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PolytraumaPatientsTelerehabilitation afterInjuries of the Elbow Joint

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The aim. The main theme of this paper is to discuss implementation of the telemedicine technology for rehabilitation of patients with injuries of the upper extremities.
Materials and methods. Consecutive polytrauma patients were recruited after recovery over a five-year period - September 2018 to February 2020 - from the waiting lists of the department of orthopedic surgery, at Ternopil Emergency Hospital that serves as a trauma center. A total of 38 polytrauma patients with upper extremity injuries were enrolled in the study after the resolution of the surgical sequelae and monitored during a 3-weeks period.Home remote monitoring for the 16 test subjects included use of a Portable device (Fig 1.) with Axis-sensor, temperature, volume and pulse sensors, that were fixed to the injured limb. Software permits the monitoring of exercise time, local temperature, the biomechanics of active movements of the injured limb.
Results. The orthopedic surgeon during telerehabilitation took significantly less time to consult patients (1.9 minutes) than the traditional rehabilitation (15.2 minutes). Patient satisfaction was higher for the telerehabilitation (78.3%) than for the orthopedic surgeon's traditional rehabilitation (36.7%).
Conclusions. Subjects reported a higher satisfaction with telerehabilitation than with the traditional orthopedic rehabilitation due to the fact that they spent less time at the hospital and had more time for exercises at home under orthopedic remote monitoring. The telerehabilitation system could be used in complex rehabilitation of patients with injuries of the upper extremities.
Key words:telemedicine, rehabilitation, polytrauma.

I. INTRODUCTION.

Today telemedicine is used for application of transferring medical information to perform consultations, medical examinations and rehabilitation procedures. The main objectives of telemedicine are bridging the gap of accessibility and communication in the medical field reducing the cost logistics [2]. The use of a device such that a person may wear, may allow for constant monitoring of a patient and for the ability to notice changes that may be less distinguishable by humans. Principles of care of the patient with polytrauma have continued to evolve with new telemedicine technology.Wireless technology applied to sensors and application to case studies related to home monitoring and have been developing during the past decade, including studies on the cost-effectiveness [3]. Polytrauma patients have numerous risk factors. Early assessment of the clinical status of patients with polytrauma is of pivotal importance in future rehabilitation [4].
The use of a device such that a person may wear, may allow for constant monitoring of a patient and for the ability to notice changes that may be less distinguishable by humans [5].

Timely access to orthopedic rehabilitation is an important problem for the world health care system. Presently, wait times to see a rehabilitologist can exceed four weeks and with the rapidly aging population as well as the increased incidence of injury of extremities, the need for orthopedic care is expected to strongly increase in the coming years.

Therefore, the maintopic of this research is to acknowledge the best tactic in implementation of the telemedicine technology for rehabilitation of the patients with injuries of the elbow joints after polytrauma. The main prerequisite for success in the treatment of orthopedic patients is to identify indications and contraindications for distance rehabilitation [7]. The upper extremity functional index (UEFI)is widely used to evaluate the functional disabilities of a patient with anupper extremity disorder, especially after polytrauma. The UEFI score ranges from 0 to 80 with a higher

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score indicating a higher functional status. The use of the UEFIin research studies has been validated and the UEFIis a reliable tool for assessing upper extremity functional status [8].

An application of the telemedicine for monitoring and gathering data on a patient's progress without the use of video communication or consultation is the study of rehabilitation system with the wireless prototype [9-11]. Joints rehabilitation system is connected through the internet to server and recorded effects of telerehabilitation therapy and efficacy of rehabilitation strategy. This is an example of the importance of wireless sensors with its capacity to easily transmit data to server which is vital in continuous monitoring. Through the current developments in patient telemonitoring, there is a support for application of telemedicine not only in hospitals but also at homes in a long distance [12]. Global insight into the diversity of telemedicine standards should be resolved with a comprehensive plan that considers regulations that are enforced by different countries.

The aim. The main theme of this paper is to discuss implementation of the telemedicine technology for rehabilitation of patients with injuries of the upper extremities.

Materials and methods. Consecutive polytrauma patients were recruitedafter recovery over a five-year period - September 2018to February2020- from the waiting lists of the department of orthopedic surgery, at Ternopil Emergency Hospital that serves as a trauma center. A total of 38polytrauma patients with upper extremity injuries were enrolled in the study after the resolution of the surgical sequelae and monitored during a 3-weeks period.

All enrolled subjects signed a consent form prior to participating in the study. The Research Ethics Board of the I. Horbachevskyy Ternopil National University, Ukraine approved the research study.

22 patients from the control group underwent traditional rehabilitation procedures for a 3-weeks period after injury.This usual care group included the generally accepted methods of rehabilitation therapy (i.e. massage, myostimulation, and exercises in the pool).

