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Original Article

Epidemiology of digital amputation and replantation in Taiwan: A population-based study

Dun-Hao Chang [a], Shih-Yu Ye [b], Li-Chien Chien [c], Hsu Ma [a,*]

[a] *Division of Plastic and Reconstructive Surgery, Department of Surgery, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*
[b] *Department of Administration, Kaohsiung Municipal Min-Sheng Hospital, Kaohsiung, Taiwan, ROC*
[c] *Division of Traumatology, Department of Surgery, National Yang-Ming University Hospital, Yilan, Taiwan, ROC*

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Abstract

Background: Publications on digital amputation and replantation have been mostly derived from case series in high-volume hand surgery practices, and epidemiological studies are few. This study used a population-based dataset to illustrate the incidence of digital amputation, patient and hospital characteristics, and their relationships with replantation.
Methods: A claim for reimbursement dataset (2008) was provided as a research database by the Bureau of National Health Insurance, Taiwan. Patients with ICD-9-CM coded as digital amputation (885 and 886) were included. These were cross-referenced with procedure codes for replantation procedures (84.21 and 84.22). We defined the patients who underwent thumb replantation (84.21) and thumb amputation (84.01) during a single hospitalization as replantation failure. Patient and hospital characteristics were studied with statistical analysis.
Results: In total, 2358 patients with digital amputation were admitted (1859 male, 499 female), mean age 39.2 ± 15.5 years. The incidence was 10.2/100,000 person–years. The highest incidence was 14.7/100,000 person–years in the age group 45–54 years. Machinery and powered hand tools caused 68.8% of digital amputations. Thumb amputation [odds ratio (OR): 1.35, $p = 0.01$], private hospital (OR: 1.40, $p = 0.01$), medical center (OR: 2.38, $p < 0.001$), regional hospital (OR: 2.41, $p < 0.001$) and hospitals with an annual volume >20 digital amputations (OR: 4.23, $p < 0.001$) were associated with higher attempt rates for replantation. Elderly patients (age >65 years) had higher risk of thumb replantation failure (OR: 32.30, $p = 0.045$), while hospitals with >20 annual replantations had lower risk (OR: 0.11, $p = 0.02$).
Conclusion: Our study of the National Health Insurance database characterized the epidemiology of digital amputation patients undergoing replantation and the facilities in Taiwan where these procedures are performed. The hospitals treating more digital amputation patients had higher attempt rates and lower thumb failure rates.

Keywords: amputation; digit; epidemiology; finger; replantation

1. Introduction

Hand and digital injuries account for >4.8 million visits/y to emergency departments in the USA.[1] Because digits are particularly vulnerable to injury, it is not surprising that digital amputation is the most common type of amputation injury in the upper extremities; it commonly occurs in the work setting in predominantly unskilled manual laborers.[2] Such injury is associated with disfigurement and disability, bringing functional, psychosocial, and financial consequences.

Replantation is the process of reattaching the digit or limb by repairing the broken bones and cut nerves, arteries, veins, and tendons. Replantation of the amputated part requires specialized equipment and well-trained staff and surgeons. As

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Hsu Ma, Division of Plastic and Reconstructive Surgery, Department of Surgery, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: sma@vghtpe.gov.tw (H. Ma).

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with advances in microsurgical techniques, replantation is now more widely performed.[3]

The publications on digital amputation and replantation have been derived from case series in high-volume hand surgery practices.[4,5] Although these series have provided important demographic and clinical data, the information from these highly selected samples may not reflect the national experience. However, only a few epidemiological studies have been undertaken.[1,6–16]

Because replantation is complicated and costly, requiring prolonged operation time, long recovery periods, and multiple procedures, facilities offering adequate treatment are limited. Previous studies have shown that age, treatment location, and primary payer status are related to the rate of replantation.[6,7]

The purpose of this study was to use a large nationwide database to characterize the epidemiology of digital amputation and replantation in Taiwan, with particular emphasis on the characteristics of the patients and the procedures they received, as well as the types of facilities where those patients received treatments.

2. Methods

2.1. Data source

Taiwan launched a single-payer national health care program, National Health Insurance (NHI), in 1995; this program covered >99% of the 23 million population of Taiwan at the end of 2008. To respond to current and emerging health issues rapidly and effectively, the National Health Research Institute, cooperating with the NHI Bureau, established an NHI research database.

