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Etiology and Survival of Secondary Revascularizations after Hand and Digit Replantations

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Abstract

Introduction Hand and digit replantations can be complicated by vascular insufficiency necessitating revision of the original replantation. To date, few studies have evaluated outcomes in secondary revascularizations following replantation. Therefore, the objective of this study was to evaluate the incidence, etiology, and survival rates following secondary revascularization after hand and digit replantations.

Materials and Methods A literature search was performed on NCBI for studies documenting secondary revascularization procedures following hand and digit replant. Studies were evaluated for the etiology of vascular failure, frequency of secondary revascularization, and survival rates following intervention. Statistical analysis was conducted across the pooled dataset.

Results A total of 16 studies including 1,192 amputations were analyzed. We found that 16.9% (201/1,192) of replants were complicated by vascular compromise. The frequency of vascular compromise was not statistically different between arterial and venous etiologies. The survival rate following secondary revascularization was 55.6%, with no significant difference between the arterial and venous groups. Secondary arterial revascularization was often treated with arterial revision (nine of nine studies) and/or with vein grafting (two of nine studies). Secondary revascularization for venous insufficiency resulted in different survival rates for nonsurgical modalities (58%) versus vein revision (37.5%) versus vein grafting (100%).

Conclusion Survival rates following secondary revascularization are lower; however, they may be improved using vein grafts following venous insufficiency. These data can be used to better understand the etiology of replant failure and guide decision-making.

Keywords
- amputation
- replantation
- revascularization
- digit
- hand

Introduction

Replantation following hand and digit amputation affords the ability to restore hand function. Various studies have attested to the psychological, physical, and financial hardships associated with amputation.[1-3] Replant survival is influenced by numerous factors including technical skill, mechanism of injury, and various sociodemographic factors.[4-9] Digit survival following replantation, however, ranges from 48 and 97% in the literature.[10] Despite improvements in microsurgical technique and evidence-based guidelines, there is a wide range of reported incidences of replant failure in the early postoperative period.

Given the need for microsurgical anastomoses to restore the arterial and venous systems, replants can be complicated by microvascular collapse and threatened survival in the early postoperative period, necessitating revision of microvascular anastomosis. Currently, few studies have evaluated the incidence and etiology of vascular failure following replant. Furthermore, there exists contradictory evidence as

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to whether arterial or venous anastomoses represent a major cause of vascular complication. Some studies indicate that arterial insufficiency is a common cause for digit replantation failure,[11-14] whereas others cite venous issues.[9,15-21] Furthermore, the optimal treatment modality following vascular compromise is not well described in the literature. Ultimately, a better understanding of the incidence, etiology, and survival rates following vascular compromise after replantation can help guide decision-making and improve outcomes following amputation.

Materials and Methods

Search Methodology

A literature search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines using the NCBI (National Center for Biotechnology Information) database.[22] The database was last accessed on May 30, 2018. The following keywords were used: "hand," "finger," "digit," "replantation," "replant," "secondary procedure," "reprocedure," "reoperation," and "revision." ►**Fig. 1** represents the study selection process for studies included in our final analysis.

Selection Criteria

Inclusion/exclusion criteria were established to define a specific study population. Full-text articles in English were considered for inclusion based on the following criteria: (1) the study cohort included patients of all ages and sexes who had undergone digit or hand replant following amputation, (2) the study reported and tabulated secondary revascularization procedures following primary replantation, and (3) the study evaluated the etiology of replant failure and subsequent treatment. We defined and included replant failure in the early postoperative period as occurring within 7 days postoperative. Exclusion criteria included (1) studies that represented reviews, meta-analysis, or case reports, (2) studies that evaluated amputations proximal to the hand (i.e., forearm, upper arm), and (3) studies that evaluated heterotopic replantations, transplantations, or cross-replantations. If the studies met inclusion criteria but also presented data on proximal amputations, heterotopic replantations, transplantations, or cross-replantations, the data were stratified to only include data that met our inclusion/exclusion criteria.

