UML Modeling in Stroke Rehabilitation Processes
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I. INTRODUCTION

Stroke continues to be a major public health concern, with more than 750,000 new strokes occurring each year in the United States. In Italy about 180,000 strokes per year occur among which the 80% are first strokes and the 20% are recurrent ones (Francescutti et al., 2005). Stroke is the leading neurological cause of acquired adult disability and the third common cause of death in industrialized countries (Greenberg et al., 2004).

In current health care systems scientific knowledge on the best treatment to use is based mainly on scientific literature and it is not systematically applied in clinical practice (Panzarasa et al., 2002). Many years are required to generate new knowledge because the demonstration of the effectiveness of a new treatment in a post-stroke rehabilitation is very complex. It requires the employment of randomized controlled trials (RCT) that are scientific experiments used in testing the efficacy or effectiveness of healthcare services such as innovative rehabilitation treatments. RCTs involve the random allocation of different interventions to subjects in order to minimize any bias and to make the results more reliable. In stroke rehabilitation process, both the high variability of the etiology of the pathology and the extreme variability of the practice in the different clinical domains make the generation of new knowledge very hard. Therefore, to improve and standardize the scientific knowledge, the re-organization of the management of the rehabilitation process is required.

Unified Modeling Language (UML) is a visual modeling and specification language capable of providing multidimensional insight to a system using behavioral, conceptual, and physical abstractions (Kumarapeli et al., 2007). This language has become a gold standard in modeling complex processes.

The aim of this study was to design and implement a model for the stroke rehabilitation process in order to assess the potential of using UML to streamline the real medical practice and improve the performance of care delivery systems. In particular, we tried to model the rehabilitation process describing the organization of all the services provided by an interdisciplinary team at the Villa Beretta Rehabilitation centre (Costa Masnaga, LC, Italy) and to allocate clearly the roles of all the involved people. The model implemented could also facilitate the recruitment of patients in the RCTs active in the rehabilitation centre. In this way it will be simpler to test innovative rehabilitation treatments, thus improving the evidence-based knowledge on post stroke rehabilitation (Speedie et al., 2008).

II. METHODS

A. Defining the context of the rehabilitation process

The complete effective care of stroke includes an initial management of the stroke, the early management of the acute stroke in the Emergency Department, the planning of rehabilitation in a post-acute phase in a specialized rehabilitation centre and finally the rehabilitation at home and the follow up (Panzarasa et al., 2002).

In this study we focused our attention only on the rehabilitation of individuals with stroke in a post-acute phase (1-6 months after the event) that are inpatients in a rehabilitation centre.

B. UML general description

The UML is used to specify, visualize, modify, construct and document the artifacts of an object-oriented software-intensive system under development (Fowler M, 2003). UML, as an object-oriented software, identifies the components of the process as objects characterized by properties and operations describing their interaction with the system. The resulting model can be intuitively interpreted by users with less familiarity about the system or less technical knowledge.
C. UML diagrams

UML diagrams can focus either on the physical organization of a system, i.e., the structure of the components and how they are statically related together (*structural diagrams*), or on the behavioral aspect of the system, i.e., how the components dynamically communicate and how the system evolves (*behavioral diagrams*).

In this study we focus on use case diagrams and activity diagrams. Use case diagrams describe the relationship between actors, i.e., people or external systems that plays a role in one or more interactions with the system, and a sequence of actions defined as use cases. An association exists whenever an actor is involved with an interaction described by a use case. Activity diagrams model the internal logic of a complex operations. In many ways UML activity diagrams are the object-oriented equivalent of flow charts and data flow diagrams from structured development.

The software tool used to design diagrams was StarUML™.

D. Defining a standard terminology

To make the model exportable in different rehabilitation centres and to make it a gold standard in the post-stroke rehabilitation, the definition of the common used terminology is crucial (Quitadamo et al., 2008).

A set of definitions is necessary for the purpose of having a deep and clear understanding of the model implemented in UML.

*Treatment*: It is the single rehabilitation intervention. It could be a physical treatment to improve motor control or a speech treatment to improve language.

*Session*: It comprises all the treatments that are performed daily on the patient. Normally an inpatient can perform 3-4 hours a day of rehabilitation which includes in average from 3 to 6 different treatments.

*Rehabilitation Cycle*: it is the complete rehabilitation prescribed by the doctor and it covers, in average, one month. It is divided in daily sessions.

*Assessment Tests*: All the tests performed by the doctor and the therapist in order to evaluate the patient condition.

III. RESULTS

A. Model of the post-stroke rehabilitation process

The rehabilitation of post-acute stroke patients involves the services of an multidisciplinary team (Fig. 1). The skills required depend on the nature of the patient’s deficits. The medical specialties commonly involved include physical medicine and rehabilitation (physician in Fig. 1) and neurology. Depending on the patient condition some external consultants, such as doctors specialized in internal medicine, psychiatry, cardiology, could be required. Therapists include both physiotherapist and speech therapist to help in the motor and language recovery, respectively.

