RESEARCH ARTICLE

Acute volar Wrist Injuries: Evaluation, Management and Rehabilitation

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ABSTRACT

Volar wrist injuries constitute a unique surgical challenge. Our aim was to evaluate early, safety and efficacy of multidisplinary team in evaluation and management of acute volar wrist injuries with good rehabilitation program and return to work after trauma. 15 patients with acute volar wrist injuries from March 2013 to April 2015 at Al Azhar university Hospital. Hand functions were grouped as excellent, good, fair & poor. Nerve injury is tested using both sensory and motor components while assessment of the hand and fingers vascularity is carried out by clinical study, pulse oximeter and hand held Doppler. All cases were followed up in first postoperative year for vascularity, sensation and functions of the hand. 15 patients over a period of a two year of clinical follow up with rehabilitation program, there was marked reduction in morbidity and mortality with satisfactory significant hand functions and no ischemia, neuroma or tendon ruptures were observed during the follow-up period.

Key words: Volar wrist injuries, Evaluation, Management, Rehabilitation.

INTRODUCTION

The hands are elegant anatomical structures that play a pivotal role in our daily lives within our family, work, and recreational environments. Best patient care and clinical decision-making rests largely upon anatomical knowledge, physical examination, and recognition of the limitations of imaging modalities, (Tolbet *et al*.,2014). At the volar side of the wrist, 16 structures including 12 tendons, two nerves, and two arteries are located just beneath the skin, and are therefore vulnerable to injury. Laceration of several flexor tendons can lead to extensive scar tissue formation, resulting in elimination of differential gliding of the tendons (Yii *et al*.,1998).

Hand injuries are common and account for 5-10% of emergency department (Allen *et al*.,2008) and4.7% of all trauma patient (Makobore *et al*.,2015). Various mechanisms of injury can lead to volar wrist injuries, and the most common are; machines injury, glass lacerations, knife wounds, and suicide attempts. Extensive injuries to flexor tendons and surrounding

structures are sometimes referred to as "spaghetti wrist". The definition of spaghetti wrist, is not firmly set (Chin *et al*.,1998). Clearly inform all patients with hand injuries of the possibility of complications and instruct them on the potential signs and symptoms of complications. Carefully; document the care, procedures, and follow-up plan for all patients (Allen *et al*.,2008). The costs for treating these injuries are considerable and include not only the direct costs of repair but also the indirect costs borne by the patient's his or her family, and society (Teefy *et al*.,2004).

PATIENT AND METHODS

The study includes fifteen patients admitted at Al-Azhar university hospitals (13 males, 2 females) who were operated from March 2013 to April 2015. The data of the patients are shown in table (1).

Table 1: Patient's Clinical data

Patient No.	Sex	Age (Years)	Hand side	Injured structures		
				*Tendons	Nerves	Arteries
1	Male	17	Right	FCR, FCU, FPL, FDS and 2-5FDP2-5 index, middle, ring and little fingers	Median and Ulnar	Ulnar and Radial
2	Male	32	Right	PL, FCU, FDS 3-5 middle ring and little fingers, FDP 4 ring finger and little fingrr5	Ulnar	Ulnar
3	Male	20	Right	PL, FCR, FDS 3-4 middle and ring fingers,FDP3 middle finger	Median	Ulnar
4	Female	35	Right	PL, FCR FDS 2index, middle and4 ring fingers	Median	Radial
5	Male	18	Right	PL, FDS 2-5index, middle, ring and little fingers.	Median	Ulnar
6	Male	22	Left	PL, FCR, FCU, FDS2-4index, middle and ring fingers	Median	Radial
7	Male	32	Right	FCR, FCU,FPL, FDS2-5 and FDP2-5 index, middle, ring and little fingers	Median and Ulnar	Ulnar and Radial
8	Male	20	Right	FCR, FCU FDS 2-4index, middle and ring fingers, FDP 2,3index and middle fingers	Median and Ulnar	Ulnar
9	Male	16	Right	PL, FDS 2-5 index, middle, ring and little fingers	Median	-
10	Male	17	Right	PL, FCR, FDS 3middle and 4 ring fingers, FDP3middle finger	Median	Radial
11	Female	22	Left	PL, FCR FDS 2-4 index, middle and ring fingers	Median	-
12	Male	33	Right	PL, FCR, FCU,FDS2-4 index, middle and ring fingers	Median	Ulnar
13	Male	37	Right	FCR, FCU FDS 2-4 index, middle and ring fingers, FDP 2,3index and middle fingers	Median and Ulnar	Ulnar
14	Male	19	Left	PL,FDS 2-5 index, middle, ring and little fingers	Median	-
15	Male	28	Right	PL, FCR, FCU FDS2-5 index, middle, ring and little fingers, FDP 4 ring finger	Median	Radial