Data Extraction and Statistical Analysis

Articles were evaluated and data extracted independently by two study members to ensure accuracy. Articles were

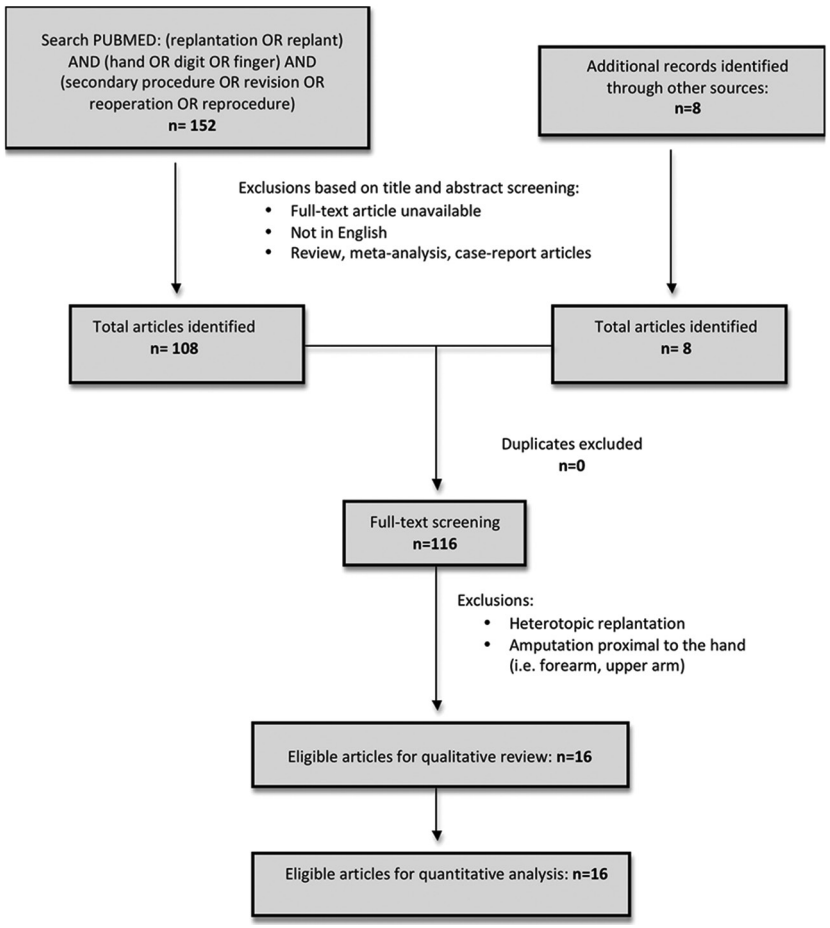

Fig. 1 Study selection process.

explored for variables related to replant failure, including the number of replants, frequency of vascular failure, and etiology of vascular failure following replantation. Next, we evaluated the treatment modalities employed and their respective survival rates following vascular compromise. Data were enumerated across studies and combined for statistical analysis. Summary statistics using Student's *t*-test and analysis of variance tests were used to evaluate the outcomes across variables. Statistical analysis was not weighted. Statistical significance was set with $p < 0.05$, with all tests two-sided.

Results

This study evaluated 16 studies including 1,192 digital replant/revascularizations procedures.[14,16,19,20,23-34] Studies were published between the years 1980 and 2016. Publications represented the following geographical locations: Italy, United States, United Kingdom, China, Taiwan, Singapore, Slovakia, Austria, Turkey, Japan, and India.

After analyzing the pooled dataset, we found that 16.9% (201/1,192) of replants had vascular issues in the early postoperative period and required secondary revascularization. Subgroup analysis was subsequently performed to determine the etiology of vascular compromise. As shown in ►**Fig. 2** we found that the frequency of vascular compromise was similar across arterial and venous etiologies ($p = 0.39$). Of note, several studies did not specify the etiology (arterial vs. venous) of vascular compromise. Furthermore, studies did not routinely report the time interval for replant failure or the timing of secondary revascularization.

Next, we explored the survival rates for replants requiring secondary revascularization to identify potential survival differences following arterial versus venous compromise. As demonstrated in ►**Fig. 3** we found no statistical difference in survival rates for replants complicated by arterial versus venous issues ($p = 0.70$). We found a survival rate of 54.9% following arterial compromise versus 64.5% following venous compromise, wherein the difference between these groups was not statistically significant. Studies did not routinely report the method of arterial versus venous anastomosis (i.e., suture vs. coupler) to conduct further analysis.

