RESULTS OF THE TREATMENT OF MAJOR, COMPLEX HAND INJURIES

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Complex hand injuries are associated with serious consequences including long period off-work, permanent disability, inability to return to original profession or to work at all. As these injuries are common, they create considerable economical consequences and, therefore, it is desirable their treatment would be as perfect as possible to reduce potential loss of function.

The aim of the study was analysis of the structure of complex, multi-structural hand injuries and evaluation of the outcomes of the treatment of these injuries in both medical (recovery of function) and economical (period of inability to work and costs of medical care) aspects.

Material and methods. The study presents the results of treatment of 78 patients suffered from severe, major hand injuries, involving damage of at least two of four anatomical structures within the hand or wrist (bones, tendons, arteries or nerves) as well as severe injury involving at least two digits. Functional results were assessed at a mean of 10 months after the accident. Tendons were repaired in all 42 patients, bones were fixed in 29 (69%), nerves were repaired in 21 (50%), arteries in 14 (33%) and in two patients skin defect was covered by the flap (one local and one groin flap).

Results. Total active motion of affected digits amounted 2/3 of normative active motion of the healthy digits and total grip strength approximated half of the grip strength of the unaffected hand. In patients with nerve injuries, a satisfactory recovery of sensation in the affected digits was obtained. Dexterity of the hand in daily activity was scored 30 points in DASH scale. Injury-related duration of sick leave in 31 patients worked at the time of the accident amounted 4.4 months in average (range 1-12). A total of 27 subjects (87% of worked) returned to work: 24 to their previous profession and three had to qualify for a new job. Total hospital costs of the treatment in the analysed group amounted a mean of 2600 PLN.

Conclusion. The outcomes of the treatment of major hand injuries achieved in our institution over the period of the one year were satisfactory, considering their severity and complexity. These results, in our mind, show clearly advantages coming from an existence of qualified service for hand injuries.

Key words: hand injury, outcome, costs

Injuries to the hand are very common. Hands are frequently exposed to trauma, because their use at all kinds of human activity. Complex injuries occur typically at work, by using potentially dangerous power machines, such as circular (power) saw, log-trimmer or press, but they may also be caused by simple tool which is a knife (1, 2). Glass – window pane or bottle – is fairly common cause of serious hand laceration. The injury is usually result of inadver- tence, non-compliance with rules of safety at work or using tools in an inadequate manner (3, 4). Hands are also traumatised at homework and leisure activities. Alcohol use is fairly common associated, or even directly causal circumstance of these injuries (4).

Serious (complex) injury to the hand is associated with damage of several hand structures (tissues): skin, muscles, tendons, nerves, vessels and bones (fig. 1-5). The adequate repair of these injuries demands complex reconstruction of all elements, what is frequently challenging. Primary reconstruction of all lacerated structures is optimal and desirable, but not always possible.
option. Tissue losses, commonly caused by power tools, which are irreparable at primary operation need delayed, secondary reconstruction.

Complex hand injuries are associated with serious consequences including long period off-work, permanent disability, inability to return to original profession or to work at all (3-6). As these injuries are common, they create considerable economical consequences and, therefore, it is desirable their treatment would be as perfect as possible, to reduce potential loss of function. This service is offered by surgical or orthopaedic units, directed to hand surgery and equipped with instruments, materials and surgeons skilled in such a complex surgery.

The objective of this study was analysis of the structure of complex, multi-structural hand injuries and evaluation of the outcomes of the treatment of these injuries in both medical (recovery of function) and economical (period of inability to work and costs of medical care) aspects.

MATERIAL AND METHODS

Over a period of 12 months (January-December 2009), a total of 78 patients with serious hand injuries meeting criteria of inclusion to this study were treated in the Department of General and Hand Surgery. These criteria included involvement of at least 2 of the 4 main structures within the hand and/or wrist (bones, tendons, nerves or vessels). In cases of digital injuries, these included involvement of at least two digits, in which at least two of above-mentioned structures were damaged (fig. 1-5). Hand, thumb or digit amputations in which successful replantation was performed were excluded, as well as degloving injuries to the hand managed by the coverage

Fig. 1. „Spaghetti” type injury of the distal forearm

Fig. 2. The range of devastation in „spaghetti” type injury

Fig. 3. Functional result at 8 months after injury from figures 1 and 2. DASH score 22 points
with greater omentum pedicled flaps. These extremely severe cases were subjected to a separate analysis. We intuitively assumed, that inclusion them to the present study, would probably overweight the average grade of severity of trauma, duration and costs of the treatment, and would deteriorate the outcomes.