*FCR: Flexor carpi radialis; FCU: Flexor carpi ulnaris; FDS: Flexor digitorum superficialis; FDP: Flexor digitorum profundus; PL: Palmaris longus FPL: Flexor pollicis longus. The numbers designate the fingers involved (2the index- 3the middle- 4the ring- 5the little).

All patients were subjected to principles of assessment (history and examination) and plain X-ray was done to affected part (table 2).The mechanism of injury gives important clues about the structures involved and potential complications. It is important to establish what forces were applied to the hand during the injury and the direction of these forces, as well as any special features of the injury. A history of any previous hand injury may predispose to further injury.

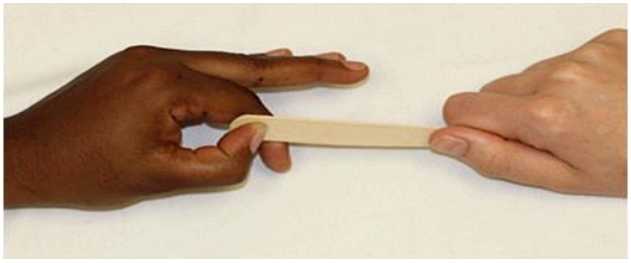

Fig 1. Froment Sign: The thumb compensates for adductor pollicis brevis weakness secondary to ulnar nerve injury, with thumb, interphalangea joint flexion and opposition (functions of the median nerve).[1]

For descriptive purpose the volar cut wrist can be classified by the flexed middle finger (axis of the hand) over the wrist into3 zones (figures3 and 4):

Middle Zone: Behind the flexed middle finger and contains MN and PL.

Pre Axial Zone: Medial to the flexed middle finger and contains UA, UN, FCU, FDS and FDP.

Post Axial Zone: Lateral to the flexed middle finger and contains RA, FCR and FPL.

Volar wrist injuries (**spaghetti wrist**) were defined as lacerations occurring between the distal wrist crease and the flexor musculotendinous junction involving at least 3-10 structures completely transected. All injuries were sharp lacerations between the distal wrist crease and the flexor musculotendinous junction (zone V). (Figures 5 and 6).

Fractures crush injuries and avulsed injuries were excluded.

Assessing Vascular Function: Vascular examination identifies gross injuries of the dual blood supply of the hand and/or evidence of impaired perfusion. Hard signs of arterial injury include bright-red pulsatile bleeding; expanding hematoma; a cold, pulseless extremity; a palpable thrill; or an audible bruit. Soft signs of arterial injury include impaired capillary refill and pallor .Capillary refill and pulse oximeter have limited diagnostic utility (Barbeau *et al*.,1985) and (Schumer and Friedman,1995).

Assessment of the hand and fingers vascularity is carried out by inspect the color; palpate the temperature of the hand, and assessment of capillary refilling and palpation of both radial and ulnar pulses with comparison of arterial blood pressure at both brachial arteries. Allen's test, the pulse oximeter and hand held Doppler were also an excellent tool for evaluation of perfusion (Lawson *et al*.,1987).

The Allen test was originally devised to identify patients with a single radial artery supply of the hand. In suspected ulnar artery injury proximal to the wrist, the Allen test is performed. The hand is clenched and elevated 30°, and pressure is applied over the radial and ulnar arteries for 5 to 6 seconds. When the hand is unclenched and ulnar artery pressure is released, color should return to the hand. Persistence of pallor raises suspicion of abnormal ulnar artery patency

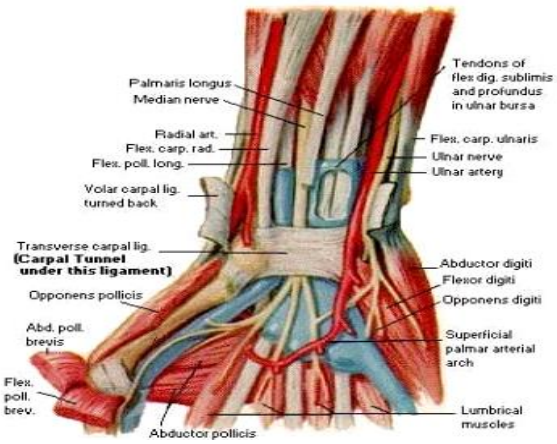

Fig. 3: Zones of the volar wrist. [8]