This population-based retrospective study used consecutive secondary data abstracted from the annual inpatient expenses database of the NHI Bureau from January 1, 2008 to December 31, 2008.

2.2. Selection of patients

Annual inpatient claim files with diagnostic ICD9 codes, as 885 (traumatic amputation of thumb) or 886 [traumatic amputation of other finger(s)], defined as digital amputation, were included in this study. These were then cross-referenced with ICD9 procedure codes for replantation procedures: 84.21 (thumb reattachment) and 84.22 (finger reattachment). Multiple finger or thumb amputations were counted as one event, and multiple digit replantations were also taken as one event, and we used these data to calculate the attempt rate for replantation (i.e., the number of patients who underwent replantation/number of patients who had digital amputation).

2.3. Failure of replantation

To obtain the failure rate of digital replantation from this population-based study, we followed Shale et al's study[8] and assumed that patients who underwent replantation and amputation during single hospitalization were replantation failures. However, patients with multidigit amputations may have undergone replantation of one finger and amputation of another, which was unclear from the database. Thus, we only included thumb replantation (84.21 thumb reattachment) and amputation (84.01 thumb amputation) as our study group. Patients having these two procedure codes were defined as replantation failures.

2.4. Demographics and covariables

We reviewed patient and injury characteristics, including age, sex, injury location (thumb or fingers), location of residency (urban, suburban, or rural), mechanism of injury, chronic comorbidity, associated injuries, length of stay, and total charges.

Mechanism of injury was analyzed from external cause-of-injury codes (E-codes). E-codes were classified into broader categories to allow for meaningful comparison with previous studies. Chronic comorbidity and associated injuries were inferred from the ICD-9-CM codes declared in the same admission data file. Diabetes, hypertension, and other cardiovascular diseases, head injury, chest injury, abdominal injury, and limb fracture were grouped as variables.

In addition, we reviewed the characteristics of the treating hospitals, including ownership (private or public), annual volume of amputation and replantation, and level of hospital. Hospitals in Taiwan were classified into three levels: medical centers (MC), regional (RH), and local hospitals. According to Taiwan's definition (in 2008), an MC needs to have >700 beds and an RH needs to have >250 beds. RHs are required to provide medical services covering fourteen subspecialties, and MCs are expected to provide services covering 19 subspecialties. A common criterion for RHs is the ability to perform operations of neurosurgery for acute brain injury. MCs are expected to maintain cardiovascular surgery service with the ability to perform open-heart surgery on a regular day-to-day basis.

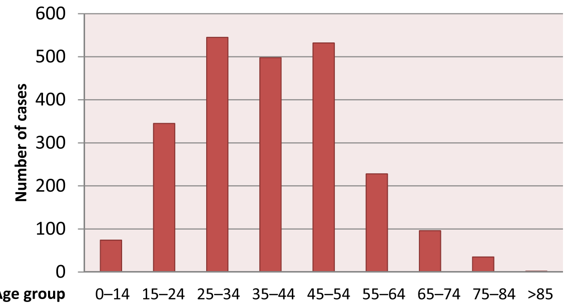
2.5. Statistical analysis

Descriptive statistics about the distribution of age, sex, weekday of admission, length of stay (LOS), and inpatient cost were analyzed. Two-sample *t*-test was used for statistical analysis of continuous variables.

Categorical variables were analyzed using contingency (cross-tabulation) tables and the χ^2 test on amputation and replantation rates. Multiple variables were analyzed using logistic regression to determine patient and facility characteristics that were associated with a higher likelihood of replantation and failure rates. For the purposes of this study, $p < 0.05$ was considered significant.

3. Results

We identified 2358 patients as having digital amputation in 2008. Of these, 1859 were male, and 499 female. Mean age was 39.2 ± 15.5 years. There were 405 patients diagnosed



Incidence	1.9	10.6	13.9	13.5	14.7	10.1	7.0	4.2	2.4

Fig. 1. Age distribution of digital amputation, Taiwan, 2008. The incidence is presented as/100,000 person−years.

with thumb amputation and 1953 patients were diagnosed with finger amputation. The incidence was 10.2/100,000 person−-years, and a higher rate was found in men than in women (16.0 vs. 4.4/100,000 person−years).

