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18시간까지의 허혈시간이 재접합 수지의 생존율에 미치는 영향

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Ischemia Time up to 18 Hours Does not Affect Survival Rate of Replanted Finger Digits

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Purpose: There are multiple dependent variables commonly attributed to survival of replanted digits. The ischemia time is thought to be a clinically relevant factor. However, controversy exists as large hand centers have reported successful replant outcomes independent of ischemic time. In this study, we present a single institution experience on the effect of ischemia time on the survival of completely amputated digits.

Methods: A retrospective review of a single institution experience was performed. This cohort included all comers who had suffered complete amputation of a digit (Zone 2-4) and underwent replantation from 2003 to 2009. Demographic information as well as injury mechanism, ischemic time, and replantation outcome were recorded for each patient. Chi-square was used to analyze the result.

Results: Mean age was 35.5 years old (2-69). Mean replantation survival was 89.5% (37/317). Survival rates were 94, 88, and 88% in respective groups of 0~6, 6~12, of > 12 hours of ischemia time. In chi-square analysis, there was no difference with *p* value of 0.257. No other independent patient factors showed statistically significant relationship to replant survival rate. In the group with longest ischemia time (12~18 hours) replant survival rate was 88% (37/42).

Conclusion: Prolonged ischemia time is commonly believed to be a contributing factor for replant survival. However, our experience has shown that survival rate is uniform up to 18 hours of ischemia.

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I. INTRODUCTION

Clinical factors known to affect survival rate of replanted digits most commonly include age, sex, nicotine use, type of injury, and ischemia time.[1-3] Ischemia causes cytoplasmic calcium influx with formation of reactive oxygen species leading to intracellular structural damage.[4] In case of muscular tissue, ischemia time of 6 hours is known to cause irreversible intracellular changes despite reperfusion.[5,6] However, different types of tissues have varying degrees of tolerance to prolonged ischemia, and such quality of a tissue affects the replant survival rate of an amputated organ.[6]

In 2000, Waikakul reported prolonged ischemia time to be a negative prognostic factor for replanted digits. However, the study included Zone 1 amputations, which could have survived by plasmatic imbibitions and inosculation rather than purely by revascularization. Further the study may have included partially amputated digits with intact circulation.[1] Such inclusion criteria allows potential confounding factor in delineating ischemia time as a purely independent factor in replantation survival rate. This study was designed with a stricter inclusion criterion to evaluate ischemia time on replantation survival rate.

II. MATERIALS AND METHODS

A single institutional experience on finger replantation was reviewed retrospectively from 2003 to 2009 using the emergency department admission database. Inclusion criteria were one or more traumatic finger amputation and did not discriminate against a patient's sex or age, or type of injury. Each amputation was distal to the metacarpophalangeal (MCP) joint exclusive of Zone I injury.[8] Any concurrent injury proximal to the MCP joint

was excluded (Fig. 1). Incomplete amputations with questionable circulation, such as soft tissue bridge, nerve bridge, or bone bridge, were excluded from the study as inclusion of such cases may have been confounding factors in previous studies.

Each patient was taken from emergency room to operating theater upon completion of the initial assessment and routine preoperative management. Replantation and vascular anastomosis was carried out in the usual fashion with intraoperative heparin infusion and volume optimization. Postoperative care included inpatient observation of replanted digit to discharge.

Ischemia time for each patient was defined as the duration of time between the reported times of injury to decompression of tourniquet upon completion of vascular anastomosis. In this study, data regarding warm versus cold ischemia time was incomplete. Even a single amputated digit may undergo warm and cold ischemia from the time of injury, through the emergency department, to the operative theather. Therefore, all available data regarding the duration of ischmia was considered as 'total ischemia time'.

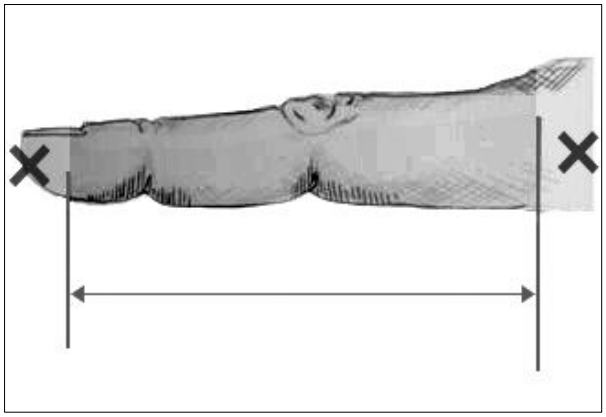

Fig. 1. Exclusion Criteria.

Any variation in replantation outcome owing to differences from age, sex, or type of injury were planned for logistic regression. Each injury was classified as clean cut, crush, or avulsion. An injury was considered as a clean cut if the wound was described as knife, glass, scissor, or sharp wound or by hand saw. Crush injuries were identified by press machine, industrial machine, hammer, electrical saw. Finally, rest of the injury was defined as avulsion if the finger was amputated by a pulling mechanism by heavy machinery or by a glove which was caught in a rotating assembly.