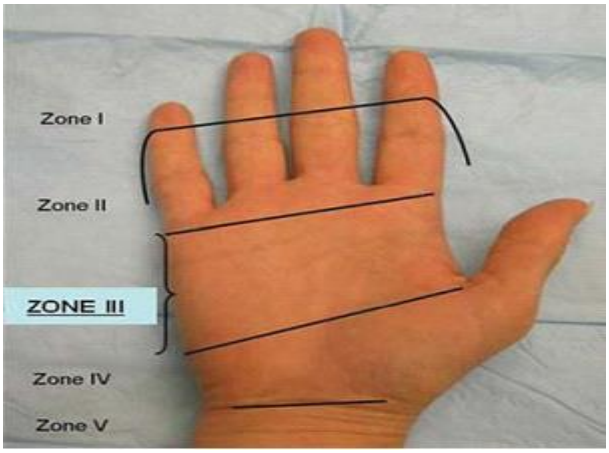

Fig. 2:Anatomy of the deep wrist.[9]

Assessing Hand Function

Hand function was grouped as excellent, good, fair & poor.

Excellent: function of tendon is 85% or distance from fingertip to distal palmar crease< 1cm.

Good: function of tendon is 70-84% or distance from fingertip to distal palmar crease< 2 cm.

Fair: function of tendon is 50-69%.

Poor: fixed contractures or adhesions.

DIAGNOSTIC STUDIES:

Laboratory Studies: complete blood count, bleeding time, clotting time, international normalized ratio, serum creatinine.

Imaging Studies: Plain Radiographs.

Operative Repair Technique: Under general anesthesia and tourniquet control (till time of vascular repair), the laceration is extended obliquely proximally and distally to ensure full exposure of the structures. The carpal tunnel is opened and all structures are identified. Flexor tendons were repaired from deep to superficial fashion. Flexor tendons are repaired using the modified Kessler technique with 3/0 prolene and reinforced with 5/0 continuous epitendinous suture, Figure (10).

The arterial repair was performed following the finger tendons repair by 7/0 prolene, simply interrupted end to end anastomosis in 11 cases and primary repairs were done for 7 cases with small tear 2 cases of UA injury were repaired by interposition graft, using cephalic vein from the same limb. The nerve injury was repaired using 9/0 prolene simple interrupted epineural sutures. Wound closure after hemostasis was done.A dorsal-blocking splint was applied with the wrist at 30° of flexion, the metacarpo-phalangeal (MCP) joints at 50° of flexion, and the inter phalangeal (IP) joints at full extension.

Postoperative rehabilitation and follow up:

All cases were followed up in the outpatient clinic weekly for the first month, then every two weeks for the second month, then monthly up to 6th months and every 3 months till the end of first year. Evaluation of vascularity of the hand was done in the early hours immediately post-operative. First aid and pre-operative management included elevation, dressing, antibiotics, analgesia, and physiotherapy were very effective and routine. Elevation minimizes swelling and pain. Antibiotics treat or prevent infection. Analgesia controls pain and rehabilitation aids early return to full function.

The patients will typically start with a modified Kleinert-Duran protocol is outlined in (*Abbreviation*), three to five days status post surgical repair (Duran *et al*.,1975) and (Klienert *et al*.,1975). Treatment for cases typically has a duration of 10–12 weeks.

Patient education will emphasize the importance of avoiding active range of motion with gross motor and fine motor movement of the fingers. The patients will actively extend the fingers to the dorsal block splint 8 repetitions per hour. The patients must have the capacity to passively stretch all fingers to the palm and actively extend fingers to the dorsal block splint prior to leaving the first treatment session.

Patients with excessive edema full passive flexion may not be obtained initially but should be followed more frequently to assure motion is achieved. Active range of motion of the wrist can start at two weeks post-operatively with fingers parked in flexion. 18 rubber band was applied to distal phalanx to allow Passive flexion- active extension and Passive range of motion (ROM) is begun within splint (figure 12). This splint facilitates a stretch reflex that provides a stretch to the extensor mechanism while passive flexing and relaxing the repaired flexor mechanism during active extension. The active flexion of the affected wrist and fingers should be limited for the first 6 weeks.

