

Reeducation of the Upper Limb: A Case Study of a Multiple Trauma Patient, Who Suffered a Car Accident

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ABSTRACT

The hand and the forearm are the main defensive organs and more than often they suffer serious traumatism in car accidents. Guiding these patients to rehabilitation areas is essential for the success of the process.

The present case refers to a multiple trauma patient who suffered a car accident which had great impact on his upper left limb. The patient was treated at Hospital de São José, and later transferred for the Centro de Medicina e Reabilitação do Sul to start his rehabilitation. The complete description of the process in Occupational Therapy/Hand Therapy starts here, with the intention of evaluating the impact of this type of intervention on a multiple trauma patient, by assessing the evolution of the open wound, scar, edema, sensitiveness, joint range, muscular activation, limb functionality as well as Instrumental and Daily Life Activities.

Despite improvements at motor and sensory levels, these were not as expected, as a result of the severity of the injuries and the late rehabilitation beginning. Nonetheless, at the functionality level the patient was able to achieve improvement levels that allowed a greater independence and a return to his job. A timely reference for treatment, in this case of multiple trauma in the upper limb, could have allowed for a greater success in the rehabilitation, at the same time, a more effective communication among all the structures involved in the case since the moment of the accident until rehabilitation would also have led to a faster closing of the wound, which would have a positive influence in the results. Although, and even with the late start, the Hand Therapy intervention was paramount for the patient's independence.

Keywords: Crushed injury, Hand, Multiple trauma, Occupational Therapy.

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I. INTRODUCTION

The upper limb (UL), in concrete the hand and the forearm, are the main defense organs of the human being. When the body senses danger, it is the hand that reacts immediately. Due to its level of tactile sensitiveness, range of movements, and reflexive attitude, it always works as a protective shield, often becoming the target of traumas [1]. This necessarily affects the function of the hand and consequently, the ability to execute actions in daily or professional life (means of sustenance) [2].

The occupational therapist, trained in physical and psychological assessment, prosthetic evaluation, orthosis manufacturing, evaluation of Activities of Daily Life training (ADL's), and functional rehabilitation is uniquely qualified to address disturbances of the UL and the Hand Therapy has evolved into a specialized field [2]. The success of the functional recovery of a traumatized hand is deeply connected to a joint and synchronized effort involving the surgeon, the hand therapist, and the patient. [1]-[3]. Due to

the intricate and delicate anatomy of the hand, its complicated kinesiology, and its extremely refined functional ability, all those involved in the rehabilitation must have an exact knowledge of the topographic anatomy, physiology, kinesiology, and biomechanics of the UL [3]. The surgeon is responsible for treating the injury and the hand therapist must restore the function, all while working together with the patient.

The reeducator must know the location and the characteristics of the fracture, identify associated tendons, ligaments, blood vessels, and nerve injuries, and analyze the peculiarity of the case [1].

The patient in this study has suffered multiple fractures in different anatomical regions (cubital, radius, femur, 2nd, 3rd, 4th and 5th metacarpal and 7th dorsal vertebra), thus being identified as polytraumatized [4]. It is possible to mention that the trauma is the most common cause for fractures [5]. Hence, a trauma in the UL with bone fracture can cause serious damage to other tissues, including skin, nerves, blood vessels, and organs. These lesions can complicate the treatment of the fracture and/or cause temporary or

permanent problems. Out of these, damage to blood vessels and nerves, Compartment Syndrome, and infections appear during the first hours or days after the injury whereas joint and tissue scarring problems develop as time elapses [5].

As such, in the present case, we highlight the following injuries and respective treatments undertaken:

Forearm fractures – comminuted fractures are related to the existence of multiple bone fragments (two or more) that change the correct orientation at the place of the fracture. [6]. The dislocation in fractures is the level at which the edges of the fracture lose their original alignment; it is described in either millimeters or percentage of bone thickness [5]. The open fractures/exposed fractures are fractures with skin rupture; these are usually associated with greater complications, such as infections, bad scarring, and neural vascular disruptions [6]. The modified open fracture classification system, described by Gustillo Anderson (1984), takes into account all the previous factors and organizes traumas in different groups according to their severity – the current case study shows fractures type IIIa, containing wounds longer than 10cm, contaminated, with severe injury in the soft tissues, with possible skin covering and multifragment bone injury [6]. Usually, both diaphysics are fractured in the forearm when the trauma occurs at the middle third level. Aside from the functional inability one can observe a curvature in the forearm. In adults, this fracture requires fixation with a plate and screws [7]. A few more recent studies highlight the importance of early rehabilitation after fracture treatment with external fixation, open reduction, and internal fixation, or even other types of surgeries, that is to say still during the immobilization period. [5];

Fracture of the metacarpal – the fixation can be made by Kirschner wires, screws, plates, and fasteners. The advantage of open reduction and rigid internal fixation is that the early exercises for joint movement range and tendinous slip can be initiated as early as 3 to 5 days after surgery. The disadvantage is the possibility of occurrence of adherence of soft tissues to the site of the fracture [1];

Finger extensor rupture – tendons, when totally severed, lose joint mobility and will have to undergo tendon suture surgery (tenorrhaphy). Although evolution in these techniques already allows for safer reparation, the normal tendon sliding after the scarring of the wound cannot be ensured [8]. Early rehabilitation, edema treatment services, patient guidance, monitoring of the correct positioning of the orthosis as well as an early active and passive exercise program, will significantly improve results, both in simple injuries and complex injuries of the extensor tendon, not only in functional terms but also when it comes to rehabilitation time, financial costs and faster ability to return to one's Job [1].