Of 78 initially included, 42 patients (54%) were available to a follow-up assessment, at a mean of 10 months (range 7-12 months) and this group constitutes the subject of the analysis. It consisted of 40 men (95%) and 2 women (5%), aged a mean of 45 years (range 19-76). Right hand was involved in 24 subjects (57%) and left in 18 (43%), and the accident was work-related in 26 cases (62%) and occurred at home in 16 (38%). The study analysed structure of sustained injuries, range of the surgical repair, time of stay at the ward and total hospital costs associated with the treatment. At a mean of 10 months follow-up, the following variables were assessed:

- **a)** total active motion of digits (abbr. TAM). It is defined as a sum of flexion of the individual digit in each joint, reduced by a loss of extension. This variable was expressed as a proportion of normative value amounting 270° for fingers and 170° for thumbs. Total active motion measurements of all involved digits were added and then divided by number of digits finally giving average TAM;

- **b)** total grip strength was measured with Jamar dynamometer and expressed as a proportion of the strength of the other (unaffected hand);

- **c)** threshold of light touch was examined with Semmes-Weinstein filaments and the result was given as Sensory Index. The filament test was performed at the pulp of each involved digit or digits innervated by injured nerve (in the median nerve – digits I-IV, in the ulnar nerve – fingers IV-V). The result was registered as a rank: 1 – normal sensation (touch detectable with green filament),
2 – satisfactory sensation (blue filament), 3 – reduced sensation (purple filament), 4 – protective sensation (red filament) and 5 – no sensation (black filament). The measurements from each digit were added and then divided by number of digits, finally giving the Sensory Index;

d) subjective (patient’s) opinion about dexterity of the hand in a daily life was assessed with DASH (Disability of Arm, Shoulder and Hand) questionnaire (7);

e) duration of hospitalisation;

f) total hospital costs;

g) duration of inability to work.

RESULTS

Injuries pattern

All injuries were open wounds, lacerated or mutilated in 33 patients (78%) and clean-cut in 9 (22%). Only digits (minimum two) were the most commonly involved – in 21 subjects (50%), followed by wrist in 8 (19%), digits combined with midhand in 6 (14%), only midhand in 5 (12%) and distal forearm in 2 (5%) patients. Circular saw was the lacerating tool in 24 persons (57%), knife or glass in 9 (21.5%) another than circular saw machinery (log-trimmer or press) in 9 (21.5%). The following anatomical structures were damaged: bones and tendons in 19 patients (45%), tendons, nerves and vessels in 10 (24%), tendons, bones, nerves and vessels in 7 (17%) and tendons, bones and nerves in 6 (14%). Injury to the tendons (flexors or extensors) was present in all patients within the group. Eleven patients (26%) had additional articular injury: 9 included interphalangeal and 2 metacarpo-phalangeal joints. Seven patients (17%) had „spaghetti – type” laceration i.e. almost all structures (nerves, tendons and vessels) of the palmar side of the wrist or the distal forearm were divided (fig. 1 and 2). In 14 patients (1/3 of the group) the injury caused tissues defects: tendons and bones in 7, nerves in 4, joints in 3, tendons in 2, and skin in 2 cases (fig. 4). Eleven patients sustained an amputation of a total of 15 digits, at various level, which were not replanted mostly because of their badly damage. The most common amputated finger was index – in 7 patients.

Of a total of 42 operations, 21 (50%) was performed by residents themselves (being in training in general surgery, but having some experience in hand surgery), 13 (31%) by residents with assistance of qualified specialist and 8 (19%) by the specialists themselves. This structure of involvement of operating surgeons arises from department-specific schedule of duties, in which some duties are fulfilled by residents, secured by specialist being on call.