After 3-5 days, rubber band was applied to distal phalanx to allow Passive, flexion,active extension and Passive range of motion (ROM) is begun within splint (figure 12).

At 3rd week, passive range of motion (ROM) is continued within splint and gradual extension of the wrist by new cast. After 4 weeks, active ROM outside of the splint is begun.The nerve regeneration could be followed at that stage as an advancing Tinel's sign.

At 6 week, splint is discontinued, and passive extension is begun but he patient was never allowed for full activity until protective sensation reached the distal phalanges.

7-8 weeks, Start isometric and isotonic strengthening, Functional passive range motion to restore intrinsic an extrinsic motion without protective posture.

10-12 weeks, Start specific training activities in order to return to full activities. Start total body conditioning exercises. All splints can be discontinued.

Functional assessment of the hand was performed according to **Kleinert and Verdan criteria**: Excellent (individual tendon function 85% to normal active motion or to finger flexion 1cm or less to the distal palmar crease), good (84-70% of total active motion or 2.0cm from distal palmar crease), fair (69-50% of total active motion) or poor (fixed contractures or adhesions) (Kleinert and Verdan,1993)

RESULTS

There were a total of 15 patient, 13 men (86.9%) and 2 women (13.4%). Their mean age was 24.5 years. Their age ranged from 16 to 37 years.

The most frequent mechanisms of injuries were glass laceration at 10 patients (66.6%), then knife wounds at 5 patients (33.4%). Right hand involvement was 80% and the left was injured in 20% of cases. The most frequently injured arteries, tendons and nerves in order were described at table (2).

In all 15 patients, range of motion of involved digits and wrist was excellent. The protective sensation was recovered in all patients and corresponded simultaneously with the progressing Tinel's sign. Two-point discrimination ranging between 5-8mm returned in all 10 patients with MN injury. One patient of the 5 suffering UN injuries showed a 5-10 mm response. The other 4 patients with UN injuries showed only protective sensation beside prolonged paresthesia of more than one-year duration. Intrinsic muscles supplied by the MN showed adequate recovery while those supplied by the UN showed more prolonged and incomplete recovery. Fingers abduction and adduction was weak and mass movement was the rule. The grip strength was weak in two patients with combined median and ulnar nerve injuries. No neuroma or tendon ruptures were observed during the follow-up period.

The least common injury was in the FPL with 13.3% involvement and the most common injury was in FDS with 100% involvement. Synchronous median and ulnar nerve injury was present in 4 cases (26.6%); figure 13. Synchronous injury in radial and ulnar arteries were presented in 2 cases (13.3%). In 5 patients (33.3%), motion in wrist and fingers was excellent, 7 cases (46.7%) were good, and 2 cases (13.3) fair and fixed contracture was observed in 1 case (6.7%).Degrees of claw hand deformity were present in these 3 cases (20%).

Table (2): the most frequent injured arteries, tendons and nerves in order.

	Structure	No	Percentage (total 15) %
Tendons	FDS	15	100
	FCR	10	66.6
	FCU	8	53.3
	FDP	6	40
	FPL	2	13.3
Arteries	UA	8	53.3
	RA	6	40
Nerves	MN	14	93.3
	UN	5	33.3

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Abbreviation List

2- The index finger; **3-**The middlefinger**; 4-**The ringfinger**; 5-**The littlefinger**; ED-**Emergency department**; FCR-**Flexor carpi radialis**; FCU-**Flexor carpi ulnaris**; FDS-**Flexor digitorum superficialis**; FDP-**Flexor digitorum profundus**; PL-**Palmaris longus**; FPL-**Flexor pollicis longus**; IP-**Inter phalangeal**; DIP-**Distal inter phalangeal**; PIP-**Proximal inter phalangeal**; MCP-**Metacarpo-phalangeal**; No-**Number**; Cm-**Centimeter**; Mm-**Millimeter**; UA-**Ulnar artery**; RA-**Radial artery**; UN-**Ulnar nerve**; MN-**Median nerve**; ROM-**Range of motion

Fig. 4: synchronous median and ulnar

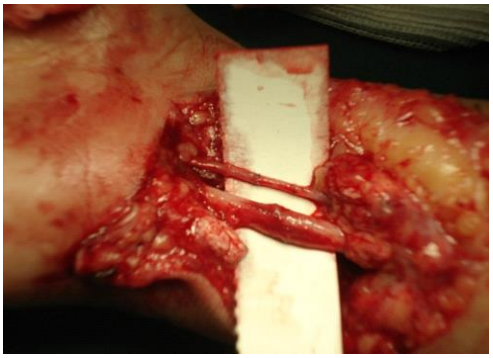

Fig.5: Repair of UA and UN

Fig. 6: Cut wrist.