A bar chart of patient ages is shown in Fig. 1. The highest frequency was in patients aged between 25 years and 34 years (545 patients), but the highest incidence rate was 14.7/100,000 person−years in the age group 45−54 years. Admissions for amputation were more common during weekdays with the highest frequency on Fridays (384 patients) and the lowest on Sundays (188 patients).

3.1. Injury characteristics

There were 1773 patients with an E-code record for mechanism of digital amputation. The most common cause was the use of machinery and powered hand tools ($n = 1220$, 68.8%). The remaining cases were recorded as injuries caused by cutting ($n = 169$, 9.5%), caught between objects ($n = 152$, 8.6%), motor vehicle accidents ($n = 137$, 7.7%), and miscellaneous ($n = 95$, 5.4%).

Among the total 2358 patients, 856 (36.3%) underwent replantation. Table 1 shows demographic and clinical characteristics of digital amputation and replantation. The mean age of patients who underwent replantation was 37.7 ± 14.7 years, compared with a mean age of 40.1 ± 15.9 years in those who did not undergo replantation ($p < 0.001$). The mean hospital LOS for all patients was 6.9 ± 6.0 days, and the mean total hospital charges were US$1909 ± 1946. The average LOS and the total charges for replantation cases were significantly longer and higher than for the nonreplantation cases (8.9 ± 5.3 days vs. 5.8 ± 6.1 days, $p < 0.001$, US$3199 ± 2017 vs. US$1173 ± 1461, $p < 0.001$).

3.2. Facility characteristics

Table 1 also lists the hospital characteristics of digital amputation and replantation. Of digital amputations treated at medical centers, 44.4% were replanted, compared with 37.3% and 11.7% at regional and local hospitals, respectively ($p < 0.001$). The average attempt rate for digital replantations in private hospitals was 38.9% and 25.3% in public hospitals ($p < 0.001$).

Table 1
Demographic, clinical and hospital characteristics.

	Replantation	Nonreplantation	Total	p[a]
Total number	856	1502	2358	
Length of stay (d)	8.9 ± 5.3	5.8 ± 6.1	6.9 ± 6.0	<0.001
Total charges (US$)	3199 ± 2017	1173 ± 1461	1909 ± 1946	<0.001
Age (y)	37.7 ± 14.7	40.1 ± 15.9	39.2 ± 15.5	<0.001
Sex				0.168
Male	688 (80.4)	1171 (78.0)	1859 (78.8)	
Female	168 (19.6)	331 (22.0)	499 (21.2)	
Age (y)				0.001
0−19	78 (9.1)	111 (7.4)	189 (8.0)	
20−44	481 (56.2)	792 (52.7)	1273 (54.0)	
45−64	268 (31.3)	492 (32.8)	760 (32.2)	
≥65	29 (3.4)	107 (7.1)	136 (5.8)	
Type of digit				0.002
Thumb[b]	174 (20.3)	231 (15.4%)	405 (17.2)	
Finger	682 (79.7)	1271 (84.6%)	1953 (82.8)	
Comorbidity				
DM	22 (2.6)	63 (4.2)	85 (3.6)	0.042
Hypertension	47 (5.5)	78 (5.2)	125 (5.3)	0.756
Associated limb fracture	115 (13.4)	238 (15.8)	353 (15.0)	0.115
Residency of patients				0.149
Urban	491 (57.7)	870 (58.5)	1361 (58.2)	
Suburban	39 (4.6)	45 (3.0)	84 (3.6)	
Rural	321 (37.7)	573 (38.5)	894 (38.2)	
Hospital ownership				<0.001
Public	113 (13.2)	333 (22.2)	446 (18.9)	
Private	743 (86.8)	1169 (77.8)	1912 (81.1)	
Hospital level				<0.001
Medical center	376 (43.9)	471 (31.4)	847 (35.9)	
Regional hospital	442 (51.6)	743 (49.5)	1185 (50.3)	
Local hospital	38 (4.4)	288 (19.2)	326 (13.8)	
Hospital yearly amputations		1502		<0.001
1−5	20 (2.3)	196 (13.0)	216 (9.2)	
6−10	27 (3.2)	143 (9.5)	170 (7.2)	
11−20	61 (7.1)	264 (17.6)	325 (13.8)	
≥20	748 (87.4)	899 (59.9)	1647 (69.8)	

Data are presented as n (%) or mean ± SD.
DM = diabetes mellitus; SD = standard deviation.
[a] The p values for categorical variables were derived from Chi-square test; the p values for continuous variables were derived from Student t test; reported p values correspond to overall comparison of proportions between replantation and nonreplantation columns for each variable and not for comparison of specific groups within each variable.
[b] Patients coded with ICD9 885 were defined as thumb ampution group, but some patients may have had simultaneous finger amputation, and they were also included in this group.

