CLINICAL STUDY WITH HUNOVA

Neurology – Acquired Brain Injury

Use of hunova for rehabilitation following severe acquired brain injury (ABI): a case study

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We decided to offer our patient a specific rehabilitation program using an innovative robotic device to analyze balance components, lower limbs strength and ankle range of motion with numerical parameters in order to improve her overall condition. Three years ago, our patient suffered of a severe traumatic brain injury which affected her severely. We share this innovative robotic approach in this case study as an inspiring tool for other physiotherapists working in rehabilitation after traumatic brain injury. The improvements we observed encouraged us to share this experience: in response to the robotic therapy program equilibrium and lower limbs status improved in a significant way. Therefore, we would like to present in this case report how we have inserted hunova in the patient's rehabilitative pathway.

Introduction

A severe Acquired Brain Injury (ABI) is a condition characterized by brain damage of traumatic or other nature, characterized by a prolonged coma (not less than 24 hours) and by the presence of sensory-motor, cognitive and behavioral permanent impairments, which lead to variable entity disabilities. Acquired brain damage is a type of brain injury that causes a change in neuronal activity and influences the regular functioning of one or more brain areas, thus modifying the normal cognitive processes. The disorders resulting from a brain injury are specific and depend on several factors, such as the type of injury, the size and location of the affected region, whose correct activation is essential for the control of specific brain functions. The clinical pictures that occur after acquired brain injury are very complex and delicate as the one of the patient who is the protagonist of this cases study. We asked ourselves how we could be more effective in our rehabilitation intervention: we decided to integrate the traditional treatment with hunova. In this report we share how we have achieved clinical improvements on balance, lower limbs strength and ankle range of motion on hunova in a case of results from a traumatic brain injury (TBI).

Medical History

We describe the case of a 20 years old young woman. In March 2017, at the age of 18, she fell from a temple of an archeological site from a height of 4 meters, with a subsequent severe precipitation trauma. Rescued, in serious general conditions, she is brought to the hospital. The lesion balance was very extent: frontal bone fracture, bilateral maxillary sinus fracture, nasal bones, lateral orbital process, sphenoid and mandible; Right pneumothorax and thin pericardial effusion; hepatic traumatic injury; vertebral fractures D5, D6 and D7.
In the hospital she underwent urgent thoraco-abdominal surgery; the Glasgow Coma Scale score (GCS) was 3. After a joint maxillofacial and neurosurgical surgery, she was transferred to an inpatient specialized rehabilitation center. She was alert but with tracheotomy, autonomous breathing but no motor autonomy, she did not speak, but have recovered understanding and non-verbal communication (GCS = 15). She has resumed autonomous walking in mid-June. At discharge, a good level of motor autonomy was reached, but a slight general hyposthenia but remained an incomplete active dorsiflexion of the right foot, particularly evident during walking. The muscular lengths of the tibial-tarsal articulation of the

right foot were maintained. She presented gaps in memory skills and acquisition of effective compensation strategies; poor problem-solving skills remained. Selective attention deficit, too.
In August 2017, she was discharged with indications to continue rehabilitation 3 times a week from September 2017 to now. At the time of our initial assessment (March 2019), she has a deficit of activation of the peroneal muscles of the right foot, showing a "drooping" foot during gait; strength deficit in the muscular compartments of the right lower limb; impairment of balance and slightly altered step pattern.

Overall treatment goals

1. Improve postural control
2. Gain lower limbs strength
3. Increase ankle range of motion
4. Work on balance and compensation strategies to instability
5. Improve symmetry between the two limbs in terms of monopodalic balance in both static and dynamic conditions
6. Stimulate attention

Initial evaluation

Clinical: The following clinical scales were chosen for the initial assessment (T0):

- Hip (Flexion and extension) and Ankle (plantar flexion, dorsal flexion, inversion, eversion) range of motion using a goniometer.
- Medical Research Council (MRC) scale for muscle strength. The muscles evaluated are the following: Tibialis Anterior, Peroneus, Gastrocnemius, Soleus, hamstring, Great Gluteus, Middle Gluteus and Femoral Quadriceps.
- Mini-BESTest: is a clinical balance test that has shown a high sensitivity in detecting balance impairments.
- Timed Up and Go test (TUG) it is a simple test to measure a person's mobility level and requires static and dynamic balancing skills.
- 10 Meters Walking Test (10MWT). This test allows to detect the speed, expressed in meters per second. The subject is required to travel a linear distance of 10 meters in the shortest possible time.
- Montreal Cognitive Assessment (MoCA) It is a rapid tool, which is used as a screening against mild cognitive impairment. It allows to verify different functional areas: attention, concentration, executive functions, memory, language, visual-constructive abilities, abstraction, calculation and space-time orientation.