Fig.7: Exploration and repair.

Fig. 8: closure of the wound with rubber drain.

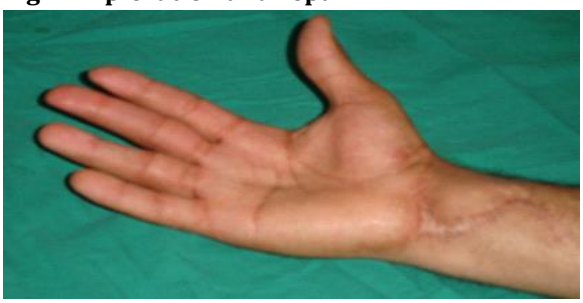

Fig.9: post-operative follow up.

Fig. 10: excellent hand function

Concerning the return of sensation in the territory of the disrupted nerve, two point discrimination was 3-6 mm in 3 patients (20%) with median nerve injury and 7-13mm in 10 patients (66.6 %) (2 patients had median nerve and 7 patients had ulnar nerve injury and 1 patient had combined two nerve injuries).

In patients with combined disruption of ulnar and median nerves, the sensation was recovered as protective. Pinch and grip strength in the injured hand was 50 percent of the normal side. After 8 months return of function was excellent

DISCUSSION

The hand is one of the most complex parts of the body. The movement of the tendons, bones, tissues and nerves allows us to grip and do a wide variety of complex jobs. Without our hands it would be

extremely difficult to do routine simple tasks, such as opening doors, using a fork, or tying the shoes. Your hands make you a skilled, valuable worker. The improper use or misuse of hand tools cause minor to serious hand injuries, which are likely when the wrong tool is used or the right tool is used improperly.

Because the hand is frequently used as a nonverbal medium of communication, a disfigured hand results in negative changes in self-image, and so optimal hand function is essential for good quality of life (Grunert *et al*.,1988).

In our study, plain X-ray is the only radiological used type, and G. Radid, R. Dina, and S. Anthony, concluded that, in the management of hand injuries, an X-ray is the most important single investigation, especially in crush injuries, which are associated with fractures and/or dislocations. Other investigations like ultrasound (include Doppler) and MRI are important (Radid *et al*.,2005) and (Wu *et al*.,2012).

Several studies have shown that ultrasound imaging is a useful diagnostic imaging tool for acute hand injuries (Le *et al*.,2000) and (Soubeyrand *et al*.,2008). Katerega found that, the average age of the injured in his study was 26 years.This falls in the most active age group. They usually have little experience in their vocation and hence are prone to hand injuries. This does not differ from our study (Katerega *et al*.,1998).

Wu and Unlu found that most injuries occurring on the road and at work were caused by road traffic crushes and machines, respectively. Young males were mostly involved and the male to female ratio was about 4: 1, similar to other studies (Unlu *et al*.,2005)

In the study by Courtney *et al*, (2004) ninety-five percent of the patients were right handed. This concurs with the proportion of the right handed people in the general population, without significant difference of our study.

Forest *et al*. (1999) found that half of the patients injured still had pain after one month. Hand injuries are painful, because the hand is richly supplied with somatic nerves.

The type of suturing technique is important because it dictates whether active mobilization is possible or not. Also, one must remember that although increasing the number of sutures per tendon increases the strength of the repair, a greater number of knots increases the risk of developing adhesions.

In most studies results of repair of tendons have been reported as good to excellent results. From 30 patients, 20 had good to excellent range of motion. 25Surgical toilet and suture, debridement, splintage, and tendon repairs were the procedures done. These procedures may not require a major operating theatre, but they must be done well. The consequences of the injury can be reduced by proper assessment, appropriate treatment and careful follow up, but betterz prevented, which achieved in our study by multidisplinary team (Mink *et al*.,2003)

Compartment syndrome of the hand is rare, but devastating. There are generally considered to be 10 compartments of the hand: thenar, hypothenar, and adductor; 3 palmar; and 4 dorsal interossei (Dolan *et al*.,2012)

Diverse mechanisms of compartment syndrome in the hand have been reported, including crush injury, high pressure injection injury, prolonged immobilization with casting, metacarpal fracture, extravasation of intravenous contrast, burn with eschar formation, and complication of arterial line placement (Ouellette *et al*.,199) and (Sharma *et al*.,2013).