To model the rehabilitation process of sub-acute inpatients of a rehabilitation centre, we identified the following four phases:

- Patient reception and first visit at the ward (phase 1)
- Visit to identify the rehabilitation (phase 2)
- Rehabilitation and assessment of recovery (phase 3)
- Patient Discharge and follow-up assessments (phase 4)

In this visit the doctor must prescribe the required diagnostic exams and the pharmacological therapy needed by the patient.

The doctor, after a careful evaluation of the diagnostic exams and the updated medical record has to decide the best rehabilitation cycle for the patient. In this phase the doctor has to check for eventual RCT or other experimental studies active in the rehabilitation centre in order to understand if the patient can be recruited.

This is the central phase in which the rehabilitation is carried out in the rehabilitation centre and the recovery of the patient is monitored and evaluated by both the doctor and the therapist.

This is the end of the rehabilitation process for post-acute inpatients which consists in monitoring the follow up after discharge.

In each phase we identified the actors and the activities they have to perform.

B. UML diagrams

Fig. 2 reports a use case model of the first visit at the ward.
In this phase the doctor, after a precise examination of the medical history of the patient, can prescribe diagnostic exams to better investigate the patient condition and to prescribe the pharmacological therapy.

The use case of the third phase of the process is shown in Fig. 3. It comprises two main activities: the rehabilitation cycle and the evaluation of recovery. The rehabilitation cycle is performed by the therapist and the patient and comprises all the daily sessions in which the patients perform the different prescribed treatments. The evaluation of recovery instead involves the patient, the doctor and the therapist and comprises all the chosen tests required to assess the current state of the patient.

Fig. 3. Use case diagram for phase 3: rehabilitation and assessment of recovery

Fig. 4 shows an activity diagram of the rehabilitation process starting from the visit to prescribe the rehabilitation till the patient discharge. Each swimlane (vertical column) represents an actor of the rehabilitation process. The activities (rounded blocks) are reported in the swimlane of the actors involved in it. When the actions are common to two actors the activity is placed over both the swimlanes (see for instance Visit Pre Rehabilitation in Fig. 4). The last swimlane comprise all the inputs and outputs of the diagram, such as the medical record continuously updated or examined by the doctor and the therapists, the document with the rehabilitation prescription and the discharge letter. An important step in the diagram is that before prescribing the rehabilitation the doctor has to check for the RCT active in the rehabilitation centre in order to understand if the patient can be recruited. This activity could be crucial to increase the knowledge about innovative treatments. Once the rehabilitation is prescribed the therapists, both the physiotherapist and the speech therapist can start the rehabilitation cycle. Every day they examine the medical record and if the patient is available they prepare the treatment with all the precautions required for the specific patient. The daily session finished only when all the prescribed treatments are performed. In some days some assessment tests to monitor the patient condition can be necessary. A very common assessment for the physiotherapist is the 6-minute walking test (Fulk et al., 2010) and for the speech therapist is the token test (Smania et al., 2010). The doctor every week visit the patient. In this occasion all the medical assessment tests are performed: clinical scales, instrumental tests and the doctor prescribes diagnostic exams if needed. At the end of the visit the doctor can decide to go on with the same rehabilitation cycle or to change it. All these activities are repeated till the patient discharge.

Fig. 4. Activity diagram of the rehabilitation program

IV. DISCUSSION

Up to our knowledge a UML model of the rehabilitation process does not exist. A preliminary model of the rehabilitation process of post-acute stroke patients was implemented starting from the experience of the Villa Beretta Rehabilitation Centre in Italy. Given the purpose of our study, many technical details were omitted and the emphasis was placed on the representation issues of the
fundamental entities involved in the rehabilitation process.

The terminology presented in this study comprised only some definitions required to clarify the understanding of the model presented. In this context a precise terminology definition has to be provided starting from some guidelines already known in literature (Ottawa Panel, 2006).

The model of the rehabilitation process implemented in this study intends to be an effective infrastructure for increasing and managing clinical knowledge to foster its application to health care delivery. UML models can be very useful to provide evidence-based guidelines on stroke rehabilitation. In particular, the model can facilitate the management of a rehabilitation treatment plan and the monitoring of the progress during rehabilitation; it permits to identify which patients are most likely to benefit from a specific rehabilitation treatment creating a structured archive. Indeed, for instance, it will be more simple to look for the most used treatment when a patient is in a specific condition because it will be possible to find similar cases already treated. Finally, the model can simplify the recruitment of patients in experimental studies such as RCT which are crucial for the improvement of evidence-based knowledge in the field.

ACKNOWLEDGMENT

We would like to thank the doctors and therapists of the Villa Beretta Rehabilitation Centre for their help.

REFERENCES