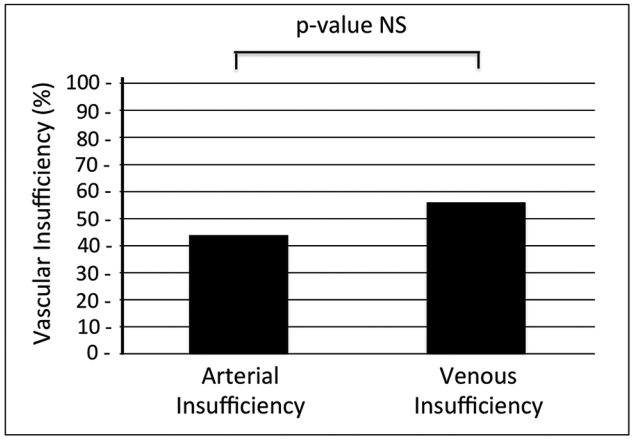

Fig. 2 Etiology of vascular insufficiency following replantation. NS, not significant.

Finally, we explored the different treatment modalities employed to revascularize the compromised replant and evaluated their respective effects on survival. We found that seven of nine studies only treated arterial insufficiency with an arterial revision procedure (44 procedures) versus two studies that vascularized with interposition vein grafting (3 procedures) or arterial revision procedures. The overall survival rate was 54.9%; however, the sample size was underpowered and precluded subsequent statistical analysis. Next, we evaluated survival following secondary revascularization in the venous group. As shown in ►**Fig. 4** we found a significant difference in survival following nonsurgical intervention (i.e., leech therapy, systemic anticoagulation, local digit heparinization) (58%) versus vein revision procedures (37.5%) versus interposition vein grafting (100%) ($p < 0.05$). Studies did not routinely specify postoperative treatment protocols (anticoagulation regimens, etc.) to conduct additional analysis.

Discussion

The aim of this study was to better understand the incidence, etiology, and survival rates of secondary revascularization after primary hand and digit replantations. To date, very few

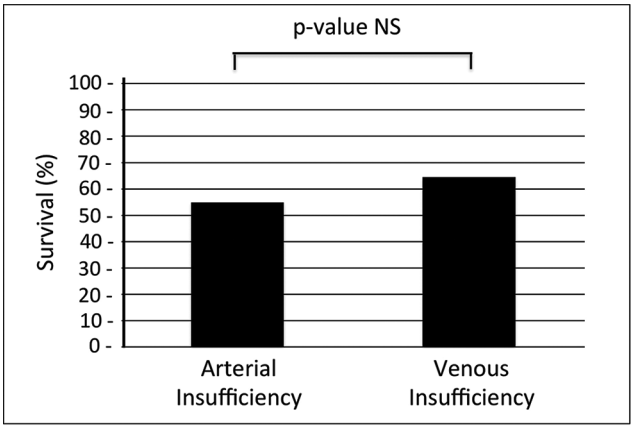

Fig. 3 Survival rates following intervention for arterial versus venous compromise. NS, not significant.

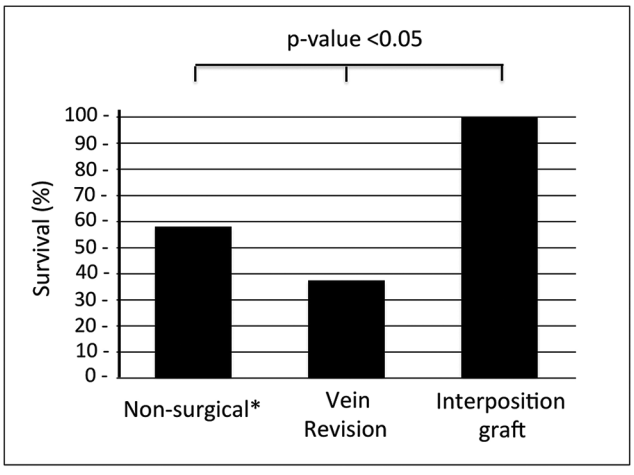

Fig. 4 Survival rates across different treatment modalities for venous insufficiency following replantation.

studies have investigated secondary revascularization following replantation. Of the 1,192 replants procedures included in our study, we found that 16.9% required secondary revascularization. This percentage is higher than the reported free flap anastomotic failure rate[35,36] and may represent the inflammatory physiology following traumatic amputation or subclinical vessel damage, resulting in vessel friability, segmental injury, a lack of substantial tunica media to maintain vascular patency, or a propensity for inflammatory vasospasm.[16] These data suggest that replant failure is not uncommon, and critical evaluation of the vasculature intraoperatively and consideration of interposition vein grafting can help improve survival rates following replantation.