Rupture of the *extensor digitorum muscle* – deserves special attention. When important muscles are completely severed, myorrhaphy could be necessary and must be executed with careful hemostasis and suture technique [9].

Rupture of the cubital artery – rarely are the arteries of the forearm hit in common traumatism, being usually injured in open fractures and often associated with tendinous and nervous injuries [10]. Injuries of the arteries are surgically treated [5] (arteriography).

Crushed injuries/Open wounds – Crushed injuries are serious injuries of soft tissues where there is a loss of substance. They are often the result of the crushing of limbs and, frequently coexist with injuries of all the areas of impact (skin, musculoskeletal and neural-vascular). Depending on the extension and areas of impact, crushed injuries can result in important hemorrhages that can be difficult to control. They usually lead to significant sequels. In the event of any type of crushed injury, the priority must be to control the hemorrhage. Furthermore, all efforts must be undertaken to prevent infections [11]. Open wounds are caused by skin laceration when the bone is fractured or suffers a strong traumatism, and these can become infected and spread that same infection [5], they are quite common in the hand and UL [11]. In situations where it is not likely that the wound will get better with bandages alone, one can resort to debridement, a process used to remove the necrotic and infected tissue of the wounds, enhancing scarring and avoiding the infection from reaching other areas of the body. Also in these cases of unlikelihood of betterment of open wounds, one can apply a skin graft. This will reduce the area exposed thus decreasing the contamination and speeding the scarring process. In some cases, the application of skin grafts may lead to complications such as graft retraction, colour change, the appearance of bruises, and infection, and must be immediately addressed. Vacuum therapy also uses a vacuum system to produce a healthy closing of the wound. It is used as a primary treatment for chronic and complex wounds, acute wounds, second and third-degree burns, and temporary closings for surgery procedures [12].

Given the complexity of the case at hand, it is important to be aware of some clinical complications that arose even before the rehabilitation intervention:

1. Rejection of the graft, which became necrotic, being the necrotic part excised leaving the wound open with difficulties in the scarring process;
2. The non-consolidation of the fractured bones (metacarpi).

The results of the existence of hand fractures can be catastrophic for hand functionality if there is no treatment or if the intervention is not adequate [1], and that is exactly why this particular case was sent for rehabilitation.

The rehabilitation starts with a complete assessment and definition of major objectives (edema control, wound treatment and closing, improvement of joint movement range and functional enhancement) which will be guidelines of a structured therapy plan directed at the patient's recovery.

The chosen case has some observations that may answer some gaps in knowledge and which can yield unexpected answers to therapy treatments that were undocumented until then. The case was chosen due to its complexity as far as diagnoses from car accidents are concerned, as the conjugation of the different diagnoses causes difficulties in the making of clinical decisions and dilemmas in rehabilitation treatments. This was mostly caused by the existence of a wound that had not scarred yet and which was difficult to close, which lasted almost all the admission time in this last institution, by the late rehabilitation, by hindrances in contacting the Hospital of origin, and by the postponing of the appointments schedules at that Hospital.

With this description, the objective is to contribute to an improvement in the area of rehabilitation of a politraumatized patient (UL), by evaluating the impact of the Occupational Therapy/Hand Therapy intervention on a patient with multiple trauma in the UL, analyzing the evolution of the open wound, scars, edema, sensitiveness, joint range, muscular activation, the functionality of the upper limb and Daily Life Activities and Instrumental Activities.

This study results from a research project on the scope of a Post-Graduation in Hand Re-education, done at IP Beja, with the support of the Associação Portuguesa de Terapia da Mão (APTM) – *Portuguese Association of Hand Therapy*. It refers to a case of a politraumatized patient who, after a long period of hospitalization at Hospital de São José in Lisbon, was moved to the Centro de Medicina Física e Reabilitação do Sul (CMRSul), which is part of the Centro Hospitalar Universitário do Algarve (CHUA), ALGARVE, Portugal, with the objective of rehabilitating the left UL.

II. METHODOLOGY

The present study case is composed of one single sample elected due to its convenience, and the data analysis will be based on a combined approach (qualitative and quantitative). The study was carried out during a 74-day period while the patient was at the CMRSul. The patient, whose clinical condition is described in this document, has signed his informed consent, authorizing the disclosure of this data for scientific purposes. This study was approved by the Ethical Committee of CHUA and authorized by the competent Administration Board, having process number 104/2022.

III. INTRODUCTION TO THE CASE

The case refers to a 73-year-old male patient, previously independent in his Daily Life Activities (DLA'S) and locomotion ability, and who was admitted at CMRSul to follow an intensive rehabilitation intervention plan for motor and functional condition, characterized by motor alterations, left-hand edema, exteroceptive hypoesthesia, flexed position of the left elbow, flexed position of the left wrist, brachial atrophy and forearm atrophy, due to a post-surgery anatomic context consequence of a car accident occurred on 11/08/2021, the patient was driving a light vehicle and had a frontal collision. He was transported from Hospital de Setúbal to Hospital de São José on this day.

