Treatment and Postsurgery Functional Outcome of Spaghetti Wrist

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Abstract

Background The outcomes of treating severe wrist injuries are not well understood and despite their complexity and prevalence, particularly among young adults, spaghetti wrist is rarely investigated. The aim of this study is to evaluate the postsurgery, functional outcome of spaghetti wrist injuries.

Material and Methods In this prospective cross-sectional study, 153 patients with spaghetti wrist injuries were followed up for approximately 20 months and were assessed regarding returning to work and postsurgical functional outcomes that included tendon functionality, opposition, intrinsic function, deformity, sensation, and grip strength.

Results The mean age was 28.3 ± 5 years. The most common cause of injury was glass window panes and bottles. Moreover, the most commonly involved structures were the tendons of flexor digitorum superficialis 3, 4, and 5. During the follow-up, the tendon functionality in 120 (78%), opposition in 115 (75.1%), and intrinsic function in 62 (40.5%) were “excellent.” Hand sensation was “fair” in 75 patients (49.1%), “good” in 46 patients (30%), and “excellent” in 28 patients (18.3%). The average return time to activities of daily living was 10 months.

Conclusion In this study, worse outcomes were seen in older patients and those with higher number of damaged structures (especially nerves).

Keywords

- spaghetti wrist
- tendon functionality
- intrinsic function
- sensation

Introduction

Hand injuries are very common since hands are used repeatedly in many activities.¹ The superficial location of critical structures, including tendons, nerves, and vasculature in the volar surface of the wrist exposes them to injuries with penetrating trauma.² Hand injuries usually occur in young

adults and generally involve the dominant hand. Hence, complex injuries to the hands can result in lifelong disability leading to social and economic hardship.³

Spaghetti wrist denotes extensive volar wrist lacerations of up to 16 different structures, including 12 tendons, 2 nerves, and 2 arteries and is considered to be among the most serious hand injuries.² Kumar-Kempelingiah reported an increase in

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the annual incidence of the injury: 6.6% from 1991 to 1995, to 9.3% from 1996 to 2000, and to 10.4% from 2001 to 2002.⁴

According to Puckett and Meyer, spaghetti wrist is the sharp laceration of the volar surface of the wrist (between its distal skin fold and the flexor musculotendinous junction) with a minimum of three transected structures, including at least one nerve and one vessel.⁵ Most studies provide no standard definition for spaghetti wrist; hence, these definitions vary from complete laceration of 3 structures (nerve, artery, and tendon), to injuries of 10 structures (including tendons, at least one major nerve and usually one major vessel).^{2,6,7}

Most clinicians would agree a combination of surgical repair, and hand therapy is the best treatment, however, the outcomes of these injuries are not quite well understood and require further study to assess the surgical outcomes of spaghetti wrist injuries.^{5,6,8,9} The aim of this study is to evaluate the combination treatment (surgical and hand therapy) outcome of spaghetti wrist, in terms of tendon functionality, opposition, intrinsic function, sensation, grip strength, and return to work.

Methods

Sample and Measures

This is a prospective cross-sectional study that reviewed the medical records of patients who presented to Poursina and Velayat Hospitals from June 2011 to February 2014. In this study, spaghetti wrist was defined as an injury involving seven structures of the distal forearm and proximal wrist, including at least one nerve and tendon (with or without vascular injuries). We chose 7 structures of the injured wrist based on the average obtained from previous studies that used most (10) and least (3) structures. The primary diagnosis for the spaghetti wrist was made by the surgeon at first; however, the final diagnosis of spaghetti wrist injury was made by the surgeon in the operating room, by closely examining the patient's wound and assessing the extent of injury for each of the wrist structures. The patients and/or their families were informed about this study and notified that the data and results from this study would be used for research publication. Specifically, the informed consent form consisted of an information sheet, which outlined the purpose and objectives of the study as well as the participant's rights regarding involvement. Patients who consented to participate in this study were included. This study was approved by the Guilan University of Medicine and Science, Institutional Review Board and Poursina and Velayate hospitals Ethical Committee. The inclusion criteria for this study included the diagnosis of spaghetti wrist and at least two postoperative follow-up visits. The exclusion criteria included fractures, replantation, degloving, and crush injuries. All of the patients experienced sharp trauma without crush injuries, soft tissue defects, or contusion. Out of the 493 patients with tendon and nerve lacerations, with or without vascular injuries, 386 patients had at least two follow-ups. From these 386 individuals, 153 patients were recognized as having experienced spaghetti wrist, and 233 patients were recognized as not having suffered from spaghetti wrist.