Initial scores for each test are reported in the results paragraph.

Instrumental: Evaluations were performed at recruitment (T0) and at the end of the treatment (T1). The evaluation consisted of the following robotic evaluations on hunova:

- *Balance test on static base* (Eyes Open - Eyes Closed; bipodalic and monopodalic left/right): the subject must maintain their balance on a static surface in standing position. Evaluators include the area and the range of oscillation, the length of the trajectory of sway. In addition, trunk compensations are evaluated.
- *Balance test on elastic base* (Eyes Open - Eyes Closed; only bipodalic stance): the subject must maintain their balance on a dynamic surface in standing position. Evaluators include the angular displacement of the platform and the length of the trajectory of sway. In addition, trunk compensations are evaluated.
- *Balance test on passive base* (Eyes Open - Eyes Closed; monopodalic stance left/right): The subject must maintain their balance on a continuous moving platform. Trunk compensations are evaluated.
- *Limits of stability*: the subject is standing on the static platform and must move the load as a pendulum as far as they can in the indicated directions (right, left, forwards and backwards). The test calculates the maximum range of load-shift in the different directions.
- *Reactive balance:* the patient is subject to random perturbations. The test evaluates reaction time.
- *Five times sit to stand:* the aim of this test is to measure the time taken by the patient to reach a standing position from an initial sitting position and back, 5 times.
- *Ankle ROM in standing position (with load):* the range of motion in standing monopodalic configuration can be evaluated: in plantar and dorsal flexion (rotations performed on the sagittal plane) and in pronation-supination movements (rotations performed on the frontal plane).
- *Ankle ROM sitting (without load):* the range of motion in sitting isolated ankle configuration can be evaluated: in plantar and dorsal flexion (sagittal plane) and in pronation-supination movements (frontal plane).
- *Isometric test:* the isometric test objectively quantifies medium and maximum force expressed by the subject in the plantar and dorsi flexion movement of the ankle.

Treatment intervention

Ten personalized hunova training sessions with variation of difficulty depending on the patient's performance were prescribed together with conventional physical therapy. The proposed exercises had an increasing progressive difficulty for each training session.
Each training session on hunova lasted 1 hour, twice a week. Sessions were focused on:

BIPODALIC
- Balance
- Dual task
- Limits of stability
- Lower limb Strengthening
- Control of dynamics
- Trunk control

MONOPODALIC
- Balance
- Dual task
- Lower limb Strengthening
- Control of dynamics

ANKLE
- Passive mobilization
- Strengthening

SEATED
- Balance
- Core stability

Results

Clinical scales - To quantify the results we compared the results of the initial assessments (T0) with the final ones (T1) in each test.
Ankle (plantar flexion, dorsal flexion, inversion, eversion)

range of motion using a goniometer results are shown in table 1.

ANKLE ROM	Passive - R		Active - R		Passive - L		Active - L	
	T0	T1	T0	T1	T0	T1	T0	T1
Dorsal flexion	2°	5°	0°	5°	10°	10°	5°	10°
Plantar flexion	30°	40°	45°	65°	60°	60°	70°	70°
Inversion	35°	40°	25°	30°	45°	45°	40°	40°
Eversion	40°	40°	20°	35°	40°	45°	35°	40°

Table 1: Ankle range of motion goniometer values at T0 and T1. Abbreviations. R: Right ankle; L: Left ankle.

The major improvement was found in the right ankle in active ROM. Hip values ranged into normality both at T0 and T1. Muscle strength was assessed using MRC scale. T0 and T1 results are reported in Table 2. Significant differences can be seen between left and right muscular tone at T0. This difference is attenuated at T1.

MRC SCALE	T0	T1	T0	T1
Muscle	R		L	
Tibialis anterior	3+	4+	5	5
Peroneals	1+	3+	5	5
Gastrocnemius	4	4	5	5
Soleus	4	4+	5	5
hamstring	4	4	5	5
Gluteus maximus	3+	4	4	4
Gluteus medius	2+	3+	3	4
Quadriceps femoris	4	4+	5	5

Table 2: Muscular strength evaluation using MRC scale. Abbreviations. R: Right; L: Left. Grade 0: No contraction or muscle movement. Grade 1: Trace of contraction, but no movement at the joint. Grade 2: Movement at the joint with gravity eliminated. Grade 3: Movement against gravity, but not against added resistance. Grade 4: Movement against external resistance with less strength than usual.

Mini-BESTtest score passes from 24 (T0) to 26 (T1) out of 28. 2 points are gained in gait and in anticipatory postural control categories. The Timed Up and Go test decreases in time from 7.56 seconds to 6.8 seconds. The same reduction in time resulted in the 10 meters walking test (10MWT): from 7.76 to 6.43 seconds. Cognitive assessment (MoCA) earns 4 points in total at T1 in respect to pretreatment (22/30 at T0; 26/30 at T1).