The patient was admitted to CMRSul 5 months later (January 2022), and transferred from Hospital de São José with the following diagnosis:

- lateral posterior dislocation of the left elbow and open fracture G IIIa treated with transarticular external fixator;
- comminuted fracture of the 1/3 medium of the bone diaphysis of the left forearm, open G IIIA, treated with osteosynthesis with Locking Compression Plate (LCP®);
- rupture of the common mass of the extensors subject to myography;
- crushed injury of the left-hand subject to osteosynthesis of the fractures of M2, M3, M4 and M5 and base fixation of M5 and uncinat by dislocation, with Kirschner wires;

- rupture of the cubital artery subject to arteriography;
- rupture of the extensors D2, D3, D4 and D5 subject to tenorrhaphy. Aside from the diagnosis related to the Left UL, there was also:
- fracture of D7 not compromising the cervical spinal canal;
- right trans trochanteric fracture with short gamma nail;
- hemothorax with pulmonary contusion with a conservative approach.

For a better identification of the case and for chronology purposes, we highlight the importance of some more specific interventions still in the hospital context, prior to the patient's arrival at the rehabilitation center, as mentioned in Fig. 1.

IV. ASSESSMENT

Hence the initial assessment was made at CMR Sul.

A. Daily Life Activities (DLA's)

The first contact with the patient in this study was in the ward context, for the evaluation of functional competence through the direct and spontaneous observation of Daily Life Activities (DLA's). This evaluation was based on the *Functional Independence Measure* (FIM). The FIM is an evaluation scale of 18 items (eating, grooming, bathing, dressing-upper, dressing-lower, toileting, bladder control, bowel control, transfers (bed, chair, wheelchair, toilet, tub, shower) locomotion, stairs, listening comprehension, oral production, social interaction, problem-solving and memory) that quantifies the level of a person's functional dependency in terms of care load. Each item is scored from 1 (requires total assistance) to 7 (completely independent) [13]. As functional dependency changes during the rehabilitation process, the results of the FIM can be used to trace these very same alterations and analyze the result of the rehabilitation. This instrument classifies the performance of a patient in a certain activity, taking into consideration the need for assistance provided by another person, resource, or support item [14].

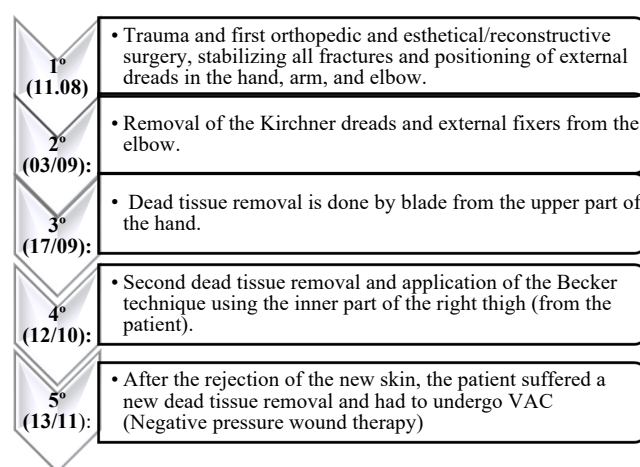


Fig. 1. Chronology of the medical interventions undertaken at Hospital de Sao Jose- Lisbon.

It must be mentioned that currently, the CMR Sul is the only institution at a national level in which technicians and doctors, namely occupational therapists/reeducators of the hand responsible for the present case, are fully accredited by the *Uniform Data System for Medical Rehabilitation – Universidade de Buffalo*, for the application of the FIM. Out of the 18 items that constitute the FIM it is defined by the CMR Sul that eating, grooming, bathing upper dressing, lower dressing, toileting, and transfers are evaluated by the Occupational Therapist, whereas the remaining items are evaluated by the other areas of intervention (Physiotherapy, Nursing, Speech Therapy and Psychology).

Therefore, in the assessment related to Occupational Therapy it was observed that in eating, the patient required assistance to cut the food (FIM 5), in the lower dressing the patient required assistance with the trousers and socks (FIM 4), the patient could bathe using a stool to wash his feet (FIM 6), in the other activities (grooming, upper dressing, toileting, and transfers) the patient performed independently, we no need for support and within the time considered normal (FIM 7).

B. Instrumental Activities of Daily Life (IADL'S)

The preparation of the meals was one of the significant activities for the patient in this study. Through a provoked direct observation, we could verify that the patient struggled to perform tasks such as peeling/cutting the food, stirring a pan with only one hand, etc. [15].

C. Skin

Nowadays there are several objective assessments, measurable, reliable, valid and standardized, that follow a biomechanical reference available for the evaluation in hand therapy and health assistance, and that can be collected by observation, touch, or palpation [16], as it happened in the present case.

Initially, during the observation of the left UL, we verified that the flexed positioning of the elbow, resulted in the incorrect positioning caused by the use of a forearm sling. In the forearm and wrist, there were scars evidencing the several surgeries undertaken, and the back of the hand had two open wounds with exposed bone tissue at the level of the

2nd metacarpal bone and some exsudated. The hand and the fingers were swollen and cyanotic.

Through palpation, we could also verify that the scars resulting from the reconstructive surgeries were adherent in the forearm and wrist.

D. Edema

The evaluation to measure the edema was made through the perimetry of the wrist and back of the hand, following the 8 technique and with the use of a metric tape, while for the fingers a finger perimetry ring was used [6]. We then concluded that there was an increase in the perimeter of the wrist and of the back of the hand when compared to the non-injured UL.