Surgical Method

Patients were laid in the supine position and underwent general anesthesia. The limb was bound by a tourniquet, and tendon repair was performed by the modified Kessler 2-strand core suture technique using 3-0 or 4-0 nylon suture. Nerve repair was performed by the interrupted epineurial repair method (8-0 nylon suture), and vascular repair was done with 7-0 and 8-0 nylon sutures. The timing of the operations ranged between 2.5 and 7 hours.

All patients had primary soft tissue closure except those with contamination that underwent delayed primary closure. Primary repair was achieved in 149 of the cases with nerve lacerations. Ulnar nerve transection with sural nerve autografts was required in four cases to relieve undue coaptation tension. Autogenous reversed saphenous vein interposition grafts were used in three cases where both the ulnar and radial arteries were damaged resulting in major gaps between the two ends. The criteria for arterial repair versus ligation was as follows: (1) if both ulnar and radial arteries were damaged, then both were repaired by primary anastomosis or reversed saphenous vein interposition autograft; (2) if either the radial or ulnar artery was damaged and there was no previous ligation of the damaged artery, then only the damaged artery was repaired; and (3) if either the radial or ulnar artery was damaged and previously ligated before transfer and 24 hours had passed, then the Allen test was done. If the result revealed normal hand perfusion, the arterial repair was not performed.

Postoperative Rehabilitation

After surgery, a dorsal extension block splint with the wrist at 15 degrees of flexion, metacarpal phalangeal joints at 20 degrees of flexion, and interphalangeal joints in full extension was applied for 28 days. Active extension of the fingers to the confines of the splint with passive flexion of the digits was commenced on the second postoperative day.

All patients had follow-up at 1 week, 3 weeks, 3 months, and every 3 months thereafter. To decrease the possibility of tendon adhesions, therapy began immediately following surgery. The physiotherapy protocol consisted of the Kleinert method¹⁰ and ranged from at least 10 to a maximum of 30 sessions, including classic sensory and motor reeducation.

Functional Outcome Evaluation

The postsurgical functional outcomes in this study, including tendon function, opposition, intrinsic function, deformity, sensation, and grip strength, were measured by the operating surgeon at the last follow-up visit. Tendon function, opposition, intrinsic function, deformity, and sensation were graded as excellent, good, fair, or poor, based on the Noaman report (►Table 1). Tendon function was assessed by measuring the individual tendon function and comparing it to the normal full range of motion. Also, the flexor tendon function was assessed on the basis of flexion deficits (the pulp to the distal palmar crease distance). The opposition was evaluated by assessing thumb movement over the three phalanges of the other four fingers. The intrinsic function was evaluated by examining finger abduction and adduction as well as the

Table 1 Author evaluation system for spaghetti wrist follow-up results¹¹

	Tendon function	Opposition	Intrinsics	Deformities	Sensation
Excellent	Individual tendon function is evident with 85% to full range of motion or finger flexion to 1.0 cm or less from the distal palmar crease	When the tip of the thumb moves freely over the three phalanges of the other four fingers	When the patient can do both finger abduction and adduction with negative Froment sign	Major if there is both clawing and ape hand	When the two-point discrimination is less than 10 mm
Good	70–84% total normal range of motion or 2.0 cm from the distal palmar crease	When the tip of the thumb touches only the tip of the other four fingers	When the patient can do both finger abduction and adduction with positive Froment sign		When the two-point discrimination is 10–20 mm
Fair	59% total normal range of motion	When the tip of the thumb cannot reach the tip of the other four fingers	When the patient can do either finger abduction or adduction with positive Froment sign	Minor if there is either clawing or ape hand	When the two-point discrimination is more than 20 mm with light touch and pinprick sensation
Poor	Fixed contractures or adhesions		When the patient cannot do finger abduction or adduction with positive Froment sign		When there is trophic changes or skin ulceration