Number of repaired structures and methods of the repair are showed in tab. 1. Tendons suture was performed in all 42 patients (flexors in 21, extensors in 15 and both in 6), bones fixation in 29 (69%), nerve repair in 21 (50%), vessels (arteries) anastomosis in 14 (33%), and in two patients (5%) skin defects were covered by flaps (one local and one groin flap). In patients with bony defects the spacer-wires were used to protect the length of the bone. In articular defects (two interphalangeal and one metacarpo-phalangeal), a definitive arthrodesis was done with K-wires. Tendon and nerve

<table>
<thead>
<tr>
<th>Structure repaired</th>
<th>Number</th>
<th>Details</th>
<th>Method of the repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor tendons</td>
<td>27</td>
<td>–</td>
<td>Kessler suture</td>
</tr>
<tr>
<td>Extensor tendons</td>
<td>21</td>
<td>–</td>
<td>mattress or Kessler suture</td>
</tr>
<tr>
<td>Bones</td>
<td>29</td>
<td>metacarpal, phalanges</td>
<td>K-wires – 27 plate – 2 cases</td>
</tr>
<tr>
<td>Nerves</td>
<td>21</td>
<td>median n=6, ulnar n=4, digital* n=9</td>
<td>epineural suture – 18, neurotuba – 1 case</td>
</tr>
<tr>
<td>Arteries</td>
<td>14</td>
<td>radial n=5, ulnar n=4, palmar arch n=5</td>
<td>end to end anastomosis</td>
</tr>
<tr>
<td>Skin</td>
<td>2</td>
<td>znaczny ubytek / major defect</td>
<td>local flap – 1, inguinal flap – 1</td>
</tr>
</tbody>
</table>

* in 2 cases nerves were not reconstructed
losses were not primarily repaired, leaving it for further secondary reconstruction which, however, was not always necessary.

The anaesthesia for the operation included brachial plexus block in 37 patients (88%) and general in 5 (12%). All operations were performed in a bloodless field with the use of tourniquet. Duration of surgery was 2.5 hours in average (range 1-5). The length of the ward stay was a mean of 3 days (range 2-7), indicating relatively quick discharge of patients with severe hand injuries. Early complications occurred in 12 patients (28%), including wound infection in 7, skin necrosis in 4 and ischemia followed by necrosis of finger in one. After discharge, patients were controlled in the Hand Clinic, supervised by the Department staff, attending a mean of 3 visits (range 2-8) in the course of the treatment. Persons living outside Szczecin underwent also ambulatory care in their home-sites. Thirty patients (72%) availed of a formal rehabilitation over the period of a mean of 1.8 months.

Results of the treatment

Final outcomes were assessed in 42 patients at a mean of 10 months (range 7-12) after injury. Results of all measurements (means and ranges) are showed in tab. 1. The total active motion of involved digits was in average of 2/3 of the normal TAM, which seems to be satisfactory, considering involvement of bones, joints and tendons in these injuries. Total grip strength averaged a half of the strength of the healthy hand; nine patients had strength greater than 80%, 15 within the range 50-80%, 16 within the range 10-50% and two had strength lower than 10%. A mean value of Sensory Index (measured in cases with nerve injuries) was 2.1 suggesting normal or satisfactory sensation in the involved digits in most cases. An average DASH score of 30 indicates moderate satisfaction of patients with the dexterity of the hand in daily living. Fifteen patients (36%) had DASH score less than 30 (mild impairment, good function), 20 patients had score within the range 21-40 (moderate impairment, satisfactory function) and 7 had score higher than 40 (serious impairment and loss of function).

Return to work

Thirty-one patients were employed at the time of injury and 11 (26%) were retired, on disability pension or unemployed. Injury-related duration of sick leave in 31 patients worked at the time of the accident amounted 4.4 months in average (range 1-12). A total of 27 subjects (87% of worked) returned to work: 24 to their previous profession and three had to qualify for a new job. Four patients (13%) did not return to work, of this number two obtained a disability pension, and two availed of prolonged sick leave for rehabilitation, thus having good prognosis for return to work.

Costs of the hospital treatment

The structure of separate costs of the treatment in authors’ unit is showed in tab. 3. Total hospital costs of the treatment in the analysed group amounted 2600 PLN in average, of this sum the greatest item constituted the average theatre cost – 1000 PLN. Costs of the anaesthesia were provided according to calculations in the authors’ hospital – a mean of 400 PLN per patient. Ward costs included average cost of one day stay – 300 PLN, augmented by the cost of drugs and

