The Reperfusion Delay in Finger Replantation by Vein Arterialization

Abstract
Background: Extensive arterial damage of arteries that were too small in diameter precluded finger replantation. Venous arterialization in which arterial blood inflows through a proximal arterial-to-distal venous anastomosis, allows performing replantation that was previously considered as impossible and has resulted in a successful outcome. The aim is to introduce the distinctive phenomenon of the reperfusion delay in finger replantation by vein arterialization and to analyze its clinical significance. Materials and Methods: In 2012–2015, vein arterialization was involved in 18 digits of 13 patients. The duration that the replants restore reperfusion following the release of tourniquet, defined as revascularization time, was recorded. Results: The results showed that revascularization time ranged from 0 to 540 min, with an average of 54.5 min. The revascularization time was shorter than 20 min in 8 digits, between 20 and 120 min in 9 digits, and 540 min in one digit. Conclusion: The study findings have shown that reperfusion delay is usual during vein arterialization. Failing to understand it would result in the premature endings of the procedure. It is worth maintaining further observation, thus rescue otherwise possibly abandoned replantation.

Keywords: Reperfusion delay, replantation of amputated finger, vein arterialization

MeSH terms: Replantation, amputation, veins, anastomosis arteriovenous

Introduction

In the past, extensive arterial damage of arteries that were too small in diameter precluded finger replantation. Venous arterialization, in which arterial blood inflows through a proximal arterial-to-distal venous anastomosis [Figure 1], allows performing replantation that was previously considered as impossible and has resulted in a successful outcome clinically and experimentally.1–6

We noticed a distinctive phenomenon in vein arterializations that some digits demonstrated pallor, low temperature, and no capillary reflow after the release of tourniquet when artery-vein anastomosis was finished, despite the exclusion of systemic factors such as insufficiency of blood volume and/or local factors such as vascular spasm and embolism. This distinctive phenomenon, defined as reperfusion delay in this study, was rare in regular replantation. To the best of our knowledge, this phenomenon was rarely reported during the replantation by vein arterialization in literature. In this study, the reperfusion delay is introduced and the proper management is discussed in cases where reperfusion delay occurs during the process of vein arterialization.

Materials and Methods

18 digits of 13 patients were replanted by vein arterialization between June 2012 and June 2015 at our institute. There were 9 men and 4 women, with ages from 19 to 53; the mean age was 32.3. The causes of injury included 8 rotary avulsion and 5 crushed avulsion. The distal arteries were as follows: artery damage in 10 digits, the vessel of small diameter in 5 digits, and no suitable vessels found in the amputated part in 3 digits. There were 6 amputated thumbs, with 3 in the proximal and 3 in the distal phalanx, 8 index fingers, with 2 in the proximal, 3 in the middle and 3 in the distal phalanx, 3 in the middle finger, with 2 in the middle and 1 in the distal phalanx, 1 in the ring finger in the distal phalanx [Table 1].

During debridement of the wound, the proper finger palmar artery and the finger dorsal and volar veins were evaluated under an operating microscope. Evaluation of the wound revealed no artery was in the amputated digit. There were numerous good caliber (0.3 mm diameter or larger) superficial veins present. One of the proper digital arteries at the proximal part was anastomosed with a vein in the amputated part to establish arterial inflow.

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Then, 1–3 dorsal digital veins were anastomosed to establish outflow if possible [Figure 1]. The treatment methods repairing the other tissues were the same as those in conventional replantation.

Following the operation, the duration after which the replanted digit changed from the pale color to red was recorded after the release of tourniquet, which was defined as revascularization time in this study and measured in minutes.

The patients were postoperatively administered with heparin subcutaneous injection (5,000 U every 6 h) for 3 days, antibiotics for 1 week, low-molecular-weight dextran (500 ml/ day) for 5–7 days, and aspirin (250 mg/day) for 2 weeks.

All monitoring was evaluated by the same experienced microsurgeon.

**Results**

Seventeen of 18 replants survived completely except 1 had stump revision after distal partial necrosis.

In all 18 digits, the revascularization time ranged from 0 to 540 min, with an average of 54.5 min. The revascularization time was shorter than 20 min in 8 digits, between 20 and 120 min in 9 digits, and 540 min in 1 digit.

Among them, a 40-year-old female suffered avulsion amputation of the ring finger at the distal digit by a rolling machine. Vein arterialization was carried out after the failure of conventional replantation. The replanted finger showed pallor and was flat in the finger pulp after the release of tourniquet. Surgical exploration revealed no arterial spasm and anastomosis patency was confirmed. Our past clinical experience in vein arterialization had revealed that process of revascularization can be lagging. Based on this, we decided not to give up the replanted finger at the request of the patient. The finger did not become dark red until 9 h after the replantation. It turned red completely 1 week later, and successful survival was obtained uneventfully 2 weeks later [Figures 2–5].