Each replantation was graded as survival or failure depending on the postoperative course. If a patient is discharged from the hospital without a secondary procedure or required a secondary procedure such as debridement or debridement and skin graft, the replantation was considered as survival. Any replantation was considered as a failure if it required any of the following procedures: amputation, bone graft, stump revision, free flap.

The tabulated data was analyzed using Fisher's exact test and Pearson chi-square test. The demographic data was analyzed in standard fashion. The incidence of survival and failure was evaluated as a function of ischemia time of two- and six-hour increments. Subgroup analysis using amputation level was performed with six-hour ischemia time increments.

III. RESULTS

There were a total of 354 complete amputations among 280 patients who were admitted to emergency room and

Table I. Distribution of Age and Survival Rate

Age	No. of digits	Success	Failure	Survival rate (%)	*p*-value*
0~9	9	7	2	77.8	
10~19	6	5	1	83.3	
20~29	49	46	3	93.9	
30~39	75	65	10	86.7	0.554†
40~49	119	109	10	91.6	
50~59	72	63	9	87.5	
60~69	24	22	2	91.6	
Total	354	317	37	89.5	

*Tested by Fisher's exact test.
†: Age had statistically significant effect on survival outcome.

underwent replantation. Mean age was 35.5 years with range of 2 to 69 years. There were 234 male to 46 female in this cohort. Overall, 89.5% (317/354) of the replanted fingers ultimately survived. Ischemia time ranged from 3 to 18 hours. Neither age nor sex had statistically significant effect on survival outcome (Tables I, II). For ischemia time of less than 12 hours, 281 of 313 replantations survived (90%). For ischemia time of greater than 12 hours, 37 of 41 replantations survived (88%). Evaluation of survival rate by ischemia time of 6-hour increments revealed 94%, 88%, and 88% respectively for 0~6 hour, 6~12 hour, and 12~18 hour groups. These variations were not statistically significant (p value = 0.257) (Table III). Survival rate in groups of two-hour interval also failed to show a statistical difference (Table IV). Survival rate was also calculated for each amputation level and ischemia time in 6-hour increments; this analysis also failed to show statistical difference by amputation level and by ischemia time (Table V). Overall, ischemia time did not seem to affect survival rate up to 18 hours in this cohort with mean survival rate of 89.5% (Fig. 2). Finally, type of injury did not appear to affect survival rate of replanted digits (p value > 0.05) (Table VI).

IV. DISCUSSION

Since successful thumb replantation as first reported by Komatsu and Tamai in 1967,[9] replantation of amputated fingers has become popularized as one of the

Table II. Sex and Survival Rate

Sex	No. of digits	Success	Failure	Survival rate (%)	p-value*
Male	291	259	32	89.0	
Female	63	58	5	92.1	0.472†
Total	354	317	37	89.5	

*Tested by Pearson chi-square test.
†: Sex had statistically significant effect on survival outcome.

Table III. Effect of Ischemic Time Interval of 6 Hours on Survival Rate

Ischemic time (h)	No. of digits	Success	Failure	Survival rate (%)	p-value*
0~6	98	92	6	94	
6~12	214	188	26	88	0.257†
12~18	42	37	5	88	

*Tested by Pearson chi-square test.
†: These variations were not statistically significant.

Table IV. Effect of Ischemic Time Interval of 2 Hours on Survival Rate

Ischemic time(h)	No. of digits	Survival rate (%)	p-value*
2~4	39	90	
4~6	113	90	
6~8	91	88	
8~10	61	90	0.609†
10~12	20	90	
12~14	15	87	
14~16	15	93	
16~18	1	100	

*Tested by Fisher's exact test
†: These variations were not statistically significant

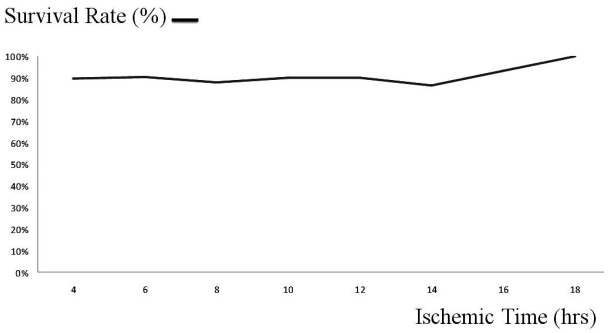

Fig. 2. Survival Rate by Ischemic Time.

main treatment modality.