Robotic evaluation

At T0 the robotic evaluation *Balance test on static base* performed in bipodalic stance reports abnormal values for most of the test's evaluators. At T1 we see improvements in overall stability of up to 60%, bringing all the values examined to normal ranges. In particular, the distribution area of the Center of Pressure decreases with both eyes open (2.36 cm^2 to 0.94 cm^2) and eyes closed (11.07 cm^2 to 4.37 cm^2). The total length of the trajectory traveled by the CoP, has decreased too (23.57 cm to 13.87 cm). The pathlength allows to evaluate indirectly the energy expenditure that the patient bears to maintain the orthostatic position. Small oscillations are synonymous with poor energy expenditure. This indicates less energy expenditure and better maintenance of precarious balance. We observe similar positive results in dynamic bipodalic conditions (*Balance test on elastic base;* Sway area from 16.42 cm^2 to 8.89 cm^2*)*. The values of the AP oscillation of the trunk, however, remain always outside normal, showing a constant tendency to compensate with movements of the trunk.

In the initial evaluation of the *Limits of stability* we observe a difficulty to move the CoP towards the right side, the most affected one (Table 3). In the final evaluation we observe a better ability to move the load in the affected direction and a bigger stability area in total.

EVALUATOR	T0	T1	IMPROVEMENT %
Max Cop Forwards [Cm]	7.64	9.00	17.79
Max Cop Right [Cm]	7.27*	9.62	32.32
Max Cop Backwards [Cm]	6.57	7.55	14.91
Max Cop Left [Cm]	7.49	10.13	35.15
Stability Area [Cm^2]	104.89	163.39	55.77

Table 3: Limits of stability test results. Max Cop: Maximum displacement of the Center of Pressure in the indicated direction.

The indicators in *Reactive balance* detect the average stabilization time of the subject's trunk following disturbances provided by the platform in the different directions of movement. Between T0 and T1 we observe improvements in reaction times both in the right and left directions. In the perturbations in forward direction, despite the improvement T0-T1, adaptation time remains outside normality (Table 4).

EVALUATOR	T0	T1	IMPROVEMENT %
Stabilization Time - Right [S]	0.85	0.41	51.03
Stabilization Time - Left [S]	0.48	0.45	7.06
Stabilization Time - Forwards [S]	0.91*	0.76*	16.62

Table 4: Reactive balance test results. Right left and forwards are the directions of perturbation of the platform.

The raising time and the sitting one in the *Five times sit to stand* improve, going from out of range to normal. The total time of execution of the 5 sit to stands remains outside the norm for her age group.

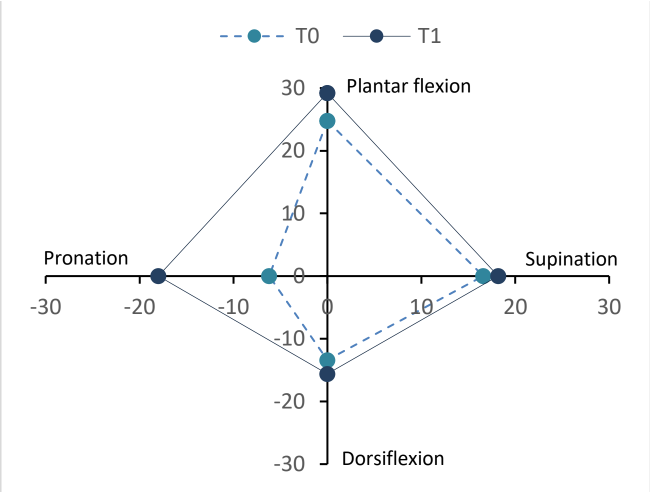
As far as tests in monopodalic and ankle configurations we carried out tests with both limbs and used the values obtained on the less impaired limb as control. In the monopodalic *Balance test on static base* we can highlight a clear improvement in maintaining balance in monopodalic stance on the right foot with eyes open and closed, approaching the performance of the left side (Table 5). The same result is maintained in the similar test but with dynamic perturbating conditions (*Balance test on passive base,* trunk quantity of movement, Table 5).

TEST	EVALUATOR	T0	T1	IMPROVEMENT %
Static – R	Area [cm^2]	8.70	7.93	8.86
Static – L	Area [cm^2]	6.70	5.01	25.22
Passive– R	Trunk Quantity of Movement [deg/s^2]	0.42	0.22	47.09
Passive – L	Trunk Quantity of Movement [deg/s^2]	0.17	0.13	21.17

Table 5: Monopodalic balance tests results. Abbreviations: Static refers to the Balance test on static base while Passive to Balance test on passive base. R: Right foot stance; L: Left foot stance.