A total of 16subjects were enrolled in the telerehabilitation group for a 3-week study periodafter injuryandwere trained with a set of exerciseswith prototypefor home use.

Home remote monitoring for the 16test subjects included use of a Portabledevice (Fig 1.) with Axis-sensor, temperature, volume and pulse sensors, that were fixed to the injured limb. Softwarepermits the monitoring of biomechanical movement, local temperature, the frequency of active movements and volume of the injured limb. During the execution of home exercises, data from the subjects Portable device were measured and sent to a server through a cellular Internet connection and to the personal smartphone of the rehabilitationdoctor and displayed as digital data and graphically.

Fig 1. Portable device with sensors.

The Tele-rehabilitation protocol included:

- Fixation of the Portable device to the injured limb and use of customized software.
- Home exercises: Passive flexion-extension in the elbow joint.
- Home exercises: Active flexion-extension in the elbow joint.

All patients were also trainedfor subjective assessment of pain on a 10-point scale. The initial implementation of this telerehabilitation model did not include prescription of medications or joint injections.

The software contained a personal rehabilitation record for health information and communication between the patient and health professionals. Basic measures for patients

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includedblood pressure, volume of limb, waist, chest, pulse, weight, height, sex, saturation, local temperature, movement activity and condition of connective tissue.

Subjects completed a questionnaire where they provided anthropometric data as well as information on their education, employment, household income, household living status, and information on clinical variables such as the joints effected, the reason for consulting, the duration of their symptoms, the use of a walking aid and the presence of any co-morbidities. All subjects from both groups also completed the upper extremity functional index (UEFI)questionnaire. The majority of patients (75%) cited pain as the reason for consult with the orthopedic surgeon and all of the patients (100%) consulted for an elbow joint disorder (after injuries of the upper extremities). All patients had imaging tests available in their file at the time of consult (X-Ray and MRI).

Based on the patient's individual condition, the rehabilitation doctor created an individualized rehabilitation plan for each subject, containing an activity plan. All patients had personal goals for daily movement activity and steps in the rehabilitation program.

All subjects from telerehabilitation group were assigned a rehabilitation doctor who worked distantly. The control group received traditional rehabilitation at home without a personal doctor.

II. RESULTS

In thetelerehabilitation arm of the study, 16subjectswith injuries of the upper extremities were symptomatic for at least 3 weeks.

Subjects from telerehabilitation group had a mean age of 48.4years and the majority were men (67.3%). The mean Upper Extremity Functional Indexof patients was 52.31. Table 1 presents selected characteristics of the participants of the telerehabilitation group.

Table 1

Characteristics of the study participants of the telerehabilitation group (n=16)

Characteristics	**n (%)**	**Mean (SD)**
Age (years)		48.4(5.4)
Gender		
Male	9(56.3 %)	
Female	7(43.7 %)	
Body mass index (kg/m^2)		29.2(4.1)
Employment		
Employed	11(68.75%)	
Unemployed	5(31.25%)	
Retired	-	
Duration of symptoms (days)		12(3)
Upper Extremity Functional Index(%)		52.31

In the control group of the study, 22subjects with injuries of the upper extremities were symptomatic for at least 3 weeks and continued rehabilitation at home without an assigned doctor. Subjects had a mean age of 48.9years and the majority were men (61.6%). The mean Upper Extremity Functional Index score of patients was 48.28.

During the telemonitoring of the telerehabilitation group, the physician controls the adequacy of execution of each stage of rehabilitation exercises and has the ability to adjust the load in real time depending on the functional state of the limb (Fig 2, Fig. 3.).

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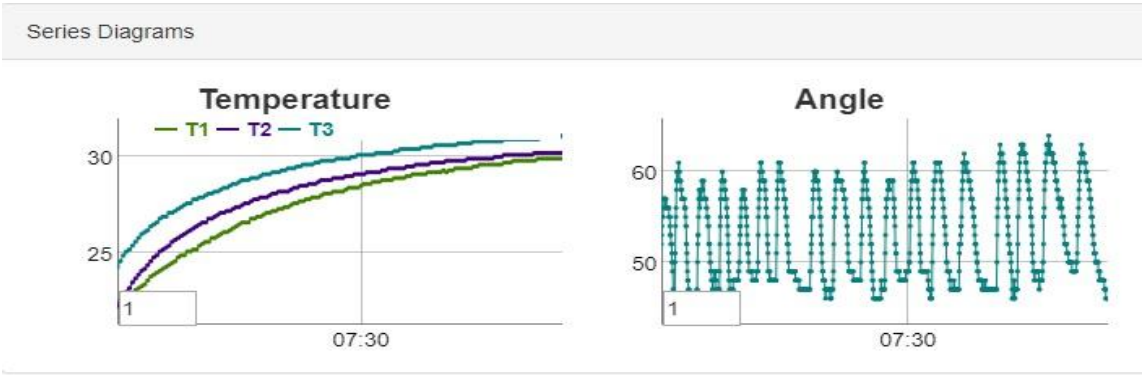

Fig 2. First day of telerehabilitation.