Froment test. Deformities were assessed as major (if the patient had both ape and clawing hand deformities) and as minor (if the patient had only either one of clawing and ape hand deformities). The sensation was evaluated by performing the moving two-point discrimination (2PD) test and it was assessed as excellent (if 2PD was less than 10 mm), as good (if 2PD was 10–20 mm), as fair (if 2PD was more than 20 mm with light touch and pinprick sensation), and as poor (if there was a trophic change or skin ulceration).^{9,11}

The grip strength was measured by using a calibrated Jamar dynamometer, when the patient was seated with adducted shoulder, elbow flexed at 90 degrees, and the forearm and wrist in the neutral position. Grip strength

was expressed as a percentage of normal and uninjured hand grip strength. Jamar dynamometer grading was considered excellent (at least 90% of normal value), good (75–90% of normal value), fair (50–75% of normal value), and poor (less than 50% of normal value).¹²

Statistical Analysis

Statistical analysis was performed using SPSS statistical analysis software (SPSS 21.0 for Windows, SPSS Inc., Chicago, Illinois, United States). In addition to a descriptive analysis of all variables, chi-square test was used for the categorical outcome (surgery function) and *t*-test was performed for the numerical outcome (number of days return to work)

Table 2 Postsurgery functional outcome, based on patients' demographics and injured structures

Independent variables	Tendon function			Opposition			Intrinsic function			Sensation		
	E and G	F and P	<i>p</i> Value	E and G	F and P	<i>p</i> Value	E and G	F and P	<i>p</i> Value	E and G	F and P	<i>p</i> Value
Gender												
Female	93.8	6.2	0.098	94.1	5.9	0.129	79.3	20.7	0.138	50.7	49.3	0.107
Male	90.2	9.8		91.3	8.7		76.6	23.4		47.2	52.8	
Age (y)												
≤ 35	94.6	5.4	0.175	93.5	6.5	0.167	82.9	17.1	0.103	51.2	48.8	0.098
> 35	89.7	10.3		88.9	11.1		75.3	24.7		43.3	56.7	
Number of injured structures												
≤ 10	95.2	4.8	0.091	95.1	4.9	0.123	80.6	19.4	0.111	53.8	46.2	0.071
> 10	87.2	12.8		89.2	10.8		74.3	25.7		44.2	55.8	
Nerve damage												
No	96.6	3.4	0.084	95.7	4.3	0.097	82.2	17.8	0.103	63.8	36.2	0.034
Yes	83.5	16.5		84.5	15.5		71.5	28.5		41.2	58.8	

Abbreviations: G, good/minor deformity; E, excellent/no deformity; F, fair; P, poor.

Note: Values given in bold were found to be statistically significant $p < 0.05$.

Table 3 Return to work, based on patients' demographics and injured structures

Independent variables	Return to work	
	wk	p Value
Gender		
Female	38.7	0.127
Male	41.5	
Age		
≤ 35	37.1	0.112
> 35	42.2	
Number of injured structures		
≤ 10	35.6	0.074
> 10	44.1	
Nerve damage		
No	33.2	0.067
Yes	45.1	

(►Tables 2 and 3). We utilized a p -value < 0.05 to identify statistically significant differences.

Results

Sample Characteristics and Wrist Injuries

The 153 patients were admitted to the hospital for an average of 1.7 days (between 1 and 7 days). Overall, 137 of the 153 patients with spaghetti wrist were males (89%) and 16 were females (11%). The average age was 28.3 years. Within the cohort of 153, 128 patients (83.6%) injured their right hand and 25 patients (16.4%) injured their left. The cause of injury included glass window panes and bottles in 96 patients (63%), knife-related injuries (street fight, robbery, alcohol related, and suicide) in 38 patients (25%), power machines in 11 patients (7.2%), and others (stone, etc.) in 8 patients (4.8%). A total of 43 injuries (28%) were work-related, and 110 injuries (72%) occurred at home or on the street. Patients with spaghetti wrist were followed up for 20 months (ranged between 19 and 22 months). The average time needed to return to work was 10 months.