There were 173 hospitals identified in this research database. These hospitals were separated into groups based on the number of digital amputation patients seen per year. Of these 173 hospitals, 94 (54.3%) treated from one to five cases, 22 (12.7%) treated from six to 10 cases, 23 (13.3%) treated 11−20 cases, and 34 (19.7%) treated >20 cases. With regard to the distribution of replantation surgery among hospitals, we found that the majority of digital replantations (87.4%) were performed at hospitals with an annual volume >20 digital amputations/y, and only 2.3% were performed at hospitals with an annual volume of one to five digital amputations/y (Table 1).

Fig. 2 shows the attempt rates for digital replantation according to hospital annual volume of amputation. Attempt rates

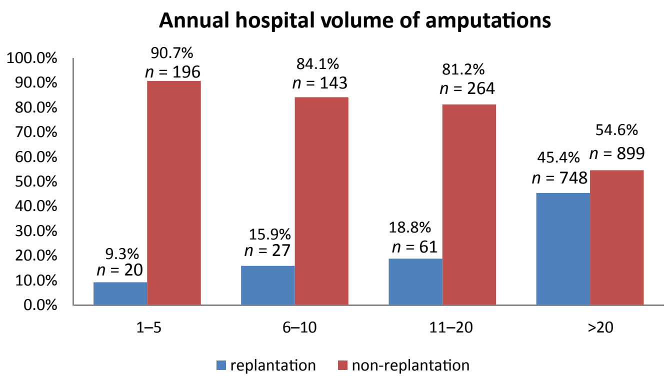


Fig. 2. Percentages of replantation and nonreplantation according to annual hospital volume of amputations.

rose when the hospitals' annual volume increased. Hospitals with annual volume of digital amputation >20 had the highest attempt rate, 45.4%, and were five times more likely to undertake replantation than hospitals that only treated 1−5 patients per year.

3.3. Multivariable analysis

Table 2 shows the results of the multivariable analysis of receiving replantation. Patient and facility characteristics significantly more likely to be associated with replantation were thumb amputation (OR: 1.35, $p = 0.01$), private hospital (OR: 1.40, $p = 0.01$), medical center (OR: 2.38, $p < 0.001$), regional hospital (OR: 2.41, $p < 0.001$), and hospitals with an annual volume >20 digital amputations (OR: 4.23, $p < 0.001$). Senior patients (age >65 years), when compared with the younger patients (age 0−19 years), seemed to have a lower likelihood of receiving replantation, even though the difference was not significant (OR: 0.59, $p = 0.054$).

Table 2
Factors associated with the odds of receiving replantation.[a]

Variable	Odds ratio	95% CI	p
Sex (ref, female)			
Male	1.10	0.88−1.37	0.395
Age (ref, 0−19)			
20−44 y	0.91	0.66−1.27	0.59
45−64 y	0.87	0.62−1.23	0.43
≥65 y	0.59	0.35−1.009	0.054
Thumb (ref, fingers)	1.35	1.07−1.70	0.01
Diabetes	0.73	0.41−1.29	0.28
Hospital ownership (ref, public)			
Private	1.40	1.08−1.82	0.01
Hospital level (ref, local hospital)			
Medical center	2.38	1.53−3.7	<0.001
Regional hospital	2.41	1.59−3.66	<0.001
Patients' residency (ref, rural)			
Urban + suburban[b]	1.037	0.86−1.26	0.71
Hospital yearly amputations (ref, 1−5)			
6−10	1.28	0.67−2.46	0.45
10−20	1.44	0.81−2.58	0.22
>20	4.23	2.47−7.26	<0.001

CI = confidence interval; ref = reference group.
[a] Logistic regression analysis was used to determine the likelihood of receiving replantation. An odds ratio >1 indicates greater odds of receiving replantation compared with the reference group and an odds ratio <1 indicates decreased odds of receiving replantation compared with the reference group.
[b] Only two counties belong to suburban area (Hsinchu County and Chiayi County), and we put urban and suburban hospitals into the same group for comparison to rural ones.