E. Muscular Strength

A few minimum requirements are necessary for the motor function of the hand to exist: useful mobility and stability of the small joints in the fingers, the integrity of the muscular-tendinous units and at least the capacity to accomplish the opposition of the thumb with another finger, as well as the integrity of the nerve structures that responsible for innervating the previous. Therefore, in order to assess the motor function it is necessary to measure joint mobility and the strength of the muscles that trigger the joints of the UL [17].

The assessment of the muscular strength of the upper limbs was based on Daniels and Worthingham's "Muscle Testing". This test guides the positioning of the patient, the direction of the movements and the direction of the resistance that is applied. With this test, one can quantify the muscle strength of the patient in a specific movement instead of measuring muscle strength in individual muscles. The assessment shows the quantitative performance of all the muscle groups responsible for that specific movement [18].

By assessing the muscle strength of the groups of muscles responsible for the movements of shoulders, elbows, wrists and hands, we were able to understand that the strength had been kept in the shoulder and elbow (5/5), at the wrist there was a hint of movement (1/5) and at the fingers, there was no visible nor palpable muscle contraction (0/5).

TABLE I: FIM ASSESSMENT OF CUNTIONALITIES IN DLA'S

	27.01.22	18.02.22	4.03.22	20.04.22
Eating	5 (needs prepared food)	5 (needs prepared food)	5 (needs prepared food) *	5 (needs prepared food)*
Grooming	7	7	7	7
Bathing	6 (uses folding bench to wash the feet)	6 (a long-handled sponge was insert to wash the feet)	6 (uses a long-handled sponge to wash the feet)	6 (uses a long-handled sponge to wash the feet)
Dressing Upper Body	6 (it takes 3 time longer)	6 (it takes 3 time longer)	6 (it takes 3 time longer)	6 (it takes 3 time longer)
Dressing Lower Body	4 (needs help putting on socks)	6 (shoehorn for socks was insert)	6 (uses shoehorn for socks)	6 (uses shoehorn for socks)
Toileting	7	7	7	7
Transfers	7	7	7	7

* Patient with good performance in cutting food with a palmar bag on the left UL, however, he maintains a preference for not doing so, and the food will continue to have to be prepared by third people while he remains in hospital.

TABLE II: ASSESSMENT OF THE EDEMA-PERIMETRY

	Right Hand 27.01.22	Left Hand 27.01.22	Left Hand 18.02.22	**Left Hand 04.03.22	**Left Hand 20.04.22
Hand (8)	41 cm	48 cm	44 cm	44 cm	42.5 cm
1 st Finger	7.5 cm	8 cm	7.4 cm	6.7 cm	6.6 cm
2 nd Finger	8 cm	8.5 cm	7.5 cm	7.5 cm	7.4 cm
3 rd Finger	8 cm	9 cm	8 cm	8 cm	7.7 cm
4 th Finger	7.5 cm	8.5 cm	7.2 cm	7.5 cm	7.7 cm
5 th Finger	6.4 cm	6.7 cm	6 cm	6.7 cm	6.2 cm

** This assessment was conducted after 1 day without using Coban.

TABLE III: ASSESSMENT OF MUSCLE STRENGTH

	27.01.22	18.02.22	04.03.22	20.04.22
Shoulder Flexors	5	5	5	5
Shoulder Abductors	5	5	5	5
Elbow Flexors	5	5	5	5
Elbow Extensors	5	5	5	5
Wrist Flexors	1	1	1	1
Wrist Extensors	1	1	1	1
Fingers Flexors	0	1	1	1
Fingers Extensors	0	1	1	1
1 st Finger opponant	1	1	1	1
1 st Finger Extensor	1	1	1	1
1 st Finger Adductor	1	1	2	2
1 st Finger Aductor	1	1	2	2

F. Joint Amplitude

Goniometry is the measure of joint angles reached by the joints of human beings. The most used instrument to measure the amplitude of movements is the goniometer. The evaluation of the goniometry of the patient in this study was conducted according to the “Manual of Goniometry” [19].

As such, in order to control the compensatory movements, the measuring at the shoulder and elbow was made with the patient in the supine position on a massage table, correctly stabilizing the segments. We observed limited joint movement in the flexing of the shoulder, shoulder abduction, elbow flexing, elbow extension, forearm supination and forearm pronation, wrist extension, and finger flexing. The passive joint amplitude of both upper limbs was compared.

Pain complaints were registered during the goniometry assessment at the end of the passive joint amplitude testing elbow flexion/extension, forearm supination/pronation, and wrist flexion/extension. The Numeric Pain Scale (NPS) was used to obtain a specific measurement of the intensity of the pain that the patient was experiencing. This is a numeric scale that goes from 0 to 10 where 0 refers to “no pain” and 10 to “the worst pain the patient has ever felt” [20]. According to the patient, His pain was set between 3 and 8 in the forearm and wrist movements.

G. Sensitivity

Sensitivity in the left UL was assessed having in mind the authors Pedretti and Early [2]. According to these authors, patients with tactile and proprioceptive dysfunctions cannot feel contact with objects nor can they feel the position and movement of the joints, which impacts the performance of daily life activities.

