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## **Assessment of the upper limb of the tetraplegic patient**

### **Evaluation du membre supérieur du patient tétraplégique**

V. Moiziard <sup>1</sup>, T. Lansaman <sup>2</sup>, E. Mauruc Soubirac <sup>2</sup>, M. Revol <sup>3</sup>, B. Coulet <sup>4</sup>, C. Hugeron <sup>2</sup>, A. Gelis <sup>5</sup>, I. Laffont <sup>1\*</sup>

1 : Département de MPR, CHU de Montpellier & Euromov, Université de Montpellier, IFRH, Montpellier, France

2 : Service de MPR, hôpital Raymond Poincaré, 104 Boulevard Raymond Poincaré 92380 Garches, France

3 : Service de chirurgie plastique, Hôpital Saint Louis, 1 avenue Claude Vellefaux 75010 Paris, France

4 : Département de chirurgie orthopédique, CHU de Montpellier, Montpellier, France

5: Centre Propara, Montpellier, France

#### Auteur correspondant :

Isabelle Laffont

Département de MPR, CHU de Montpellier & Euromov, Université de Montpellier, IFRH, Montpellier, France

i-laffont@chu-montpellier.fr

#### Autres auteurs :

Thibaud Lansaman

Elsa Mauruc Soubirac

Marc Revol

Bertrand Coulet

Caroline Hugeron

Anthony Gelis

Isabelle Laffont

**Conflits d'intérêts :**

Les auteurs déclarent ne pas avoir de liens d'intérêts.

## **Assessment of the upper limb of the tetraplegic patient**

## **Evaluation du membre supérieur du patient tétraplégique**

### **Abstract**

The aim of our study is to describe the assessment of the upper limb in tetraplegic patients to follow his (her) neurological progression and to define the medical or surgical treatment program. We selected upper limb assessment tools and scales for tetraplegic patients described in the medical literature through a PubMed search over the last four decades. For each method, we present the implementation rules and its metrological properties, including its validity in French. We selected five clinical scales for functional evaluation of grasping, as well as four scales for evaluating the overall function of these patients. Finally, we identified three complementary precision assessment tools. The AIS (ASIA Impairment Scale) classification describes the level and the severity of the spinal cord lesion. The Giens classification is more practical for describing the upper limb in middle and low tetraplegia. Impairments can be assessed with most common generic scales and nonspecific measurement devices: range of motion, strength, sensory loss, spasticity, joint pain. Measurement of pinch and grip strength is widely used and easy to perform. The Capabilities of Upper Extremity (CUE) and the Jebsen Taylor Test are the best validated and usable scales. At a general functional level, the Spinal Cord Independence Measure (SCIM) is the most relevant scale in these patients. Motor nerve blocks, electromyography, movement analysis and echography are promising additional methods. Assessment of the upper limb of tetraplegic patients relies both on generic and specific assessment tools and scales.

### **Résumé**

Le but de notre étude est de décrire l'évaluation du membre supérieur des tétraplégiques utilisables pour suivre leur éventuelle évolution neurologique et définir le

programme thérapeutique médical ou chirurgical. Nous avons sélectionné des outils d'évaluation du membre supérieur du patient tétraplégique et les échelles décrits dans la littérature médicale dans PubMed durant les quatre dernières décennies. Pour chaque méthode, nous présentons les règles de réalisation et ses qualités métrologiques, y compris sa validité en langue français. Nous avons sélectionné 5 échelles cliniques d'évaluation fonctionnelle de la préhension et 4 échelles pour l'évaluation des capacités fonctionnelles globales de ces patients. Enfin, nous avons identifié 3 outils complémentaires d'évaluation instrumentale. La classification de l'AIS (ASIA Impairment Scale) décrit le niveau et la gravité de la lésion de la moelle spinale. La classification de Giens est beaucoup plus pratique pour la description du membre supérieur pour des niveaux moyen et bas de tétraplégie. Une déficience peut être évaluée par des échelles génériques plus courantes et appareils de mesure non spécifiques : amplitude des mouvements, force, déficit sensitif, spasticité, douleur articulaires. La dynamométrie de poigne et de pince est largement utilisée et facile à exécuter. La Capacity of Upper Extremity (CUE) et le Taylor-Jebson Test sont les échelles d'évaluation les plus utiles et les mieux validées. À un niveau fonctionnel général, la Spinal Cord Independence Measure (SCIM) est l'échelle la plus pertinente chez ces patients. Blocs anesthésiques moteurs, électromyographie, analyse du mouvement et échographie sont des méthodes complémentaires prometteuses. L'évaluation du membre supérieur des patients tétraplégiques Fait appel à des outils d'évaluation et des échelles génériques et spécifiques.