**Discussion**

Recently, as a remedial measure and an alternative to conventional replantation, vein arterialization has raised
widespread interest in this area of the replantation surgery. \(^3\)\(^5\) The unique characteristic of its nonphysiological blood supply requires special implementations through intraoperative vascular monitoring. Comprehending phenomenon will improve the success rate of this unusual replantation.

In conventional finger replantation, artery supply is re-established by artery-to-artery anastomosis. The finger would be red immediately after the release of the tourniquet, except when there is vascular spasm or thrombosis. According to the definition of the reperfusion delay, this phenomenon will not occur in regular replantation. In vein arterialization, the blood supply was recreated by arteriovenous fistula between the venous and arterial systems of the finger, following which the venous system serves as a route of arterial inflow [Figure 1].\(^1\)

As far as perfusion delay was concerned, there was the difference between traditional replantation and replantation by vein arterialization. First, reperfusion delay occurred more frequently in replantation by vein arterialization according to our clinical experience. In our study, the reperfusion delay occurred in most cases in replantation by vein arterialization. The time from pallor to dark red, as we called revascularization time, was 54.5 min at average during the operation. There is short literature which shows revascularization time or reperfusion delay in traditional replantation as we have known. In addition, reperfusion delay would occur in traditional replantation when there was vasospasm or thrombosis. However, there was no vasospasm or thrombosis during replantation by vein arterialization when reperfusion delay occurred. Finally, it was true that it was always advisable to wait before abandoning

![Figure 3: Preimplantation X-ray of hand anteroposterior view showing amputated distal phalanx of ring finger](image)

![Figure 4: Clinical photograph showing (a) Dark red of ring finger on postoperative 1 day (b) Bright red of ring finger on postoperative 1 week](image)

![Figure 5: Clinical photograph showing (a) Stitch removal on postoperative 2 weeks (b) Survived completely on postoperative 4 weeks (the dorsal side) (c) Survived completely on postoperative 4 weeks (the volar side)](image)
a revascularization when reperfusion delay occurred. Nevertheless, in traditional replantation, anti-spasm treatment or re-exploratory surgery should be carried out when there was vascular spasm or thrombosis, respectively. Neither anti-spasm treatment nor re-exploratory surgery should be done during reperfusion delay in replantation by vein arterialization. Only wait-and-see was needed. Then, reperfusion would be possible to restore and the replanted finger survived.

We believe, the exact mechanism of reperfusion delay may be related to the specific hydrodynamics. The exact mechanism of reperfusion delay is still unknown. When the arterial blood perfuses through the vein inversely, the lag of reperfusion occurs due to the repulsion of the valve. Over the course of time, revascularization will eventually take place when the strength of vein valves is overcome by the persistent impact of arterial blood flow. The further experimental studies are needed to understand the exact mechanisms of the reperfusion delay.

Clinically, it is crucial to be aware of the phenomenon of the reperfusion delay through the replantation procedure. When no reperfusion is observed during the initial phase in spite of the high quality of vein arterialization, reperfusion delay should be considered. At this stage, waiting for the restoration of blood supply becomes essential to salvage the replant which could have been given up otherwise.

### Table 1: Clinical details of patients

| Case number | Age/sex | Injured finger | Type of injury | Vessel repair | Revascularization time | Outcome |
|-------------|---------|----------------|----------------|---------------|------------------------|---------|
| 1           | 19/male | Right thumb/index | RA              | A/V1          | 0/0                    | CS      |
| 2           | 32/male | Right index     | CA              | A/V2          | 10                     | CS      |
| 3           | 34/male | Left index/middle | RA              | A/V1          | 45/45                  | CS      |
| 4           | 40/female | Right ring     | RA              | A/V1          | 540                    | CS      |
| 5           | 35/male | Left thumb      | CA              | A/V2          | 15                     | CS      |
| 6           | 37/male | Right thumb     | CA              | A/V3          | 30                     | CS      |
| 7           | 28/male | Right index/middle | CA              | A/V1          | 30/30                  | CS      |
| 8           | 25/female | Right index    | RA              | A/V2          | 10                     | CS      |
| 9           | 53/male | Left thumb      | RA              | A/V2          | 100                    | CS      |
| 10          | 26/male | Right index     | RA              | A/V1          | 18                     | CS      |
| 11          | 29/female | Left thumb/index | CA              | A/V1          | 40/40                  | CS      |
| 12          | 35/female | Left thumb     | RA              | A/V2          | 28                     | CS      |
| 13          | 27/male | Right index/middle | RA              | A/V1          | 0/0                    | CS      |

A=Artery anastomosis by vein arterialization, V1, V2, V3=1 to 3 vein anastomosis, respectively, RA=Rotary avulsion, CA=Crushed avulsion, CS=Complete survival

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