During this assessment we could observe that the patient in this study showed superficial sensitivity (tactile, pain, and thermic) on his arm and 1st finger, on the distal third of the forearm (cubital region), absent in the 4th and 5th fingers, and on the 2nd finger, when under stimuli, the patient felt paresthesias, on the initial evaluations, fortnightly until the end of the patient’s hospital remaining parts of the hand and forearm the patient was experiencing hypoesthesia. As for combined sensitivity, the patient showed alterations in topognosy and total absence in stereognosis. Concerning deep sensitivity the patient failed on 4 of the 6 positions tested, was able to correctly identify the position of the forearm, but failed to identify the positions of the fingers.

The reassessments were conducted using the same formula as the stay at CMR Sul (74 days).

H. Diagnosis Exams

The radiology evaluation is always important for the observation of the alignment of the bone structures and fragment reduction [1], and since the patient’s file did not include any X-ray, the therapists suggested an X-ray and an Electromyography. In the x-rays made already at CMRSul, halfway through the intervention plan, it was possible to observe several deformities, consolidation issues, and joint problems that necessarily led to the scenery of pain with movement limitation and function loss displayed by the patient (Fig. 2).

- “Absence of response of the sensory action potential of the Ulnar Nerve, indicating an injury on this nerve”;

TABLE IV: ASSESSMENT OF PASSIVE RANGE OF MOVEMENT / GONIOMETRY/ PAIN MEASUREMENT (NPS)

	27.01.22	18.02.22	04.03.22	20.04.22
Shoulder Flexion	135°	145°	155°	155°
Shoulder Abduction	115°	120°	120°	120°
Internal Rotation	35°	45°	50°	55°
External Rotation	50°	55°	55°	55°
Elbow Flexion	100° (nps 8)	105° (nps 8)	110° (nps 7)	128° (nps 7)
Elbow Extension	-50° (nps 5)	-33° (nps 6)	-30° (nps 5)	-25° (nps 2)
Pronation	10° (nps 4)	10° (nps 5)	12° (nps 4)	15° (nps 4)
Supination	20° (nps 3)	23° (nps 3)	25° (nps 3)	25° (nps 3)
Wrist Extension	-10° (nps 5)	10° (nps 5)	5° (nps 5)	5° (nps 5)
1 st Finger MCP Flexion	45°	50°	55°	60°
1 st Finger PIP Flexion	40°	50°	55°	55°
2 nd Finger MCP Flexion	50°	55°	Not assessed (due to wound healing)	Not assessed (due to wound healing)
2 nd Finger PIP Flexion	55°	80°	80°	85°
2 nd Finger DIP Flexion	40°	60°	65°	70°
3 rd Finger MCP Flexion	40°	50°	Not assessed due to wound healing)	Not assessed due to wound healing)
3 rd Finger PIP Flexion	50°	70°	70°	70°
3 rd Finger DIP Flexion	55°	70°	75°	75°
4 th Finger MCP Flexion	30°	55°	60°	60°
4 th Finger PIP Flexion	60°	70°	75°	80°
4 th Finger DIP Flexion	55°	75°	85°	85°
5 th Finger MCP Flexion	20°	30°	40°	45°
5 th Finger PIP Flexion	50°	65°	75°	80°
5 th Finger DIP Flexion	35°	60°	65°	70°

TABLE V: SENSITIVITY ASSESSMENT

		Superficial		Combined		Profound
		Tactile	Pain	Thermal	Stereogosis	Topognos y n
27.01.2022		Kept on the arm absent in the distal region of the forearm (ulnar), hypoesthesia in the rest of the forearm, absent in the 3rd, 4th and 5th finger (dorsal/palmar), tingling in the 2nd finger when stimulated, held on the 1st finger.	Not tested due to skin being too sensitive (thin)	Kept in the arm, absent in the distal region of the forearm (ulnar), hypoesthesia to hot and cold in the rest forearm; absent in 3rd, 4th and 5th finger (dorsal/palmar); feel tingling in the 2nd finger when stimulated; held on the 1st finger.	Changed	Absent
18.02.2022		Maintains previous evaluation	Not tested due to skin being too sensitive (thin)	Kept in the arm, absent in the distal region of the forearm (ulnar), hypoesthesia remaining forearm, absent 4th and 5th finger, feels tingling whwn 3rd finger is stimulated, identifies cold in 2nd finger, 1st finger maintained.	Maintains previous evaluation.	Maintains previous evaluation.
04.03.2022		Kept on the arm, absent in the distal region of the forearm (ulnar), dorsal region – kept on the 1st, 2nd finger, hypoesthesia on the 3rd finger; tingling in the 4th finger and absent in the 5th finger. Palmar region: maintained on the 1st and 2nd finger, absent on the 4th and 5th finger, hypoesthesia on the volar side.	Not tested due to skin being too sensitive (thin)	Maintains previous evaluation.	Maintains previous evaluation.	Maintains previous evaluation.
20.04.2022		Maintains previous evaluation	Maintains previous evaluation	Maintains previous evaluation	Maintains previous evaluation	Maintains previous evaluation



Fig. 2. (a) X-ray of the left hand, 6 months after the date of the trauma (accident), already at CMRSul, (b) X-ray of the left forearm, 6 months after the date of the trauma (accident), already at CMRSul.

- “Low amplitude motor and sensitive response of the left Radial Nerve, indicating a severe partial injury in this nerve”;

- “Absence of response of the motor and sensitive action potentials of the Median Nerve, indicating a severe injury of this nerve”.

V. INTERVENTION OBJECTIVES

The following intervention objectives were defined, after the initial assessment, regarding the sensory-motor evolution of all the left UL:

Within 45 days the edema on the left hand is expected to decrease, and the perimetry values should get close to those on the right hand (see Table II).