*Keywords:* Tetraplegia; Upper limb; Assessment; Grip

*Mots-clés :* Tétraplégie ; Membre supérieur ; Evaluation ; Préhension

## **1. Introduction**

Tetraplegia is caused by a cervical spinal cord injury (SCI) due to trauma or to a medical procedure. Depending at which level the injury occurs, upper limb impairment will be more or less complete and widespread. An upper limb assessment is essential to determine the patient's functional ability [1,2]. This evaluation makes it possible to track neurological changes and is essential to plan potential upper limb neuro-orthopedic surgery. Upper limb assessment in tetraplegic patients relies on clinical assessment tools and instruments.

This article describes the upper limb assessment of tetraplegic patients based on the International Classification of Functioning, Disability and Health (ICF) where the limbs are assessed in terms of body function, activities, and participation. In the first part of the article, we provide a general account of a very specific scale dedicated to SCI patients: the American Spinal Injury Association Impairment Scale (AIS). We also included a broad clinical description of the functional capacities of tetraplegic patients according to their neurological level of injury (NLI).

The next part of the article describes the assessment of the upper limb in terms of body function and structure, according to range of motion, strength, muscle tone, selective motor control, sensitivity and stereognosis. Both clinical scales and precision assessment tools are described in detail. The assessment of activities distinguishes grasping ability and performance in daily life. As capacity is the ability to execute grasping tasks at the highest probable level of functioning, we describe the five most used scales in this context. Performance assessment, defined as the spontaneous use of the hand during activities, is addressed in the last part of the article, based on the three most relevant scales that assess general function in these patients.

Finally, we describe the potential use of precision assessment tools to complete the clinical examination and validated scales for body function and functional capacity.

## **2. Spinal cord injury assessment**

### **2.1. International Standards for Neurological Classification of Spinal Cord Injury: AIS scale**

To standardize the assessment of SCI patients, the American Spinal Injury Association (ASIA) first published the ASIA impairment scale (AIS) in 1982 [3]. It has been updated several times since, with the last major revision dating from 2011 [4,5]. This assessment focuses on the motor capacity of key muscles in the four limbs and a sensory examination, including light touch and pinprick sensation, of each dermatome. SCI patients are graded according to their NLI, corresponding to the level of the last healthy segment for both motor and sensory components, and on the type of injury, complete or incomplete, depending on whether perineal sensation is absent or intact.

Patients with AIS grade A injury have no sensory or motor function. AIS grade B patients retain some sensory function but no motor function. AIS grade C and D patients have an incomplete injury affecting both sensory and motor function; the motor function of AIS grade C patients is less than 3/5 for more than half the muscles tested below the NLI, whereas in AIS grade D patients, at least half the muscles below the NLI score 3/5 or better during manual testing. AIS grade E patients have normal motor and sensory function.

Tetraplegia can affect the high cervical (C1, C2, C3, C4), mid cervical (C5, C6) and low cervical (C7, C8) vertebrae. According to the AIS classification, patients with impaired motor function above C4 have no upper limb motor control. In patients with a C4 injury, only the trapezium, and sometimes the external rotator cuff muscles of the shoulder, still have motor function. The diaphragm can be more or less affected in C4 SCI patients, since its innervation can be below or at the level of injury, making them dependent on a mechanical ventilator. Patients with a C5 injury have motor function of the external rotator cuff, deltoid, and elbow flexor muscles.

Patients with a C6 SCI retain motor function of the wrist extensors as well as the previously mentioned muscle groups. Patients with a C7 SCI can also perform elbow extension. Motor function of the flexor tendons is preserved in patients with a C8 injury and T1 patients can contract their 5<sup>th</sup> digit abductor. This assessment, although widely used in clinical practice, lacks specificity, especially for tetraplegia at the mid and lower cervical vertebrae level.

This evaluation must be supplemented by an assessment of the lesional segment and of its extent. The lesional segment corresponds to the first metamere level showing impairment. At this level, there is a peripheral nerve injury, either because of cord segment damage with injury to the anterior horn, or because of an injury to the spinal root at this level. Clinically, patients have an impaired sensory function and flaccid paralysis together with an absence of deep tendon reflexes. The lesional segment plays an important role in the potential for recovery. It has an important impact on upper limb functional outcome, especially when tendon transfer surgery is considered [6].