The etiology of replant failure is often secondary to loss of arterial or venous anastomotic patency in the early postoperative period. To date, studies have presented contrary data, with several authors citing arterial issues, whereas others have implicated venous etiologies.[14,16] We found a similar frequency of arterial versus venous compromise following replant. This may reflect a similar pathophysiology of the arterial versus venous systems following traumatic amputation. While venous issues (vs. arterial) are often the cause of free flap failure, the equal incidence in the hand replant population likely results from the mechanism of injury and its similar effects on both arterial and venous vasculature. Combined with the frequency of required secondary revascularization, these data suggest that accurate clinical evaluation and meticulous technique are necessary when considering a repair versus interposition vein grafting of the arterial and venous systems.

The overall survival rate following secondary revascularization was 55.6%, and this rate was similar across arterial versus venous etiologies. Similar to other studies, our analysis found a reduced survival rate following secondary revascularization procedures.[37] This may reflect the diffuse zone of injury and irreversible tissue damage that may preclude digit viability. As such, some surgeons have even recommended against secondary revascularization surgery altogether, whereas others have suggested repairing all possible arteries/veins to afford the greatest chance for replant survival.[17] Ultimately, the decision for operative revision and secondary revascularization must be individualized for each patient. Intraoperative findings during the index procedure (i.e., lack of distal vein targets) may limit options and availability of secondary attempts (i.e., vein grafting). To this end, replant surgeons should individualize the decision for secondary revascularization, as operative revision may not be suitable for all patients.

The presence of vascular compromise following replant may necessitate secondary revascularization. Ultimately, several options exist, including anastomotic revision, interposition vein grafting, and nonsurgical modalities (leech therapy, heparin-induced bleeding, systemic anticoagulation, etc.).[15,25,29,30,38] To date, there has not been a thorough investigation on their efficacy in secondary revascularization. In our study, we found that replants complicated by venous compromise had higher survival rates if managed with interposition vein grafts (vs. vein revision and nonsurgical modalities). This likely represents the vascular zone of injury that persists despite vessel repair and revision but is bypassed through interposition vein grafting. This finding suggests that replant surgeons should employ interposition vein grafts if secondary revascularization is required and may benefit from more a liberal use of vein grafts during the primary replant procedure.

This study should be considered in light of several limitations. First, this study represents a retrospective study and has potential for unmeasured bias. While attempts were made to include all studies meeting our inclusion/exclusion criteria, this study may have not incorporated a conclusive list of studies. Furthermore, our study was unable to evaluate the specific timing of replant failure and revascularization, which may limit interpretation of outcomes. Several studies had a lower sample size and may represent underpowered statistics (i.e., 100% success rates with vein grafting). To date, the literature provides variable conclusions regarding outcomes in children versus adult replants.[6,39] As such, we elected to include data on children in our analysis. Due to limitations in data reporting, we were unable to determine whether the chosen modality for replant revision (i.e., nonsurgical management) was influenced by the use of vein grafts during the index procedure, lack of identifiable veins available for anastomosis, or lack of distal vein targets. Lastly, this study may overrepresent the incidence of vascular compromise, as most replant studies in the literature do not discuss postoperative vascular issues and thus were not included in our study. Nonetheless, the incidence of vascular comprise reported in our study falls in the same range of other studies reporting the percentage of postoperative vascular compromise in the early postoperative period after replantation.[40-43] Ultimately, this study identifies significant outcomes in replant medicine, and further research is necessary to better detail the specific treatment modalities provided.

Hand and digit replants can have vascular issues requiring reoperation in the early postoperative period. In this study, we characterized the incidence, etiology, and outcomes following vascular compromise in the replant population. Survival rate following secondary revascularization procedures is lower than the rate of primary replant survival. Different treatment modalities may yield different survival rates and must be considered in the surgical decision-making process. Ultimately, vascular viability is paramount for replant survival, and a better understanding of the etiology, survival, and treatment of vascular issues can help improve outcomes for our replant patients.

Conflict of Interest
None declared.

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