Throughout the rehabilitation process, fortnightly, a 5° increase in the passive joint amplitude of all the Left UL is to be expected.

Within 45 days, an increase (of at least level 3 in the Muscle Testing) in muscle strength in the wrist and fingers of the Left UL is to be expected.

Within 45 days, we expect to see improvements in superficial sensitivity and deep sensitivity in the forearm and hand of the left UL.

The functional evolution of the patient, that is the type of support products one uses or does not use, or the speed in accomplishing tasks (according to FIM), depended on the evolution of all of the Left UL during the treatment period. As such, the following objectives were set regarding the functional component of the patient:

Within 45 days, the patient of this study was expected to be able to perform eating, lower dressing, and preparation of the meals, taking 3 times longer than the time that is considered normal or by resorting to a support product (FIM 6).

Within 45 days, the patient of the study was expected to be able to perform bathing with qualitative improvement, that is in the orthostatic position, by using a long handle sponge (FIM6).

VI. INTERVENTION

Due to the scarce literature available concerning multiple traumas in the UL – as whatever literature there is, is always directed to protocols related to a single type of trauma, and also since all the available literature refers to precocious rehabilitation – the intervention in this case, which is far too complex, and which is already considered as being of late referral was undertaken as explained herein:

The present study case had a 2h to 3h daily intervention of Occupational Therapy/Hand Therapy 5 days a week.

A. Wound

In order to meet the objectives set, the intervention of Occupational Therapy/Hand Therapy began by targeting the open wound on the back of the left hand, which had exposed bone and some had exudated. It was essential to close the wound as fast as possible so that the hand could recover in the best possible way. Hence, the physiatrist doctor responsible for the patient at CMRSul, assisted by the responsible therapists, ran all the cleaning processes and closing attempts during the period of therapy. It is worth mentioning that the follow-up of the wound carried out by the Hand Therapy allowed all the interventions to be adjusted to the needs of the wound.

B. Scar

Scars can take several months to heal [21]. The alteration of sensitivity in scars must be treated with desensitization and the modeling of the scars may occur with compressive measures, for example, Coban, with cicatricial manual and vibrating massage [1], [21], as these are techniques that press the scarring tissue vertically, aiding in the cicatricial remodeling by reorganizing the collagen fibers [22]. Therefore, the massaging of the scar on the forearm (graft) was executed in the direction opposed to the tension forces

of the tendon.

C. Edema

Chronic edema is one that persists for longer than 3 months, and it is harder and more difficult to work with. As a result of the prolonged contention of plasma in the interstitium, the tissue becomes fibrotic [21].

As it is well known that a reduction of the edema is a priority in order to obtain advances in mobility [21], some strategies were passed on to the patient so that he could apply them during the longest time possible outside the therapy schedule: the left UL, whenever possible, should rest at an elevated position and active torso, shoulder, and elbow movements ought to be made (segments with conserved muscle strength) several times a day, spaced by resting periods.

The elevation of the hand above the heart reduces the edema because it reduces the hydrostatic blood pressure. Thus, the affected limb was positioned with an inclination of more than 45°; this means that when lying the cushions were placed in a way that positioned the elbow higher than the shoulder, and the hand higher than the elbow and wrist [21].

The proximal active movement (torso and shoulder) is also used to reduce the edema. We began with torso exercises so as to facilitate the lymphedema pump. Even low-level aerobic exercise causes alteration in pressure in the thoracic duct. Pressure changes move lymph proximally into the venous system. Shoulder and elbow exercises began afterward as a way to move the proximal edema toward the thoracic duct, creating a space that allowed the more distal edema to move proximally. Wrist exercises ensued and the last exercises would be in the hands/fingers [21].

During the rest periods, the stabilization orthosis of the forearm and wrist was considered.

At the end of each therapy session, Coban was applied to the hand, wrist, and fingers, as a soft compression method. This type of compression (Coban, elastic glove, etc.) allows the venous system to absorb small molecules and the lymphatic system to absorb large and small molecules [21]. Coban was placed on the fingers circumferentially, creating a compression effect that pushed either the distal edema the proximal edema, or even both. Slightly overlaying spirals of Coban, from distal to proximal along each finger facilitate the absorption and the displacing of the edema onto the proximal region; these were placed carefully in order not to impede joint movements, and the tips of the fingers were left uncovered so that one could observe blood circulation on the finger's digit pulp. As it provides a minimum movement restriction and exerts a soft and constant compression, Coban was used daily for several hours, including at night [1].

Due to the existence of an open wound, some techniques of edema reduction were excluded for example the contrast bath and the use of compression gloves [1].

D. Sensitivity

The first stage of reeducation of sensitivity is the transmission of strategies that might compensate for the loss of the sensory protection that was present on the left UL. Considering that this limb was unable to identify objects that could be potentially dangerous with being aided by sight [20]. At a later stage, objects of different textures were used repeatedly as a way to bombard sensory receptors, in a

sequence that alternated between eyes closed and eyes open so as to receive feedback during the reeducation process [2].

E. Joint and Movement Amplitudes

Passive joint mobilization techniques were applied to all joints of the left UL, with special attention dedicated to the region of the hand fractures, due to stiffness, edema, and pain [1].

The combination of therapy exercises and orthosis is the most effective way of gaining joint and movement amplitude [21], and it often occurs during the treatment, that one orthosis may be used to meet more objectives [1].