The most commonly involved structures were the tendons of flexor digitorum superficialis (FDS) 3 and 4 in 150 patients and FDS 5 in 147 patients. The degree of involvement of each structure is presented in ►Table 4. Ulnar nerve injuries occurred in 132 patients (86.27%), median nerve injuries in 113 patients (73.86%), and both in 101 patients (66.01%). The ulnar triad (ulnar nerve, artery, and flexor carpi ulnaris) injuries occurred in 77 patients (55.33%), and concomitant injuries to the ulnar and radial arteries occurred in 35 patients (22.88%).

Surgical Treatment Outcome of Spaghetti Wrist

In this study, the majority of patients with spaghetti wrist injuries had excellent or good outcomes for tendon function (92%), opposition (93%), intrinsic muscle function

Table 4 Degree of involvement of each structure ($n = 153$)

Structure Involvement	Number	Percentage (%)
FDS 3 and 4 (injured simultaneously in 98% of the cases)	150	98.04
FDS 5	147	96.08
FDS 2	138	90.2
FCU	137	89.54
FDP 3, 4, and 5	136	88.89
PL	133	86.93
Ulnar nerve	132	86.27
FDP 2	127	83
Median	113	73.86
Ulnar artery	112	73.2
FCR	105	68.63
FPL	78	50.98
Ulnar triad (nerve + ART + FCU)	77	50.33
Median + FCR + PL	75	49.02
Median + ulnar nerve	101	66.01
Ulnar + radial artery	35	22.88
Two artery intact	32	20.92
Radial artery	6	3.92

Abbreviations: ART, artery; FCR, flexor carpi radialis; FCU, flexor carpi ulnaris; FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis; FPL, flexor pollicis longus; PL, palmaris longus.

(78%), and grip strength (66%); however, the majority (52%) experienced a fair or poor sensation (►Table 5). Secondary surgery was performed for the ulnar artery secondary repair in five patients, separation of tendons in seven patients, and skin sloughing in two patients. Regarding the functional surgery outcome, patients without nerve injuries significantly experienced better (excellent/good) sensation outcome when compared with patients with nerve injuries (p -value = 0.034), but none of the other variables were significant (►Table 2). As for a quicker return to work, none of the variables were significant (►Table 3). Additionally, this study revealed that younger patients (younger than 35 years), females and patients with less than 11 damaged structures showed trends toward improvement in having better surgery outcomes and quicker return to work (►Tables 2 and 3).

We did not find any complications resulting in amputation (such as distal necrosis and infections) with the initial or secondary operations. No arthrolysis or tendon transfers were performed. Tenolysis and neurolysis were performed together in three cases who had their primary surgery by a nonhand surgeon and they received at least 20 sessions of physical therapy (including classic sensory and motor reeducation) and did not have any significant improvements on the electromyogram (EMG) and nerve conduction velocity (NCV) test (complete nerve degeneration, without

Table 5 Results of complete follow-up of patients based on different categories ($n = 153$)

	Tendon Function	Opposition	Intrinsic Function	Grip Strength	Sensation
Excellent/no deformity	120 (78%)	115 (75.1%)	62 (40.5%)	18 (11.8%)	28 (18.3%)
Good/minor deformity	21 (13.7%)	27 (17.7%)	57 (37.3%)	83 (54.2%)	46 (30%)
Fair	7 (4.5%)	6 (3.9%)	30 (19.6%)	43 (28.1%)	75 (49.1%)
Poor	5 (3.3%)	5 (3.3%)	4 (2.6%)	9 (5.9%)	4 (2.6%)
Total	153 (100%)	153 (100%)	153 (100%)	153 (100%)	153 (100%)

nerve regeneration) 6 months after the primary surgery. During reexploration surgery, it was revealed that adhesion happened when scar tissue formed and also the median nerve had been attached to the adjacent tendon and not to their original stump. Therefore, the affected tendon by adhesions was released during surgery and the nerve was repositioned. Additionally, following tenolysis or neurolysis procedures, active finger and wrist range of motion exercises were initiated on postoperative day 2 to prevent tendon adhesion.