Finally, it is important to note that regardless of this basic classification, patients with the same NLI can use their available sensory-motor functions very differently, depending on their manual skills and their overall body dynamics.

## 2.2. Grasping function in patients with tetraplegia

Patients can have bilateral grasping function starting at C5 and unilateral function beginning at C6. From this level on, the patient uses what is called “tenodesis grasp” or “automatic grasp” (Fig 1): the patient closes the hand through the passive shortening of the thumb and finger flexor tendons during active wrist extension; the hand is opened through passive wrist flexion, using gravity (C6 level), or active wrist flexion by contracting the wrist flexor tendons (C7 level and beyond), thanks to the passive shortening of the thumb and finger extensors. For a patient with a C6 SCI, the tenodesis grasp makes it possible to grip lightweight and small objects. The lower the NLI, the more these grasps are active, strong, and efficient. Patients can also employ an interdigital grasp, allowing them to use utensils.

Weak grasping function can be compensated by a hook grip in wrist extension (for C6 patients and beyond), to lift their lower limbs for example (Fig 2A). Hooking the contralateral limb around the back of the wheelchair will help stabilize the trunk and make grasping with the other limb easier (Fig. 2B). Quick shoulder movements, combined with optimal use of gravity and inertia to move the forearm, allow these patients to achieve elbow extension or



forearm pronation, despite paralysis of the muscles normally needed for these movements (triceps, pronator muscles) [7,8].

### **3. Assessing functional impairment**

Most generic functional assessment tools can be applied to patients with tetraplegia: goniometer (range of motion (ROM)), Medical Research Council (MRC) scale for manual muscle testing, the Ashworth scale to measure spasticity, clinical assessment of sensory function, nociceptive and neuropathic pain assessment. Here, we will focus on the specificities of tetraplegia assessment and the scales dedicated to this pathology [2].

#### **3.1. Orthopedic assessment**

There is no specific orthopedic upper limb assessment tool for the tetraplegic patient although orthopedic deformities are common in this population. These deformities are most often the result of muscle strength imbalance and the result of spasticity. They are most commonly found in patients with C5-C6 injuries, prone to developing elbow flexion contracture and forearm supination over time because of biceps prevalence, accompanied by a wrist extension deformity through the overuse of the carpal extensors with gravity (Fig. 3). Whatever the NLI, wrist and finger joint stiffness should be strictly avoided in SCI patients. Indeed, this will help maintain tenodesis grasp capability, which relies on wrist and finger joint mobility (especially the metacarpophalangeal joints), while retaining the possibility of tendon transfer later on.

#### **3.2. Motor skills assessment**

##### ***3.2.1. Assessing elbow ROM in extension***

Elbow muscle strength in extension is crucial for grasping and transfer ability and can be measured with the MRC scale and an isokinetic dynamometer [9]. The ability to extend the elbow relies heavily on the mobility and strength of the shoulder in tetraplegic patients, as triceps muscle weakness is often compensated by a quick, combined flexion/external rotation

movement of the shoulder. As such, assessing passive and active ROM of the muscles attached to the scapula is essential to determine the overall grasping ability of these patients.

### *3.2.2. Motor skills assessment of the distal upper limb*

In tetraplegic patients, the AIS grade defines motor function impairment and the extent and severity of the sensory–motor impairment, but cannot provide a detailed assessment of upper limb motor capacity. The Giens classification, proposed in 1984 [10], is a preoperative assessment to determine the motor function of upper limb muscles and their transfer potential, i.e., muscles scoring 4/5 or more on the MRC scale. It only measures muscles active below the elbow. Therefore, it is not meant to assess patients with motor function above C5. Typically, it is completed by testing cutaneous sensation at the tip of the index finger (Cutaneous Cu+ or Cu–) and a visual test (Ocular O+ and O–).

It is divided into nine groups, ranked from 0 to 9, depending on the number of muscles below the elbow with motor function (Table 1). Very precise, reproducible, and extremely easy to use, this scale makes it possible to accurately assess muscle impairment of the distal upper limb. It has helped determine indications for neuro-orthopedic surgery of the upper limb in tetraplegic patients and is widely used.