<table>
<thead>
<tr>
<th>Parameter analysed</th>
<th>Outcome at a mean of 10 months</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>mean</td>
</tr>
<tr>
<td>Total active motion</td>
<td>67%</td>
</tr>
<tr>
<td>Total grip strength</td>
<td>50%</td>
</tr>
<tr>
<td>Sensory Index</td>
<td>2.1</td>
</tr>
<tr>
<td>DASH score</td>
<td>30</td>
</tr>
<tr>
<td>Time in ward</td>
<td>3 days</td>
</tr>
<tr>
<td>Duration of out-patient treatment</td>
<td>2 months</td>
</tr>
<tr>
<td>Duration of rehabilitation</td>
<td>1.8 months</td>
</tr>
<tr>
<td>Time off-work</td>
<td>4.4 months</td>
</tr>
</tbody>
</table>
Patients with complex hand injuries were categorised for National Health Fund by the following JPG codes: H41 (microsurgery) – reimbursement of 9000 PLN, H42 (tendon, nerve repair) – reimbursement of 4200 PLN and H63 (bone fixation) – reimbursement of 3000 PLN. As seen from this specification, in each case NHF reimbursement exceeded real costs of the hospital treatment, thus being profitable for the Department.

DISCUSSION

As it was mentioned in the introduction, hand is frequently exposed to trauma, including severe, mutilating and potentially devastating injuries of several anatomical structures (1, 3, 4). Hand is considered an extraordinary complicated and perfect instrument, being a mechanical manipulator controlled by bioelectrical stimuli conducted by nerves. Management of hand injuries is challenging and – in complex cases – restoration of the anatomical structure followed by recovery of function is frequently impossible. In our country traumatised hand is commonly treated in orthopaedic and general surgery units by doctors having no particular training in this field (2, 3, 4, 8). It concerns both insufficient surgical skills (i.e. tendons repair, fixation of small bones’ fractures, suture of the nerves and anastomosing of vessels) and adequate postoperative care, with a fundamental rule of the earliest mobilization of digits, to prevent their contractures. In most cases, in these units the primary care for severe hand injuries is neither complex nor optimal. Thus, it is desirable to manage the majority these cases in reference (tertiary) hand departments, capable for primary and complex repair of all damaged structures (2, 3, 4, 8).

Evaluation of the activity of such a department was one of the objectives of this study, to convince if outcomes of the treatment factually justify necessity of separate service for hand trauma.

In general, we estimate positively the outcomes achieved in this survey, considering severity and complexity of the injuries. A mean range of total active motion of the digits and total grip strength amounted 2/3 and a half of its values in the healthy hand, respectively. Bearing in mind that tendons were damaged in all cases and bones were involved in 70%, this result may be considered good. Over the period of 3 months after injury, 12 patients (28%) received a total of 15 secondary operations in order to improve function of the hand after primary supply. These included: flexor tendon tenolysis (n=4), secondary reconstruction of tendons (flexors or extensors, n=4), bone graft (n=3), division and debulking of the flap (n=3) and arthrolysis (n=1). One may suppose further improvement of the function of the involved hands in these patients, because they were assessed at 2-6 months after the last reconstructive procedure. DASH score amounting 30 points in average, suggest also satisfactory hand function. Only 7 patients (16%) had the DASH score higher than 40 points, indicating serious functional impairment. Rosberg et al. reported a mean DASH score of 21 points (range 5-62) in a group of 26 patients assessed at one year after severe hand trauma (9). Although this result is significantly superior to our (lower score indicates better hand function), but the structure and severity of injuries were different between the studies.

It is difficult to estimate the duration of the sick leave (a mean of 4.4 months) as a determinant of the effectiveness of the treatment. We compared this with duration of the sick leave in patients after carpal tunnel release, which we analyse in our earlier study (10). It amounted a mean of 2.3 months (range 1-6),

