG et al (2013) Effect of postoperative aspirin on outcomes in microvascular free tissue transfer surgery. Otolaryngol Head Neck Surg 148(1):40–46
25. Lee KT, Mun GH (2015) The efficacy of postoperative antithrombotics in free flap surgery: a systematic review and meta-analysis. Plast Reconstr Surg 135(4):1124–1139
26. Lee JY et al (2016) Controlled continuous systemic heparinization increases success rate of artery-only anastomosis replantation in single distal digit amputation: a retrospective cohort study. Medicine 95(26):e3979
27. Veravuthipakorn L, Veravuthipakorn A (2004) Microsurgical free flap and replantation without antithrombotic agents. J Med Assoc Thai 87(6):665–669
28. Matsusue T (2019) Is antithrombotic therapy necessary following replantation of an amputated digit? J Hand Surg Asian Pac 24(1):1–5
29. Chen YC et al (2013) Low molecular weight heparin for prevention of microvascular occlusion in digital replantation. Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD009894.pub2
30. van Alphen NA et al (2014) Ciprofloxacin-resistant Aeromonas infection following leech therapy for digit replantation: report of 2 cases. J Hand Surg Am 39(3):499–502
31. Whitaker IS et al (2009) Preventing infective complications following leech therapy: is practice keeping pace with current research? Microsurgery 29(8):619–625
32. Han SK, Chung HS, Kim WK (2002) The timing of neovascularization in fingertip replantation by external bleeding. Plast Reconstr Surg 110(4):1042–1046
33. Pickrell BB et al (2020) Leech therapy following digital replantation and revascularization. J Hand Surg Am 45(7):638–643
34. Pickrell BB et al (2020) Leech therapy following digital replantation and revascularization. J Hand Surg Am. https://doi.org/10.1016/j.jhsa.2020.03.026
35. Chen YC et al (2013) Fingertip replantation without venous anastomosis. Ann Plast Surg 70(3):284–288
36. Erken HY, Takka S, Akmaz I (2013) Artery-only fingertip replantations using a controlled nailbed bleeding protocol. J Hand Surg Am 38(11):2173–2179
37. Crowe CS et al (2022) Management of artery-only digit replantation: a systematic review of the literature. Plast Reconstr Surg 150(1):105–116
38. Whitaker IS et al (2012) The efficacy of medicinal leeches in plastic and reconstructive surgery: a systematic review of 277 reported clinical cases. Microsurgery 32(3):240–250
39. Arami A et al (2018) The use of medicinal leeches for the treatment of venous congestion in replanted or revascularized digits. J Hand Surg Am. 43(10):949e1-949e5
40. Kayalar M et al (2020) Survival and comparison of external bleeding methods in artery-only distal finger replantations. J Hand Surg Am 45(3):256e1-256e6
41. Kadota H et al (2020) Successful local use of heparin calcium for congested fingertip replants. Arch Plast Surg 47(1):54–61
42. Han SK, Lee BI, Kim WK (2000) Topical and systemic anticoagulation in the treatment of absent or compromised venous outflow in replanted fingertips. J Hand Surg Am 25(4):659–667
43. Wolfe SW et al (2011) Green's operative hand surgery, 6th edn. Churchill Livingstone, Philadelphia
44. van Adrichem LN et al (1992) The acute effect of cigarette smoking on the microcirculation of a replanted digit. J Hand Surg Am 17(2):230–234