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Letter to the editor

Needs of individuals with tetraplegia and expectations regarding implanted neuroprosthesis

Dear editor,

The incidence of spinal cord injury (SCI) in western Europe and the United States is estimated at 16 and 40 cases per million, respectively [1], with the high proportion of cervical injuries increasing progressively [2]. SCI is devastating for individuals, and restoration of active wrist, forearm, and hand movements could significantly increase their independence and quality of life. For several decades, functional surgery based on tendon–muscle transfers, and more recently nerve transfers, has been used to improve the functional potential of people with tetraplegia. However, these 2 methods require sufficient muscles or nerves under voluntary control, and rehabilitation does not allow for systematic recovery of desired movements. Therefore, some people with tetraplegia are not able to undergo neuro-tendinous surgery.

The use of functional electrical stimulation (FES) can be an alternative method for restoring grip movements. The aim of FES is to create, via an electric current, a depolarization of axon or myocyte cell membranes, to elicit muscular contractions and restore motricity of deficient members. Upper-limb (UL) FES devices have undergone significant technological advances until the abrupt commercial stop of the Freehand® system [3] in 2001; since then, UL FES devices have been sidelined.

Here, I aimed to determine whether this technique should be updated. To identify the real needs and expectations of tetraplegic patients, I developed an experience-based questionnaire with the help of both a clinical rehabilitation team and one person who has had C6-level SCI since 1999 and had used the Freehand® UL neuroprosthesis. This study was conducted in accordance with the French legislation. The questionnaire was administered to individuals with tetraplegia who were ≥ 18 years old, had traumatic SCI and complete motor tetraplegia (American Spinal Injury Association [ASIA] Impairment Scale A or B), and were hospitalized or undergoing care.

The questionnaire (Supplementary material), was divided into 3 parts:

- demographic and functional characteristics of individuals;
- expectations and needs of individuals with tetraplegia vis-à-vis an external or implanted device or a functional surgery;
- acceptability of an implanted device.

To allow participants with tetraplegia to better understand concepts underlying implanted neuroprostheses, images of the Freehand® neuroprosthesis were shown to each participant and the device operating mode was explained. These patients may have an electrical stimulation neuroprosthesis to restore grip functions. Indeed, such individuals do not have enough forearm muscles under voluntary control to recover many hand movements via tendon transfer but retain a certain number of active muscles in the UL. Contraction of those muscles may be a control for FES [4]. The interview, conducted orally, lasted approximately 30 min.

We identified 40 people with tetraplegia from February 2013 to June 2013; 31 met the inclusion criteria. The demographic characteristics are in Table 1. The distribution of neurological levels was consistent with spinal cord lesion standards [5].

All participants used human help and technical aids to assist them in tasks of daily life. Nearly 80% solicited human help for control of vesico-sphincterian and intestinal functions, transfers and/or personal grooming, and 84% for food intake. One participant had an animal aid. One participant used the Freehand® neuroprosthesis to help with daily living tasks and stated that he limited his use of human aids for food intake, writing, and taking care of his appearance when he used this device.

Among the tasks proposed, participants chose 3 tasks that they considered among their recovery priorities. Being able to perform personal grooming alone and eat without the help of a third party (Fig. 1a) were the main priorities. Use of an FES device or undergoing functional surgery is particularly motivated by a gain in autonomy (74% for all levels of injury) and respect of intimacy (e.g., to be able to wash and catheterize oneself alone, for 45%) (Fig. 1b).

To recover hand movements, more than three-quarters of participants were willing to accept functional surgery, but if not enough muscles are under voluntary control to perform neuro-tendinous surgeries, 61% were willing to benefit from a neuroprosthesis implantation. As compared with all individuals interviewed, most with C6 or C7 SCI were open to the implantation of a stimulation neuroprosthesis that allowed for prehension (80% and 73%, respectively) ($P < 0.02$). Some (10%) did not give their opinion and wished to have more time to decide, and 29% categorically refused; 85% of these refused the Freehand® neuroprosthesis because of the external control unit, considered too imposing; for 61%, the visible external shoulder actuator was an issue, and for 55%, the transmission coil antenna placed on the chest was an issue. The time since the accident was also an output: 75% of participants with 3 to 20 years since their accident were willing to accept the implantation of a hand neuroprosthesis, whereas more than 90% of participants who had an accident < 2 years ago or > 22 years ago were not.

Through the questionnaire, the use of human and technical assistance was consistently identified, and the demand for autonomy was identified as very important. Among a set of daily life tasks, the main ones participants wished to perform by themselves were using hand movements. To this aim and to avoid unnecessary heavy surgical procedures and foreign bodies, neurotendinous surgery should be favoured over implanted FES. However, the use of neurotendinous surgery is not sufficient for individuals with tetraplegia with a score of 0–2 in the Giens classification. In that case, implantable neuroprostheses, combined

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Table 1
Demographic characteristics of individuals with tetraplegia ($n = 31$).

Sex	Male: 25 (81%)/female: 6 (19%)
Age at the time of the accident, years, mean ± SD	27.3 ± 13.15
Age group at the time of the accident, years	
16–30	67.7%
31–45	12.9%
46–60	6.5%
> 60	6.5%
Neurological level (AIS A or B)	
C4	6.5%
C5	6.5%
C6	32.3%
C7	35.5%

AIS: American Spinal Injury Association Impairment Scale.

with tendon-transfer surgeries, can solve some of the UL mobility restorations.