Table 3. Items comprising hospital costs in authors’ institution

<table>
<thead>
<tr>
<th>Item</th>
<th>Price (zł)</th>
<th>Mean values</th>
<th>Total amount (PLN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theatre costs per hour</td>
<td>400</td>
<td>operation av. 2.5 hrs</td>
<td>1000</td>
</tr>
<tr>
<td>Ward 1 day stay</td>
<td>300</td>
<td>3 days stay</td>
<td>900</td>
</tr>
<tr>
<td>Anaesthesia</td>
<td>240-480</td>
<td>average</td>
<td>400</td>
</tr>
<tr>
<td>Operation materials</td>
<td>100-500</td>
<td>average</td>
<td>200</td>
</tr>
<tr>
<td>Drugs and materials in ward</td>
<td>100</td>
<td>average</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>2600</td>
</tr>
</tbody>
</table>
but 8 of 56 employed persons (14%) did not return to work within 6 months after surgery. In the light of these data, the time of inability to work as a consequence of severe hand injury may be regarded as relatively short, thus suggesting good quality of the service. Likewise, the proportion of subjects no returning to work within 6 months after hand trauma amounting 13%, the same as after carpal tunnel release – 14%, confirms this opinion. In Rosberg et al., study, the time of sick leave in 26 patients with severe hand injuries was a mean of 6.2 months (range 1-12), and 90% of them returned to work within one year. The differences in duration of a sick leave may arise both from different types of injuries between studies and specificity of post-traumatic care in Sweden (9). In our material as many as 27 patients (87%) returned work, of this 24 to their original job. It is important to notice that this group consisted of 10 persons with amputations of at least one finger. Only the patient with amputation of three fingers (non-dominant hand, at the level of proximal interphalangeal joint, DASH score of 28) did not get back to work. Two persons assessed at 8 and 10 months after “spaghetti” type injuries (fig. 1 and 2), involving most of flexor tendons, radial artery and median nerve (53 years, DASH score 63) and ulnar artery and nerve (26 years, DASH score 56) were on extended sick leave. However, the function of the hand achieved by those patients justified a good prognosis regarding their recovery and return to work (11). In the previously cited paper, a mean time of sick leave after treatment of isolated nerve injuries at the level of the forearm amounted 7 months (range 1-155) (12).

Our calculations of costs of the hospital treatment were based on institutional reckoning and price list. It was shown that in-patient care is not particularly expensive in average and, moreover, the expenses are mostly consisted of wholesale costs, including cost of theatre’s hour and ward’s one day stay, amounting total of 1900 PLN per person (73% of the total amount). Thus, the factual costs spent for materials and drugs did not exceed 700 PLN. In comparison, in Sweden the cost of treatment of similar injuries is counted at an average of 11 000 Euros per patient (9). These wholesale costs included also the value of surgeon’s work, which is calculated – depending of the degree of qualifications and mode of employment – within the range of 35-100 PLN per hour on duty (regardless the operations performed). Comparing to the 21 Euros per minute (!) paid for Swedish hand surgeon work it is “relatively cheap” (12). Except of hospital costs, a total medical care costs consist of expenses spent for ambulatory care, rehabilitation and sick leave refunding. Assuming that employed persons received the salary equal the national average (in 2009 it was 2900 PLN per month), a mean period of the sick leave of 4.4 months gives a refund sum of 12 760 PLN per patient. These calculations indicate the significance of the mentioned issue for state but not only health care budget. However, comparing to the Swedish system, these expenses are minor, because a total economical effect of severe hand injuries is calculated for 25 000-70 000 Euros per patient, including costs of medical care and amount of the “lost production”, constituting the greatest item in this sum (9). The total cost of the treatment of a single patient with median or ulnar nerve injury, calculated in this way amounted in Sweden 45 800 Euros (12).

In Polish literature, results of the treatment of hand injuries were presented in several publications. In a series of studies coming from Cracow, a total of 1200 patients suffered form hand trauma were analysed. The most devastating injuries were caused by circular saw, amounting 19% of the total number of cases. Duration of treatment of these patients were longer and outcomes were poorer than those injured by other machinery and 13% of patients obtained a disability pension (2). It the other study, authors showed that 27% of patients sustained hand trauma were at alcohol abuse. Duration of treatment of these patients was a mean of 2.5 months and almost 60% of them sustained a permanent disability of a various degree. Similarly to our study, the main portion of the total costs of the treatment of these patients consisted of sick leave refund and compensations (4). In the other study it was shown that the most devastating injuries were caused by machines used in industry and agriculture (3). It was also shown that hand traumas in patients older than 60 years were more serious in average than in other persons and resulted in greater reduction of the function of the hand (8). Gryś et al., reported the results of the treatment of 78 patients with major hand injuries. A mean
duration of in-patient stay was of 14 days and ambulatory care of 4.5 months. A half of these patients return to their previous work, 13 (17%) qualified for the new job and 12 (15%) were permanently unable to work (disability pension) (5).

CONCLUSIONS

The outcomes of the treatment of major hand injuries achieved in our institution over the period of the one year were satisfactory, considering their severity and complexity. These results, in our mind, show clearly advantages coming from an existence of qualified service for hand injuries. Number of such a qualified units is in Poland insufficient, comparing to our neighbouring countries (except of those at the east side). Therefore, it is desirable to continue the efforts for establishing specific sub-speciality in hand surgery, in order to adequately qualified specialists were available in most of orthopaedic and surgical departments. This, certainly would elevate the quality of management of these injuries.

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