Parviz mafi found that, the most common injured structure had been FCU,which is the 3rd one in our study (Parviz ,2006).

While we and Andhadi Beikpour found that FDS has been the most commonly injured tendon. And the most common injured artery has been the UA (Andhadi and MD,2012) .

Ng CY concluded that, there is no consensus on the most effective rehabilitation regimen following flexor tendon repair of the hand.34The resulting negative impact on quality of life can be significant. An understanding of the principles that are unique to the management of hand injuries, such as reduced periods of immobilization, will help ensure that optimal healing and function is achieved. There has been a steady trend toward early controlled active motion following tendon repair by different types of protocols but all protocols protect the tendon by limiting active flexion for the first 3 to 6 weeks.

Although potentially very debilitating, most victims of spaghetti wrist have good outcomes if the proper surgical treatment is received. Almost 70% of patients will have good to excellent outcomes with little or no decrease in power, ROM, or sensation. The rest may experience loss of stereognosis and 2point discrimination, muscle atrophy and trophic changes (Kabak *et al*.,2002)

Various definitions have been used, ranging from a relatively minor injury of three lacerated structures, including injuries without nerve-laceration, to a major trauma with laceration of at least 10structures including the median and/or ulnar nerve. Therefore, comparison of these studies is difficult. In addition, numbers of patients reported are small and all studies focused on functional out come.Little attention was paid to the impact of a spaghetti wrist trauma on employment and to posttraumatic psychological stress (chin *et al*.,1998)

Jean Bart Jaquet demonstrated that despite a mean follow-up of 10 years, spaghetti wrist patients were still functionally impaired in performing certain tasks of daily living. The impact of spaghetti wrist injury on employment is not to be underestimated. Almost half of the study population employed on the day of injury could not return to work within 1 year following the accident. Moderate to severe psychological symptoms (Impact of Event Scale score>17during the first month following the injury were present in 28 patients (64 percent).Previous studies on spaghetti wrist injury mainly assessed sensory recovery, motor recovery, and range of motion to evaluate long-term functional outcome (Jean *et al*.,2005)

Most factors associated with time off work after traumatic hand injuries could not be influenced. Possible interventions should probably target improved injury prevention, optimal clinical treatment and rehabilitation starting early after injury. Whether improvements in communication and enhancement of cooperation between the treatment teams, the workplace and the insurance carrier can help early return to work (Oberfeld *et al*.,2015) And we can doing that through our multidisplinary team.

Return to productivity is becoming an issue of growing national concern for economic reasons (Tate,1992). Taha and Taha 1998 reported a 0 percent return-to-work among patients with combined median and ulnar nerves injury following missile injuries. Both studies reported small numbers of patients (eight and seven patients, respectively). Furthermore, spaghetti wrist patients took sick leave with a mean of 35 weeks.

CONCLUSION

Injuries of the hand are associated with significant patient morbidity and medico legal risk for physicians. Care of patients with acute hand injury begins with a focused history and physical examination. In most clinical scenarios, a diagnosis is achieved clinically or with plain radiographs. While most patients require straightforward treatment, the emergency clinician must rapidly identify limb-threatening injuries and obtain critical clinical information.

From all results reported in the present study, it can be said that, multidisplinary team can evaluate and manage acute volar wrist injuries saving time and decreasing post-operative functional disability with short time to return to patient's daily activity due to accurate repair of injured structures, early movement and appropriate physiotherapy which need patient co-operation.

RECOMMENDATION:

Ultrasound imaging is an important, rapid and noninvasive diagnostic imaging tool for acute hand injuries.

Furthermore, we recommend that in future studies spaghetti wrist injury be defined as a laceration of the volar wrist with aminimum of 10 structures involved including at least one of these arteries or nerves (UA, RA, MN or UN).

Spaghetti wrist injuries should be placed among the severe disabling injuries. Assessment of long-term outcome following nerve injury should include a patient-derived assessment of function, evaluation of the return-to-work ratio, and assessment of psychological distress following the injury.

Conflicts of interest: The authors stated that no conflicts of interest.

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