Discussion

Spaghetti wrist is a very severe injury of the hand; however, there are limited studies that focus on the functional post-surgery outcomes.² In addition, a literature review of studies conducted on this topic, show that adequate sample size is an issue.^{5,6,11,13} In previous studies, the number of patients who were followed up after spaghetti wrist surgery ranged between 11 and 124.^{5,7,11,14} However, in our study, 153 patients with spaghetti wrist were assessed, which provides a larger sample size to compare with previous studies. A comparison between our study and previous studies is depicted in ►Table 6.

While exploring the pattern of injury in many studies, flexor carpi ulnaris, median nerve and ulnar nerve were considered as most often involved structures and injury with glass (sharp trauma) was reported as the most common cause of spaghetti wrist, followed by knives and suicide.^{2,13}

Similar to previous studies, our findings have demonstrated that glass (sharp trauma) is the most common mechanism of injury (63%). It has also been shown similar degrees of involvement of the median (73.86%) and ulnar (86.27%) nerves, however, the most commonly injured structures in our study were FDS 3 and 4 (98.04%). This may be attributed to our study's focus on extensive injuries involving more than seven anatomical structures. Interestingly, our results showed that the palmaris longus is the sixth most common injured structure. Given the superficial location of this tendon, one can assume that this relatively low percentage is due to the absence of palmaris longus in the patients without injury.^{15,16}

Fig. 2 Intraoperative Image. **Fig. 1** Preoperative Image. **Fig. 3** Postoperative image.

Table 6 Comparison between this study and previous studies

Studies	Year	Age (mean)	Patients' number	Follow-up period (mean)	Flexion action (%)				Opposition (%)				Intrinsic (%)				Sensation (%)			
					E	G	F	P	E	G	F	P	E	G	F	P	E	G	F	P
Chin and coworkers	1988–1996	29	60	20 mo	63	37	0	0	N/A	N/A	N/A	N/A	0	58	0	42	20	33	47	0
Hudson and de Jager	1981–1990	28.7	60	49 mo	36	5	0	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20	20	60	0
Kabak et al	1990–1995	N/A	21	6.4 y	70	30	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Noaman	1997–2005	17.1	42	1–8 y	89	8	0	3	82	13	0	5	76	19	3	2	84	13	3	0
Present study	2009–2012	28.3	153	20 mo	79	14	5	3	75	17	4	3	41	37	20	3	18	30	49	3

Abbreviations: G, good/minor deformity; E, excellent/no deformity; F, fair; N/A, not available; P, poor.

Regarding the functional postsurgery outcome of spaghetti wrist injuries, previous studies have reported more suitable recovery (80–93.3%) for tendon function, opposition, and intrinsic muscle function, compared with sensation (47%).^{2,3,6,11,13} Our results were similar to most of the previous studies, indicating excellent or good outcomes (66–92.8%) for tendon function, opposition, intrinsic muscle function, and grip strength, compared with sensory recovery (48.3%). Other studies report that 54.8% of patients with spaghetti wrist injuries return to work within 1 year with the average time of 34.7 weeks.¹ In our study, the average return to work time was 10 months, however, 68% of our patients could go back to work within 1 year which is higher than prior studies. This may be related to using a combination of surgical repair, and hand physiotherapy treatment or cultural differences. The 13 patients who required precise manual dexterity (musicians or electricians) had a hard time due to tingling sensation or reduction in the hand strength for gripping/grasping and changed their occupations or retired.¹⁶

Furthermore, previous studies recommended exploring the previous repair sites in spaghetti wrist injuries by hand surgeons if they have any suspicions regarding the technique performed and the success of previous management of spaghetti wrist to protect these patients from paralyzing sequela of the injured nerves. In our study, the reexploration surgery was done by a hand surgeon in 28 patients that their primary hand surgery was done by a nonhand surgeon and in 3 of those patients, the median had been attached to the adjacent tendon and not to their original stump.¹⁶

Based on this study findings, future research in this area should focus on the impact of age, degree of injury, nerve injury, the number of damaged structures, and time lapse from injury to repair on surgery, and rehabilitative outcomes. In addition, further studies conducted regarding the assessment of physiotherapy effectiveness as well as the validity and reliability of the EMG and NCV to evaluate the effectiveness of physiotherapy among patients who underwent spaghetti wrist surgery could be greatly beneficial.

Note

This article describes original work and is not under consideration by any other journal. All authors approved the article and this submission. The authors of this study declare no conflict of interest.

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