As we observed that obtaining gains of joint amplitude on the wrist and fingers was difficult, we opted for applying, after 5 days of treatment, the technique *Casting Motion to Mobilize Stiffness* (CMMS). This technique consists of placing a splint in plaster with the objective of selectively immobilizing the proximal joints in an ideal position while limiting the distal joints so that these only move in the intended amplitude and direction [20]. It has been proven that the adequate application of stress on injuries on soft tissues can effect permanent changes to the periarticular structures and surrounding muscles, which in turn enhances stiffness and joint function. The CMMS Technique is one way of recovering the normal movement patterns through the application of the intended level of stress on the joints [23].

The splint used in the present study case was made with the wrist at its maximum extension, so that the flexor muscles could reach their peak functional length, allowing a complete flexion of the fingers. The splint stretched over the back of the hand covering the proximal phalanges, which would then position the metacarpophalangeal joints at a maximum level of passive flexion [24].

During the sessions, still with the plaster splint on, the team began to ask the patient to execute flexion and extension movements of the finger in the desired pattern, with the assistance of the therapist with the objective of allowing the acquisition of the new movement pattern in the motor cortex [23]. There was a reevaluation of the splint every 48h, and this technique was applied for 8 days in a row.

After this period, and taking advantage of the previously produced splint that stabilized the wrist (made in thermoformable material, with the wrist at approximately 5° of extension – the extension tolerated by the patient), a female Velcro elastic was added which formed small loops for the fingers in so that these could flex, and leaving a static progressive splint for the flexing of the metacarpophalangeal joints [25]. Then, the patient was instructed to use this splint for about 20 minutes in each hour. The wrist stabilization orthosis had as its objectives to maintain the joint amplitude and extension of the wrist that had been gained with the CMMS and to increase the joint amplitude for finger flexion.

Due to the open wound and edema, some of the techniques that could help gain amplitude had to be excluded, for example, the use of paraffin, moist heat, paraffin wax, and hydro massage [1].

F. Muscle Activation

In Neuromuscular Electric Stimulation (NMES), muscle contraction is produced by the depolarization of motor neurons. Electrodes may be positioned over the muscles that will be stimulated or over the motor nerve that controls the

muscles, and the main benefits resulting from the use of NMES are enhancement of the movement amplitude, edema reduction, treatment of atrophy caused by lack of use and improvement of muscle recruitment for muscular reeducation [26].

The NMES consisted of the therapeutic application of electric current of low frequency through electrodes applied over the muscle belly of the finger extensor muscles, finger flexor muscles, thumb extensor muscle, and thumb opponent muscle, to achieve muscle strengthening [27], while assisting the learning process and volunteer motor control, by increasing muscle activation and muscle awareness [20]. The patient was usually requested to contract the muscles in sync with the stimulation [26].

It must also be mentioned that the application protocol of the NMES therapy at CMRSul, was based on *Juan Rioja Toro's* work [28] and consisted of the following parameters:

Pulse – 300 us

Frequency – 35 Hz

Work time – 6 seg

Pause time – 10 seg

Rise – 2 seg

Decay – 1 seg

Mirror therapy was used with the objective of restoring the volitional control of the affected hand, instructing the patient in the present case to observe the movement of the hand that had not been affected on a mirror image placed at a middle line (the affected hand was behind the mirror), using the visual system to stimulate the mirror neurons [20].

In cases where there is still pain and movement limitations, exercises of isometric contraction are recommended [1].

G. Functionality of the Left UL

At the end of the sessions, and before applying the Coban, functional activities and specific activities with a purpose were made as a way to incorporate the movements stimulated during the intervention and to work on the selectiveness of movements of the shoulder and elbow and to strengthen the muscle groups of the shoulder, elbow, and thumb. The functional activities also have the objective of promoting a feeling of usefulness of the limb, they improve movement coordination, muscle conditioning, and muscle reinforcement, and they stimulate the proprioceptive function of the limb. They are also used to obtain active movement amplitude gains, in this case mainly at the shoulder, elbow and I finger. The patient is able to monitor his performance under the guidance of therapists, keeping his focus on the objectives of the activity and avoiding compensatory movements to escape the pain [1]. In this case, the patient executed reach activities (shoulder and elbow) using a side grip, maximizing thumb movement. These activities were always executed with the wrist stabilizing orthosis on, as a way to keep the wrist in a functional position tolerated by the patient.

H. DLA's and IDLA's

Training the patient to execute Daily Life Activities within his possibilities is one of the approaches that better defines Occupational Therapy. The politraumatized patient suffers from a series of alterations that are limiting during the rehabilitation process, and which interfere with the prognosis

and with the independence potential [29].

DLA's and IDLA's training were undertaken, in a ward context and in a simulated environment context, with the intention of transmitting functional strategies and of studying support products/adaptations that could facilitate the functional performance of the patient in this study case.

The adaptations suggested and trained in the Occupational Therapy intervention serve to minimize the different factors that might interfere with the independence potential, and that should be worked on with the intention of maximizing the patient's independence, according to his prognosis [29].

In this case, some of the strategies that were trained were:

- Eating: the patient was trained to eat with a palmar clip placed on the left hand containing a fork and with a regular knife on his right hand. Initially, the training occurred in a simulated context, in the occupational therapy room, and, when the patient was ready, training moved on to the real context, at the eating hall at CMRSul. The training was very positive and the patient accepted it.