In the evaluation of the standing *ankle ROM* (with load) of the right foot we note that on the frontal plane the patient reaches the maximum pronation and supination

allowed by the platform; on the sagittal plane the ROM in plantar flexion at T0 did not reach the maximum (15°) while at T1 yes (18.5°). The left foot reaches the maximum possible excursion on both movement planes.
The right *ankle ROM in sitting position (without load)* improved in all directions. There is a clear increase in ROM in pronation: at T1 the patient manages to reach the end of maximum excursion of the platform, while at T0 she failed. Numerical results are reported in graph 6.



Graph 6: Right ankle ROM in the different directions (Plantar-dorsiflexion and pronation - supination) results at T0 (light blue, dashed line) and T1 (dark blue, continuous line).

Correlating the data belonging to the right foot with the left foot, we observe that at T1 the values are very close to symmetry.

THRUST DIRECTION	EVALUATOR	T0	T1	IMPROVEMENT %
Plantar flexion - R	Mean Torque [Nm]	36.67	43.00	17.27
	Max Torque [Nm]	38.03	46.75	22.95
Dorsi flexion - R	Mean Torque [Nm]	19.33	18.00	-6.90
	Max Torque [Nm]	20.80	20.01	-3.80

Table 7: Isometric test results. Abbreviations. R=right foot.

In the *isometric test* we observe improvements in the plantar flexion pushing test with the right foot, bringing at T1 the relationship between right foot strength and left foot one very close to symmetry (left foot mean torque at T0: 47 Nm).
All the mean and maximum torque values from all the isometric tests performed with the right foot are reported in Table 7. Dorsiflexion strength has remained impaired with an asymmetry compared to the left foot (left foot mean torque at T0: 38 Nm).

Conclusions

Following this patient's rehabilitation course, we became passionate about the case. Severe brain injuries are very delicate conditions with different disabilities; every treatment day we asked ourselves how we could be more effective in our rehabilitation intervention. Coming to know this new technology, we decided to integrate our traditional treatment with a robotic training with hunova. Hunova allows precise and objective evaluations, offering progressive training of increasing difficulty that make treatment more stimulating.

At the first clinical evaluation (T0) we noticed two macroareas of intervention which became our treatment goals:

1. Ankle range of motion and strength of the distal district of the lower limb
2. Equilibrium in bipodalic and monopodalic stance in static and dynamic conditions.

The focused training on hunova has been personalized in difficulty, thinking of dividing the 9 sessions into 3 blocks, each one divided into easy/medium/hard difficulty.
For the balance training it was possible to follow the progression of the difficulties, for ROM and strength training we remained on easy / medium difficulty.
The improvements obtained in the two areas of intervention are documented both by evaluations with hunova and by traditional clinical ones. Furthermore, a significant improvement in performance emerged from the walking evaluations (TUG and 10MWT).
The patient expressed her satisfaction with the use of hunova, also highlighting benefits in the activities of daily life and sports, managing to perform some CrossFit exercises that he could not do before.
In conclusion we can affirm that the integration of hunova in the rehabilitation of the patient affected by severe acquired brain injury was positive and effective. This case study represents an excellent starting point for a broader and more in-depth study on the integration of robotic rehabilitation in treatment following severe acquired brain injury.

About us

Thanks to hunova we had the wonderful opportunity to undertake a rehabilitation program on a very young girl who has suffered a serious cerebral injury acquired. It was a very instructive experience and we can say that the integration of hunova in the rehabilitation of patients with GCA has been positive and effective. We hope that this represents an excellent starting point for integrating robotic rehabilitation in the treatment of GCA.

Marta Burlando is a physiotherapist who graduated in 2016 from University of Genoa. Having worked in a variety of settings: hospital-based physiotherapy, outpatient orthopedic clinics, medicine, and oncology, she brings a multifaceted perspective to treatment. She also has a history of working with people with complex musculoskeletal conditions and people post fracture and post-surgery. Marta has also participated to a Master in robotic rehabilitation technologies at University of Genoa.

Benedetta Bollo is a physiotherapist who graduated in 2013 from University of Genoa. She also got a master's degree in rehabilitation sciences in 2015 and a master in lymphology in 2016. She has worked in various rehabilitation contexts: hospital physiotherapy, outpatient and clinical activities, and at the patient's home. She brings a multi-faceted perspective to treatment thanks to specific training in manual orthopedic therapy, manual lymphatic drainage, neurological rehabilitation, oncological rehabilitation and postural reeducation. She also has a history of working with people with complex musculoskeletal conditions, athletes, people with spinal dysmorphism, people post fracture and post-surgery with varied functional and motor disabilities. Benedetta has also participated to a Master in robotic rehabilitation technologies at University of Genoa.