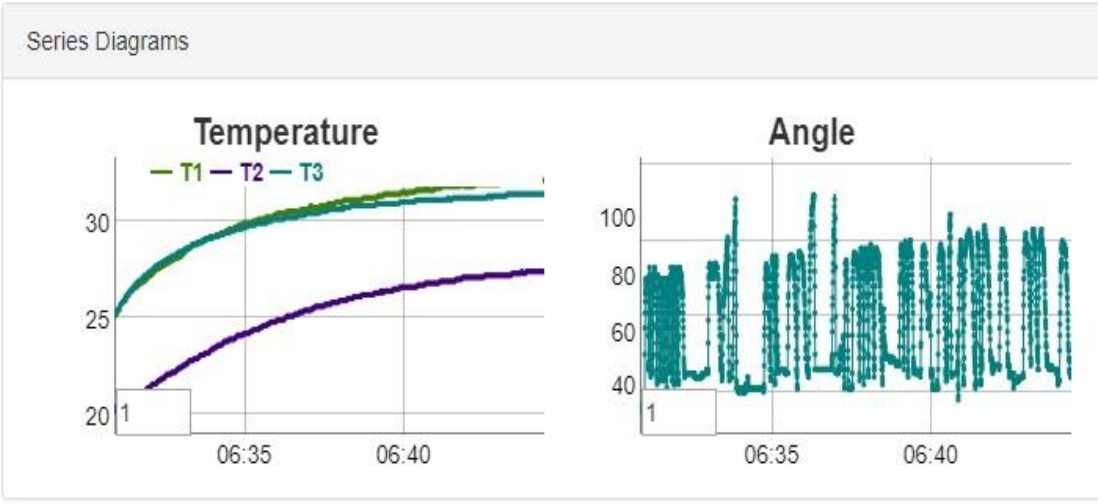

Fig 3.14th day of telerehabilitation.

Subjects were also asked if their pain level increased after the first exercise and in the event that it did, they were asked to indicate by how much it increased by picking one of the following three options on the smartphone: 1-4 pain was a bit stronger; 5-7- pain was moderately stronger; 8-10 pain was much stronger. Software allows increasing the daily load,if the assessment of pain after exercise was not more than 7 points on 10-point scale and progressive limb edema was absent. If pain persisted or questions persisted,there was correction of therehabilitation algorithm by doctor.

The rehabilitilogist during telerehabilitation took significantly less time to consult patients (1.9minutes, SD:0.5) than the traditional rehabilitation (15.2minutes, SD:2.7). Patient satisfaction was higher for the telerehabilitation(78.3%, SD:12.6) than for the orthopedic traditional rehabilitation (36.7%, SD:7.3) (Table 2).

Table 2
Comparison between visit time length and patient satisfaction for telerehabilitation(n=16) and traditional rehabilitation (n=22)

	Mean value fortelerehabilitation	**(SD)**	**Mean value fortraditional rehabilitation**	**(SD)**
Visit time length, in minutes	1.9	0.5	15.2	2.7
Patient satisfaction, %	78.3	12.6	36.7	7.3

III. DISCUSSION.

Subjects reported a higher satisfaction with telerehabilitation than with the traditional rehabilitation due to the fact that they spent less time at the hospital and had more time for exercises at home under orthopedicremote monitoring.It is

assumed that less clinical time per subject using telerehabilitation translates into reduced costs of rehabilitation during the studyperiod.

The telerehabilitation system can be used in complex rehabilitation of patients with injuries of the upper extremities. This will improve the quality of life in this group of patients and significantly reduce the cost of the rehabilitation period. These results provide preliminary evidence supporting the telerehabilitation model for orthopedic care. We conclude that telerehabilitationshould be considereda key component in the long-term management of patients who have upper extremities injuries.

We are at the age of development of telemedicine, a technology that can exceed the capabilities of and can greatly enhance manual procedures and even existing technology. The simplicity of being able to apply this technology allowed it to be of great use in telerehabilitation and this paper shows importance of its implementation to the field of medicine.

IV. CONCLUSIONS.

An application of telemedicine is versatile process and it has endless possibilities of development, an application can mean accommodating more patients or discovering the best practice for a telerehabilitation, which will improve quality of patient's life. The implementation of these researches will be the most important contribution, which is why it is also important to begin researching on how this technology can be made more cost effective so it can be used in rural areas and underdeveloped hospital facilities.

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Research Topic:«Development of specialized medical equipment and treatment and rehabilitation techniques for providing telemedicine (remote) care to patients with injuries and diseases of the musculoskeletal system»