Telecommunications technology in cognitive rehabilitation

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Summary

Cognitive disorders are a common long-term consequence of many forms of acquired neurological damage of different aetiology. The already high prevalence of diseases causing cognitive deficits (in particular stroke) is expected to increase in the near future, leading to a greater need for cognitive rehabilitation. The impact of cognitive impairment on daily functioning may be even greater than that of physical limitations in affected patients, contributing to the high cost of brain disorders.

New technologies, including telerehabilitation, may provide an effective response to this challenge, allowing increased access to rehabilitation services as well as reduced care costs for individuals needing cognitive rehabilitation.

KEY WORDS: cognitive rehabilitation, stroke, telerehabilitation, traumatic brain injury.

Introduction: the cost of cognitive impairment

Brain disorders account for more than a third of the total cost of all diseases in Europe (1). In addition to the direct healthcare costs relating to the goods and services used in prevention, diagnosis, treatment and rehabilitation, it is also necessary to take into account direct non-medical costs, which include all disease-related use of other resources (e.g., transportation, social services), and indirect costs, mainly due to lost workdays and early retirement. In Europe, indirect costs account for nearly half (46\%) of the total cost of brain disorders (Fig. 1) (2).

Among the acquired brain disorders, stroke and traumatic brain injury (TBI) are the leading causes of adult disability. Consequently, they generate a substantial proportion of the direct and indirect costs of these disorders (3). As the incidence and, therefore, the prevalence of stroke are expected to increase, and no considerable decrease in the prevalence of TBI is foreseeable in the near future, the related costs will probably also rise, unless more effective means are developed to meet care needs.

Currently, there are 1.1 million new strokes each year in Europe (4), and about 150,000 new cases of stroke can be expected each year in the Italian elderly population alone (5) (Table I). Considering the close relationship between stroke incidence and age and the rapid growth of the elderly population, if incidence rates remain stable at their current levels, the number of new stroke cases recorded each year in Europe will be 1.5 million in 2025 (4), while Italy can expect to be recording 193,000 new stroke cases per year in 2020 (5). Consequently, the prevalence figures for this disease are high. It is estimated that there are about 6 million stroke survivors in Europe, 900,000 of whom are in Italy (6).

The general picture deriving from epidemiological data on TBI is also dramatic. According to a recent review by Berg and co-workers (7), the overall average incidence rate of hospitalisation for TBI in European countries is about 235/100,000/year; in Italy, this rate ranges from 250 to 314/100,000/year. The primary causes of TBI are road accidents and falls. Therefore, two peaks of incidence are usually reported: in the second and third...
decades of life (due to road accidents) and after the age of 70 years (due to falls). To our knowledge, no large-scale reports on TBI prevalence in European countries have been published. Estimates based on incidence data report that about 700,000 subjects living in Europe have sustained a TBI (around 90,000 in Italy) (1). Although the incidence of TBI in the younger age group might decrease in the future, as a result of preventive measures such as speed limits and the use of helmets, prevalence figures are likely to remain stable due to the continuous improvements in neurosurgical and intensive care (8).

According to a recent study on the cost of brain disorders in Europe, both stroke and TBI feature among the most prevalent and the most expensive brain disorders, having an annual cost of €22 billion and €3 billion, respectively (1). However, these estimates are probably very conservative due to the general lack of studies tracking the long-term outcomes of these pathologies. Since stroke and TBI often result in permanent limitations in activities of daily living due to physical and/or cognitive impairment, a good estimate should also include lifetime economic costs. Currently, however, most estimates are based primarily on acute hospitalisation costs, which, especially for TBI, probably represent only a small proportion of the direct and total costs (8).

The need for cognitive rehabilitation

The role played by cognitive rehabilitation in the picture presented above is twofold. On the one hand, if we consider the huge need for cognitive rehabilitation services in patients who survive brain injuries, particularly stroke and TBI, it emerges as a grossly underestimiated source of healthcare costs; on the other hand, however, it is an effective means of reducing long-term functional impairments and related (mainly indirect) costs in brain-damaged people. In the next paragraphs, we analyse the need for cognitive rehabilitation, and in the next section look at its effectiveness in the management of acquired neurological focal damage.