- Bathing: the bathing training consisted of the patient starting to take a bath in the orthostatic position, no longer sitting on the stool, and, being able to wash his feet using a sponge with a long handle. The training was successful and the patient accepted it.

- Dressing, lower part: here we had to understand what support product was better suited for the patient so that he could put his socks on alone and the answer was a shoehorn. The training was successful and the patient accepted it.

- IDLA's training (meal preparation): took place in a simulated context with the support of a multiuse board, that replaced the function of the left UL in the activity. The training was positive and the patient thought the support product was important and beneficial.

VII. DISCUSSION

During the reevaluations that occurred throughout the 74 days of treatment, we understood that the open wound was a handicap in the whole process of intervention of Hand Therapy. Knowing that, and knowing how important it was to close the wound as quickly as possible in order to obtain the best rehabilitation results possible, all the cleaning process and closing attempts during the period of therapy were made by the physiatrist doctor from CMRSul, always with the assisted by the hand therapists allocated to the case. It is important to note that, despite being defined that at CMRSul the nursing team is responsible for the treatment and dressing of open wounds, in this specific case, the presence of the doctor and hand therapists was essential, so that they too could see the evolution of the wound, and prevent the therapy sessions from having a negative influence on that evolution.

At a certain time, and in spite of significant improvement on the wound, after constant postponements of the Plastic Surgery Appointment at HSJ, we realized that a certain area of the wound kept a fragment of the metacarpal bone exposed, and the physiatrist opted for attempting to close the skin in this region, by suturing it. As it did not close completely, we continued to wait for the Plastic Surgery Appointment at HSJ to occur still during the treatment period

at CMR Sul so that some of this bone fragment could be worn off finally enabling the closing of the wound.

The Plastic Surgery Appointment at HSJ did not take place during the hospital stay period at CMR Sul, which conditioned the whole rehabilitation process of this hand.

Despite not having been closed, the open wound did get better throughout the treatment period.

The existence of the wound prevented the application of some intervention techniques (contrast baths, paraffin wax, and compression gloves).

With the different techniques used, described in the Intervention part, we verified a betterment of the scars, when it comes to the adhesences.

Bearing in mind the perimetry measures of the Left UL during the reevaluations, we could verify that when a technique that increased tissue hydrostatic pressure, such as Coban, was applied, the edema would decrease. When there was an interruption of these techniques and we reevaluated the edema, we could see that it had again increased. As the chronic edema elongates the tissue spaces, the prolonged use of compression techniques is necessary to avoid the reoccurrence of any regrowth in the edema [30]. Because of the open wound, we decided not to use a compression glove, and despite the fact that it would have been a lot more practical for the patient to use, we opted instead for the use of Coban applied by the therapists.

By resorting to the CMMS technique, as described by Midgley [23] and Skirven et al [20], in this study, we have also verified: edema reduction, finger flexor and extensor activation, joint amplitude gains in finger flexors and extensors.

The functional activities led to some muscle activation in thumb movement but also to some functional gains in the side grip ability and amplitude gains in UL. They were also important in the awareness process that promoted the integration of the UL in the tasks, as referred to by Freitas [1].

Improvements in the performance of DLA's and IDLA's were observed, and the patient was able to reach the objectives initially set, and the patient accepted the introduction of all the support products suggested.

As for the sensitivity, improvements were not very significant. This might be justified by the results of the electromyographic study, which indicates injuries in the sensitive nerves.

Also in muscle activation, in spite of slight gains, the results were not as initially expected, and despite the different techniques used, this might also be justified by the results of the electromyographic study, which indicates severe injuries in the motor nerves.

This situation necessarily compromises the final result of the rehabilitation and is quite limiting for the therapists and for the patients who have worked to restore the amplitude and function, however, the bad alignment verified in the x-rays does not allow a more positive outcome [1].

Obviously, hand therapists cannot rehabilitate everything. In some cases, such as the present one, traumas are too severe to allow for a full recovery [21].

In these cases, it is important that the patient accepts the residual limitations and resumes his normal life with compensatory techniques/ support products in order to

maximize function. Therapists, along with the responsible doctor, psychologist, and patient, began to identify a clinic plateau to help the patient understand that he may have met all the possible objectives during the rehabilitation process [21]. A continuation of the rehabilitation in Hand Therapy in the patient's residential area in an ambulatory context is recommended, so that the intervention can be longer in time, as at this stage improvements come at a slower pace, and the treatment in a system of intensive rehabilitation, such as is the one at CMRSul, is no longer justified.

VIII. CONCLUSION

During this study, the limitations found were related to the difficulties in communication and follow-up of the plastic surgery medical appointments with the hospital of origin (HSJ), which kept the wound open during all the treatment period, in spite of all the medical attempts to close it. Also, the scarcely available bibliography for this type of case limited the gathering of information in terms of intervention, which is why it is believed that this Case Study can contribute in this sense, in particular with regard to the role of Occupational Therapy / Hand Therapy in the intervention of complex cases, of the multiple trauma UL.

After analyzing the results it is possible to verify that the impact of Occupational Therapy/ Hand Therapy in the rehabilitation of a patient with a multiple trauma UL resulting from a car accident, even when transferred at a later stage, is essential to the improvement of the neuromotor status, even if it occurs at a slower pace, and if, due to exactly that, it requires a more prolonged intervention, which will still, however, have a great impact in the patient's functional independence.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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