Established contraindications to replantation are severe injury, multiple level amputations, concurrent trauma to other organs, or an underlying medical illness.[10] However, with the advancement in replantation and perioperative management of finger amputation the survival rates have improved drastically, and those contraindications have become relative rather than absolute. Still, stronger contraindications exist for patients who are considered to be adversely affected by the results of replantation, who have severe crush injury to amputated tissue,

Table V. Effects of Ischemic Time Intervals of 6 Hours on Survival Rate at Different Digital Levels

Level	No. of digits	Ischemic time (h)	Survival rate (%)	*p*-value*
Distal phalanx	72	0~6	96	0.147‡
		6~12	73	
		12~18	83	
DIPJ†	86	0~6	85	1‡
		6~12	86	
		12~18	100	
Mid phalanx	57	0~6	100	0.408‡
		6~12	95	
		12~18	83	
PIPJ†	81	0~6	95	0.445‡
		6~12	92	
		12~18	82	
Proximal phalanx	38	0~6	100	1‡
		6~12	96	
		12~18	100	
MPJ†	21	0~6	100	1‡
		6~12	86	
		12~18	75	

†: DIPJ, distal interphalangeal joint; PIPJ, proximal interphalangeal joint; MPJ, metacarpophalangeal joint.
*Tested by Fisher's exact test.
‡: These variations were not statistically significant.

Table VI. Type of Injury

Type of injury	No. of digits	Success	Failure	Survival rate (%)	*p*-value*
Clean cut	99	90	9	90.0	
Crush	173	155	18	89.6	0.794†
Avulsion	82	72	10	87.8	

*Tested by Pearson chi-square test.
†: Type of injury did not appear to affect survival rate of replanted digits.

concurrent psychiatric disorder, or are known to abuse substances.[7]

Replant survival is known to be affected by age, gender, injury type, ischemia time, underlying medical disease, and nicotine use.[11] Of these, ischemia time is the only factor which can be addressed in a clinical setting by expedition of the operation or streamlining the preoperative management and hospital environment as well as modifying intraoperative strategy.

Generally, tissue ischemia time was less than 6 hours at room temperature and 12~14 hours at low temperature. These same allowable ischemia time limit was considered permissible up to 16 hours for amputated fingers.[12] In 1998, Hangitaek et al. reported animal model study on the affects of ischemia time on island flap using mice where ischemia appeared to irreversibly affect replant survivability at around 6 hours of ischemia.[5] Despite the animal model study, retrospective reports on replantation of muscle-free tissue such as finger are known to tolerate prolonged ischemia time.[13] Many have reported successful replantation after prolonged ischemia time, and upper limit of ischemia time for finger replantation continues to increase with experience.

Under ischemia conditions, glycogen storage is quickly depleted with ensuing lactic acidosis accumulation of toxic metabolites due to anaerobic metabolism. With activation of phospholipase and lysozyme, the cells in ischemic tissue undergo irreversible change-which is recognized as necrosis grossly.[4] Prolonged ischemia, therefore, was previously thought to be a negative prognostic factor in replantated organs. However, in finger replantation where the tissue is free of oxygen-dependent muscle clinical experience has demonstrated ischemia time not to have a strong correlation with survival of replanted digit.[1,2]

Previous studies on affects of ischemia time on finger replantation has included all types of amputations including potential injuries in which the replanted digit may have survived by reasons other than purely by revascularization. In Yamano Zone I amputations, survival rate can be as high as 78% for a composite graft without vascular anastomosis.[8,14] Additionally, Zone I amputation is highly operator dependent because of the diminutive vascular sizes and is often complicated by postoperative venous congestion.[15] Finally, previous studies have included partial amputations which may have provided a hidden vascular supply which would allow prolonged but attenuated "ischemia".

In 2000, Waikakul et al. reported that because finger is devoid of metabolically active tissue such as muscle, ischemia does not appear to be a critical factor in replant survivability.[1] In 2008, Li et al. also made a similar observation on amputated finger to withstand prolonged ischemia time.[2] Despite evidences suggesting prolonged ischemia does not appear to negatively affect replant survival rate in finger amputations, Dec reported in a 2006 meta-analysis that ischemia time greater than 12 hours does appear to cause elevated failure rate.[3] However, the studies included in the meta-analysis appears to have included Zone I injuries as well as partial amputations.

In this study, we have excluded cases which may lead to confounding errors mentioned above. Our experience on complete finger amputations exclusive of Zone I injury has shown that total ischemia time greater than 12 hours does not appear to negatively affect replant survival rate. In our cohort, total ischemia time of up to 18 hour was tolerated with overall survival rate of 89.5%. Though logistic regression was planned for any confounding demographic variables which may contribute to improved survival rate of amputated digits. However, as reported in the results section, these variables did not show statistically significant difference. Therefore, logistic regression was deemed unnecessary and was not performed.

V. CONCLUSION

A single institution review of replantation of complete finger amputations are reviewed with respect to the effects of ischemia time on replantation survival rate. In this cohort, the survival rate was uniformly high regardless of injury zone, type of injury, or ischemia time.

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