First, let us consider the case of stroke. After the acute event, severe limitations in daily functioning due to physical and cognitive impairments persist in about 35% of survivors (6). In particular, aphasia is present in 40% of stroke patients at hospital admission, and 15%-20% of patients are still aphasic six months later (6). Memory and attention disorders are long-term stroke sequelae and they hamper recovery in about 25% of stroke patients (6). Finally, if we are considering the most common post-stroke cognitive impairments, spatial neglect must also be mentioned. This impairment is present in 25% of stroke patients at hospital admission, and 12% of patients still show it three months later.

Patients who survive a severe TBI (Glasgow Coma Scale, GCS, scores 3-8 (9)) or moderate TBI (GCS scores 9-12) have a period during which they are confused and unable to retain new memories. After resolution of this so-called post-traumatic amnesia, these patients usually still have some degree of physical and cognitive impairment (10). Indeed, disorders of memory, attention and executive functions are the most common cognitive sequelae of TBI (11). Virtually all survivors of severe TBI continue to show cognitive impairments at one year post injury (12) and, although a "good recovery" (as defined by the Glasgow Outcome Scale (13)) is the most common long-term outcome, even in the severe TBI population (10), it should be noted that people in this recovery class may still have some physical and cognitive impairments. Thus, only some of the subjects who make a "good recovery" are able to return to all the social roles they fulfilled prior to injury. It is worth noting that, according to Brooks and co-workers (14), only about a third of severe TBI survivors are able to return to competitive employment.

The question of the effectiveness of cognitive rehabilitation

It is well known that disability in brain-damaged patients is due not only to physical but also to cognitive impairments. This is certainly the case in TBI and stroke survivors (3,15-17). There is also little doubt that the two most prominent undesired effects of disability are i) the reduced quality of life of affected subjects (18), and ii) the huge (mainly indirect) illness costs borne by the community (2).

Cognitive rehabilitation is aimed at counteracting both of these undesired effects, improving quality of life and reducing disability; however it is also a very expensive service. Thus, the question of the effectiveness of cognitive rehabilitation is very critical one and will become even more so if, as expected, the prevalence of patients needing cognitive rehabilitation increases in the near future.

Unfortunately, however, there is little agreement as regards the effectiveness of cognitive rehabilitation. The case of language therapy is a case in point; while a recent study made available by the Cochrane collaboration (19) found that it was not possible to draw any evidence-based conclusion supporting the view that language therapy is either effective or ineffective, the view of Cicerone and co-workers, in the light of a different evidence-based review, was the opposite (16). Indeed, according to these authors, "good evidence exists to support the effectiveness of cognitive-linguistic therapies, beyond the period of spontaneous recovery, for the treatment of subjects with language deficits from left hemisphere stroke."

There are three main reasons for the inconsistent results of studies aimed at evaluating the effectiveness of cognitive rehabilitation (15,16): i) the heterogeneity of the patients studied, ii) the heterogeneity of the rehabilitation approaches evaluated, and iii) the heterogeneity of the outcome measures considered. The first two points need only a brief discussion. As regards the patient heterogeneity, it is fairly obvious that the pattern of spared and impaired cognitive processes may vary greatly from patient to patient. Since the number of different patterns of cognitive impairment is virtually infinite, the question of how an "average" cognitively impaired patient might respond to a rehabilitation treatment is obviously very hard to answer. As for the second point, it should be noted that rehabilitation interventions are based on an underlying theoretical model of the unimpaired cognitive process. Just as not all theoretical models are equally able to explain the impaired function, likewise not all rehabilitation approaches can be expect-
ed to show the same degree of effectiveness. Thus, the “average” rehabilitation intervention, too, is a very problematic concept.