3.4. Failure rate analysis

We identified 154 patients with thumb replantation in the database. Among these patients, 13 had undergone thumb amputation during the same hospitalization and were defined as replantation failures. The failure rate was 8.4%. Elderly patients (age >65 years) had higher risk of replantation failure (OR: 32.30, $p = 0.045$). The hospitals with annual amputation of >20 had a similar failure rate when compared to those with <20 (OR: 0.67, $p = 0.64$). However, the hospitals with annual replantation of >20 incurred lower risks of thumb replantation failure (OR: 0.11, $p = 0.02$; Table 3).

4. Discussion

The incidence of traumatic digital amputation has been reported in several studies. Conn et al[1] showed an estimated 27,886 non−work-related finger amputations treated in US hospital EDs annually during 2001−2002, and the estimated national incidence of hospitalized persons was 1.1/100,000 person−years. Gavrilova et al[9] revealed 2.13 digital amputations/100,000 person−years in North Carolina during 2004−2006. Liang et al[10] reported the annual incidence of work-related upper-limb amputations in Taiwan was 12.5/100,000 person−years, and about 96% of those involved digital amputation.

Table 3
Factors associated with the risks of replantation failure (thumb).[a]

Variable	Risk ratio	95% CI	p
Sex (ref, female)			
Male	1.01	0.15−6.96	0.99
Age (ref, 0−19 y)			
20−44 y	1.43	0.11−19.43	0.79
45−64 y	0.72	0.05−10.86	0.81
≥65 y	32.30	1.08−965.2	0.045
Hospital ownership (ref, public)			
Private	0.64	0.13−3.24	0.59
Hospital level (ref, MC)			
Regional hospital	0.26	0.06−1.17	0.08
Local hospital[b]	—	—	—
Patients' residency (ref, rural)			
Urban + suburban	0.57	0.13−2.44	0.45
Hospital yearly amputations (ref: <20)			
≥20	0.67	0.12−3.62	0.64
Hospital yearly replantations (ref: <20)			
≥20	0.11	0.017−0.725	0.022

CI = confidence interval; MC = medical center; ref = reference group.
[a] Logistic regression analysis was used to determine the likelihood of replantation failure. A risk ratio >1 indicates greater risk of replantation failure compared with the reference group and a risk ratio <1 indicates decreased risk of replantation failure compared with the reference group.
[b] Only nine patients underwent thumb replantation in local hospital, but none of them had replantation failure.

We found that the incidence of digital amputation in Taiwan in 2008 was 10.2/100,000 person−years, which was higher than previous reports from Western countries. Workers doing manufacturing in Taiwan might have a higher risk for digital injuries. Additionally, the database of those Western studies was based mostly on part of the population and could not represent the entire nation. In our study, we used the NHI research database, which covered >99% of the national population and could be more comprehensive in evaluating the national incidence of digital amputation.

Previous studies reported that digital amputation injury commonly occurs in the work setting, with significantly higher frequency among young men.[11,12] Similarly, the findings of our study showed that digital amputation in Taiwan occurred most commonly on weekdays, among working-age men, and as a result of industrial machinery, suggesting that work-related injury was the primary cause. It seems that more effort is required to emphasize industrial safety and safety education.

Regarding the attempt rates for digital replantation, previous epidemiological studies from Western countries revealed that 9.7−16.5% of digital amputation patients had received replantations.[6−9,13,14] In our study, the overall attempt rate was 36.3%, much higher than the Western results. One reason for this huge difference is that Taiwan's traditional concept encourages maintaining the body integrity and physical appearance, and therefore, surgeons have more motivation to perform replantations. A second reason is that nearly all the patients in Taiwan had NHI, and 90% of the medical cost would be covered by this program. While Friedrich et al[7] revealed that self-pay, Medicare, and Medicaid patients had lower replantation rates than patients with other payer status in the USA, the NHI in Taiwan alleviated the financial burden of digital replantation.

In the univariable analysis, similar to Friedrich et al's[7] report, we found that digital replantations were more commonly performed at large and private hospitals. We also found that hospitals that saw more amputation patients annually had higher attempt rates. Moreover, in the multivariable analysis, the annual volume of amputation was found to be the most significant factor associated with attempt rates for replantation, and the hospitals with >20 annual replantations had the lowest failure rates. These findings are similar to Shale et al's[8] report, which is specific to thumb amputations.