Most participants were ready to accept implanted FES devices, especially those with an SCI at C6 or C7 level, to gain autonomy in daily life tasks and regain gripping movements. The ASIA score, based on preserved sensory and motor functions below the level of injury, is used to assess the possibility for functional surgery or FES, but this is not enough. Instead, the Giens classification, based on the number of remaining active muscles under the elbow, is preferred and is more relevant. In this study, Giens classification was not assessed, but it should be used to screen future individuals who may benefit from an implanted FES. Although individuals with tetraplegia need help in activities of daily living, those with the injury for more than 2 decades showed low acceptability regarding implanted FES devices. One can assume that they became used to their tetraplegia and did not see the advantage or a sufficient limitation ratio (heavy surgery, invasive device, no full sensory and motor function recovery possible etc.) to benefit from it. If we focus on the Freehand® neuroprosthesis, which does not allow bimanual movements and requires daily human assistance for implementation, some participants (20%) were ready to accept this implantation, but images of the Freehand® device caused them to refuse it. Hence, the use of a neuroprosthesis is not problematic for these people, but instead, the design of the Freehand® system is. Indeed, refusal of the Freehand® device was essentially related to lack of ergonomics, and participants wanting a less imposing device and more natural control.

Moberg [6] estimated that 60% of individuals with tetraplegia were eligible for upper-extremity musculotendinous transfer surgery, whereas Gorman [7] estimated that almost 12% were eligible for an FES to recover hand movements. However, only a small number of individuals (14% [8] and less than 2% [7] of US individuals, for functional surgery and FES, respectively) benefit from solutions offered to them. Wagner [9] showed that learning about upper-extremity reconstructive surgery from healthcare workers, especially physicians, strongly affected patients.

Thus, a patient who had not heard of transfer surgery by his/her physician is 15 times more likely to want functional surgery than one who heard about it. In our survey, the percentage of acceptance of both surgery and electrostimulation devices was high. The Propara Clinic that hosted this survey worked collaboratively with clinicians (including surgeons) and a robotic research centre.

Unlike for lower limbs [10], surveys that assess the degree of multifactorial acceptability of individuals with tetraplegia vis-à-vis an implanted FES device to regain gripping movements are lacking. During interviews, the need for FES implanted devices was still perceived relevant, and restoring hand grip is still considered a priority among people with tetraplegia [11]. Physicians who implanted the Freehand® system in France were orthopaedic

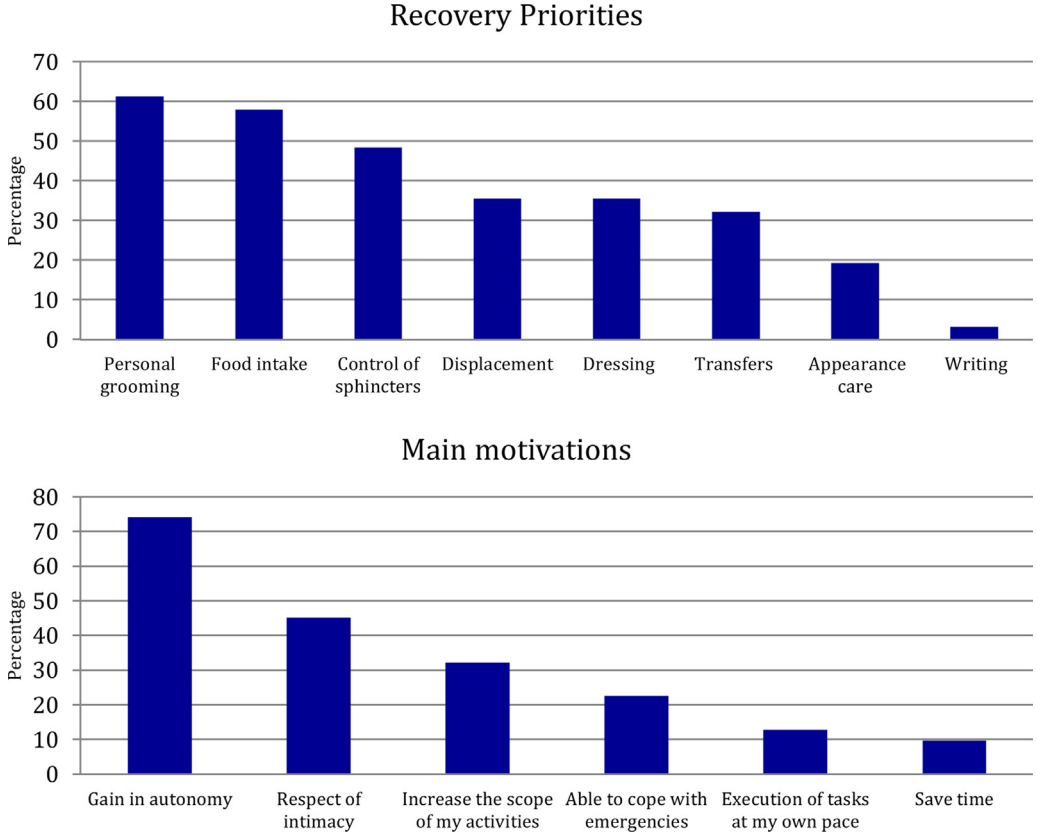

Fig. 1. (a) Tasks that the individuals with tetraplegia want to recover and listed as 1, 2 or 3 among the 12 items of recoveries. (b) Motivations of individuals with tetraplegia listed as 1 or 2 among the 8 items of motivations. ($n = 31$).

surgeons trained for tendon-transfer surgeries. A low number of surgeons trained for both functional surgery and FES technology, with no reliable commercial FES devices available, could also explain the weak use of these systems. Privileged collaborations between rehabilitation teams, orthopaedic surgeons, scientists, and industry could provide a solution for hand-grip restorations for individuals with tetraplegia. To this end, a clinical trial of multipolar nerve stimulation has begun.

Disclosure of interest

The author declares that he/she has no competing interest.

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Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rehab.2019.01.004.

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