In our opinion, the third point deserves particular attention. As we discussed above, cognitive impairment causes disability, which, in turn, creates illness costs and a decrease in the quality of life of those affected. In this context, disability and impairment need to be considered separately. According to the World Health Organisation (18), the term *impairment* refers to the loss or the disorder of a (cognitive) function, while *disability* refers to the limitations in carrying out activities of daily living due to the presence of a (cognitive) impairment. With this distinction in mind, it is easy to see that the aims of cognitive rehabilitation may be very different, depending on whether impairment or disability is the target of the intervention. Thus, coming back to the question of the effectiveness of cognitive rehabilitations, an additional source of confusion is the possibility of evaluating the outcome in terms of either restored function or diminished disability. These two measures are not always interchangeable. For example, only disability outcome measures are suitable for evaluating the effectiveness of Shoiberg and Mateer’s approach to the treatment of severe memory deficits, which consists of teaching amnesic patients to use, independently, a compensatory memory book (20). In this case, in fact, the intervention is not geared at restoring the memory function, only at reducing its disabling consequences.

What about quality of life? We agree with Weisscher and co-workers (21) that this concept “has a strong focus on patient’s social functioning, perceived health status and well being” which, in turn, strictly depend upon the patient’s degree of disability. It seems, to us, important that any assessment of the effectiveness of a cognitive rehabilitation also take into account its outcomes in terms of the impact on the patient’s quality of life. But, obviously, this would create an additional source of heterogeneity in the literature aimed at evaluating the effectiveness of cognitive rehabilitation.

**Social and economic challenges facing cognitive rehabilitation services**

As shown above, there are so many factors to be taken into account when addressing the question of the effectiveness of cognitive rehabilitation that it is to be wondered whether a definite and clear-cut answer to this question can be provided within the near future. It should be noted, however, that even a negative answer, such as “cognitive rehabilitation is ineffective”, will not exempt us from the necessary task of developing and administering other, more effective interventions to cognitively impaired people in the future. In other words, the need for rehabilitation services will not decrease even if there is an evidence-based demonstration of the ineffectiveness of current approaches. Hence, whatever may be the answer to the question of how suitable current methodologies are for rehabilitating cognitively impaired subjects, we do not believe that it will condition the main social and economic challenges that rehabilitation services will be faced with in the near future. In our opinion, these challenges can be summarised as follows: on the economic side, the epidemiological trends of several brain diseases indicate that rehabilitation services are likely to have to cope, in the near future, with the needs of an increasing number of patients. As a result, these services will have to be able, simultaneously, to consume less and to impact on the high indirect costs generated by cognitive impairment. On the other hand, rehabilitation services will be faced with the social challenge of improving the quality of life of a growing number of patients. These latter two targets, i.e. reducing indirect costs and improving the quality of life of brain-damaged people, can be achieved if cognitive rehabilitation is able to have a strong impact on disability, since disability is recognised as the major source of indirect costs and decreased quality of life.

In summary, to be able to rise to the social and economic challenges of the near future, a rehabilitation service must be able to provide therapy that is both inexpensive and effective in reducing patients’ disabilities. In the next section, we consider how advances in technology have provided us with new tools, particularly telerehabilitation systems, for tackling these challenges.

**Telerehabilitation**

Recent advances in telecommunications technology, particularly the development of videoconferencing, now make it possible, by linking therapists with patients, to administer physical as well as cognitive rehabilitation services at a distance (22). Telerehabilitation in the cognitive domain is usually based on a two-way videoconferencing system using a fast network connection, which makes real-time audio and video available to both the patient and the therapist for live interaction. Furthermore, exercise protocols can be downloaded and, as the patient performs the exercises, the therapist can provide remote feedback on his/her performance.

Today, telerehabilitation is an expanding area in cognitive rehabilitation. Indeed, in recent years a considerable amount of research has focused on the development of low-cost, accessible, home-based telerehabilitation systems. In the following sections we discuss how telerehabilitation can impact on the emerging needs of rehabilitation services.

**The clinical effectiveness of telerehabilitation: a poorly-framed question**

Although the first attempts to provide medical services at a distance date back to 1976 (23), telerehabilitation, i.e. the above-described videoconferencing system for providing (cognitive) rehabilitation remotely, is still in its infancy. In fact, the term telerehabilitation did not appear in the literature until 1996 (24), given that the first period in the history of *telemedicine* was dominated by the attempt to provide diagnostic and follow-up services remotely, rather than rehabilitation services (25). In a recent review of the literature, Hill and Theodoros (25) found only two empirical investigations dealing with telehealth applications in speech-language pathology (26, 27). There is a similar lack of data relating to application of telerehabilitation to other cognitive disorders, e.g., memory impairments or other impairments typically found in TBI, although some studies have been conduct-
ed (27,28). As the present paper has shown, while there is a very rich empirical literature on traditional face-to-face approaches, the presence of many confounding factors means that it is still not clear whether or not conventional rehabilitation is truly effective. In view of this difficulty, and also of the current lack of empirical data on telerehabilitation, we feel that this latter area may well be almost impossible to address seriously.