Indeed, replantation remains relatively uncommon because of associated high costs, need for extensive follow-up, and potentially serious complications that can lead to replantation failure. It requires a high level of microsurgical technique, and the operation should be performed not by the occasional microsurgeon but by a microsurgeon who has substantial training and commitment. A vicious cycle is created when surgeons do not perform an adequate number of digital replantations in order to acquire the requisite skills. Less experience leads to more failures and ultimate abandonment of this important operation.

Today, the current criteria for digital replantation include thumbs, single digits distal to flexor digitorum superficialis tendon insertion, multiple fingers and all amputations in children.[3] The final determination of whether to replant a digit should be based on these criteria and the patients' general condition. In Taiwan, with such a high replantation rate, the overuse of replantation should also be avoided. By contrast, treating hospitals should have the ability to perform the procedures; otherwise they should transfer the patients to facilities with technical expertise. Taiwan is a relatively small country that is only 35,980 km^2, and its well-developed transportation systems facilitate transferal and minimize the geographic differences in medical accessibility. This is compatible with our observation in this study that no significant difference of replantation rates exists between urban and rural areas. Therefore, it is of primary importance to send patients to hospitals treating an adequate yearly number of digital amputations. Trauma centers in Taiwan have already developed triage and transfer criteria and have provided for the availability of specialized surgical care (e.g., major burn injury). Adding the care of patients with hand injuries to this framework may help evenly distribute the patient load and improve the timely delivery of hand surgery services to patients with serious hand injuries.

In a previous epidemiology study in Taiwan, Lee et al[15] used a 1/20-sampled inpatient NHI research database to analyze extremity replantation from 1996 to 2000. During the interval, 368 patients receiving replantation were extracted (the estimated total number was 7340), and 94% of those patients underwent finger or thumb replantations.[15] Although the replantation rates among total amputation patients were unknown in Lee et al's[15] report, the nearly 1500 replantations performed/y indicated much higher replantation rates when compared with our study period in 2008. This decline also occurred in the USA.[16,17] The proposed reasons for this decline include time-consuming procedures, relatively low payment for surgery, busy surgeon schedules, inadequate training/confidence, and disappointing results. These data provided reference for policy makers to seek solutions for the current situation.

Although this study of the NHI database provides important findings that may stimulate further research, large database analyses of this kind have certain limitations. Firstly, confidentiality issues prevent the verification of individual cases of finger replantation through chart reviews. Secondly, we only studied the inpatient dataset; the outpatient/emergency room data were not included. The patients might have had replantation failure after being discharged and undergone revision or amputation surgery in an outpatient setting. This might cause underestimation of the failure rates. Thirdly, ICD-9 injury coding does not provide a detailed description of the level and severity (partial or complete) of amputation, the number of replanted fingers, or outcomes related to the replantation effort, although the current procedural terminology code (64153B replantation of 1 digit; 64154B 2 digits; 64155B 3 digits; 64156B 4 digits; and 64157B 5 digits) could be used to extract the patients undergoing multiple digital replantations. However, not knowing which patients had multiple digital amputations, it was difficult to calculate the replantation rate among patients with multiple digital amputations. Therefore, we did not analyze multiple digital amputation and replantation. For the same reason, we used an indirect method to determine replantation failure only in thumb replantations. The small number of replantation failure cases may have caused bias. For example, there were only nine patients who underwent thumb replantation in local hospitals, and none of them had replantation failure (Table 3). This 100% success rate for thumb replantation was even better than that in medical centers. Further studies should collect more years' data to enroll more patients and eliminate the bias.

In conclusion, our study of the NHI database characterized the epidemiology of digital amputation patients undergoing replantation and the facilities where these procedures were performed in Taiwan. We demonstrated that the hospitals with greater annual volume of replantations had higher attempt rates and the hospitals with greater annual volume of replantations had lower thumb failure rates.

Note

This study had been presented at the 2015 Annual Meeting of the American society of plastic surgeons, on Oct. 17, 2015, at the Boston Convention and Exhibition Center, USA. The abstract had been published in Plast Reconstr Surg. 2015 Oct;136(4S Suppl):27−28.

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