The scarcity of available empirical data is not, however, the only reason why one might refrain from addressing the question of the effectiveness of telerehabilitation. We also believe that although this is a recurrent question, it is, in fact, poorly framed. Telerehabilitation is not a new therapy in need of empirical validation, it is simply a new channel for administering “old” therapeutic interventions. Thus, instead of asking whether telerehabilitation is effective in counteracting cognitive impairments and related disabilities, we should be asking whether telerehabilitation is a suitable vehicle for applying our current knowledge and expertise in the management of cognitive impairments. In other words, we should be asking which aspects of the patient-therapist interaction taking place in the face-to-face setting are affected by the use of videoconferencing. The real challenge is not to develop a new and effective therapy but “only” to develop a new and effective channel for administering old therapies outside the usual face-to-face setting. As Brennan and co-workers correctly pointed out (24), to date, a realistic and sensible goal in the evaluation of telerehabilitation would be “to assess the influence of telerehabilitation on aspects of the communication process.” In this respect a critical issue for future research is to investigate empirically how to select good candidates for telerehabilitation. This is not a trivial issue, since, as these authors argue (24), “stroke-related symptoms such as poor vision, poor attention, severely impaired comprehension, or bilateral motor impairment may adversely affect a person’s ability to interact with telerehabilitation equipment.” Although not all patients in need of cognitive rehabilitation are good candidates for telerehabilitation and although further work is needed to investigate this issue thoroughly, a growing body of evidence demonstrates the feasibility of using videoconferencing for delivering cognitive (as well physical) rehabilitation to brain-damaged people (24,25,28-31).

Social and economic advantages of telerehabilitation

If telerehabilitation proves to be a useful channel for administering therapeutic interventions that, until now, have always been administered in a face-to-face setting, how can this new technological device help us overcome the major challenges that rehabilitation services will be faced with in the near future?

In this final section, we focus on two potential advantages to be derived from the use of telerehabilitation. First, we consider the potential advantages of this type of service from the perspective of the user; then, we review the potential advantages in terms of reduced care costs. The major social advantage we can expect from telerehabilitation is the opportunity it offers clients to have improved access to rehabilitation services. In fact, this kind of service can be provided to patients who would not otherwise have access to rehabilitation, due to mobility or transportation restrictions (32,33). This is an important point, since brain-damaged people often suffer from mobility restrictions; however, even people able to access conventional rehabilitation facilities would also benefit from a home-based rehabilitation service, which would allow them to reduce travelling time and associated costs. Finally, conventional rehabilitation services are lacking in some rural areas and telerehabilitation is the only way to provide services to people living in these places.

The second major attraction of telerehabilitation is its potential to impact on growing healthcare costs. Indeed, advocates of telerehabilitation usually highlight two major sources of its potential cost effectiveness (32). First, telerehabilitation can, potentially, impact on direct healthcare costs by reducing the length of hospital stays. This type of rehabilitation makes it possible to discharge patients as soon as it is clinically safe to do so, allowing them to continue their therapeutic interventions at home. The second way telerehabilitation can help to reduce healthcare costs is by increasing the efficiency and productivity of the therapist. The use of this type of service could allow “for less experienced professionals to conduct telerehabilitation under supervision of more highly educated professionals” (32). Furthermore, caregivers could also become involved in the rehabilitation intervention if they were taught how to administer additional exercises to the patient outside the treatment session. Although this second aspect is appealing it does raise a number of issues about the obvious need to ensure quality of services for all patients.

Concluding remarks

In the near future, the two major challenges facing cognitive rehabilitation services will be the need to treat an increasing number of patients and the need to keep healthcare costs under control. Telerehabilitation has the potential to rise to and overcome both these challenges. However, this new approach is still in its infancy and much empirical work must be done to resolve definitively the major issues of feasibility and cost effectiveness.

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