### *3.2.3. Incomplete SCI cases*

The neurological profile of SCI patients can sometimes be very atypical, especially in case of incomplete injury or in case of cervical canal stenosis [11]. Patients with an incomplete SCI and a high NLI are distinctive as they have some upper limb motor function below the level of injury, but with altered muscle strength and tone. Motor function impairment varies in severity and localization, depending on the damage to the pyramidal tracts. Spasticity is common and can be more or less severe, with a functional impact that varies depending on the muscle groups involved. Usually, tenodesis grasp is not possible. Furthermore, these patients can show sensory impairment on the highest metameres and, to

a varying degree, at the shoulder and elbow flexor level. This is extremely detrimental when positioning the upper limb in space, limiting function.

In these cases, the Giens classification is of little or no use. A motor nerve block, because it can discriminate between spasticity and soft tissue contracture and can adequately assess antagonist muscle strength in case of spasticity, is particularly useful in patients with incomplete SCI. Treatments using botulinum toxin injections are common whereas surgical indications for tendon transfer are less common.

#### *3.2.4. Measuring grip strength and pinch grip*

Grip strength, or grasp, is measured with the Jamar® dynamometer in Kilograms or in Pounds converted into Newtons (Fig.4). Key pinch grip can be measured with a pinch dynamometer or, more rarely, with the Preston® pinch gauge, the B & L Engineering® Pinch Gauge, or the computerized Dexter® dynamometer.

There are important discrepancies in the measurements reported in the literature [12] which makes it difficult to compare studies:

- Variability in units of measurement
- Variability in testing conditions: recommendations from the American Association for Hand Surgery are only followed in some studies (measurements taken with the arm in adduction, elbow 90°, neutral pronation–supination of the forearm) [13]. Some authors also specify the exact position of the wrist, elbow, and shoulder.
- Variability in the number of measurements: usually three are taken, the mean or highest of the three is then retained.

Nonetheless, the Jamar dynamometer and pinch gauge are of limited use for most tetraplegic patients, except to evaluate tendon transfer outcomes, as they are not very sensitive to small variations in strength.

#### **4. Assessing grasping function**

Given the specificities of grasping function in tetraplegic patients, it cannot be assessed with tests that are non-specific and normally used for other pathologies in physical medicine and rehabilitation (PM&R). The five most used scales are presented in Table 2.

##### **4.1. Capabilities of Upper Extremity (CUE) instrument for tetraplegia**

This scale is meant to assess upper limb motor function impairment in SCI patients [14,15]. It consists of 17 items divided into five domains: the ability to reach or lift an object, the ability to pull or push an object, the ability to perform tasks requiring the wrist, the ability to use the hands and fingers, and the bilateral use of the upper limbs. The first 15 items are rated for the right upper limb and the left upper limb, the last two items are each rated only once. This tool can be used for baseline patient assessment, but also to assess the patient over time. A higher test score means better upper limb motor function.

A simplified version, the Upper Extremity-Questionnaire (CUE-Q), has also been published [16]. This questionnaire is true to the original version but easier to use for the patient. It has been translated into French but has only been validated in English. The French version is shown in Fig.5.

##### **4.2. The Jebsen-Taylor Test or the objective and standardized test of upper limb function**

The Jebsen-Taylor Test (JTT) or Jebsen Hand Function Test (JHFT) is a generic standardized test for motor hand function [17]. It is not specific to patients with tetraplegia.

The JHFT consists of seven items that measure: (a) fine motor skills; (b) non-weighted functional tasks; and (c) weighted functional tasks. The assessment requires the unilateral manipulation of seven objects from daily living activities: writing a short sentence, turning over playing cards, picking up small objects, spooning up beans, stacking checkers, picking up large lightweight boxes, picking up large heavy boxes. The assessment focuses on the speed at which the tasks are completed rather than how they are carried out. This test

does not assess hooking, grip strength, bilateral coordination, or activities above the shoulder level.

The time to complete each task is measured twice, once for the dominant limb and once for the non-dominant limb. These times are compared to minimum, mean and maximum reference values (and can be expressed as percentages of a mean reference time).

The metrological quality of this test is poor [18,19]. A complete overview in French has been published by Decourcelle [20].

#### 4.3. The Sollerman Hand Function Test (SHFT)

The SHFT assesses the ability to successfully complete 20 activities of daily living involving the seven most used handgrips [21]. The score depends on the ease of execution, the quality of grip and the speed of execution. The novelty of this test is that it scores which type of grip the patient chooses, the ability to perform the task, grip quality, as well as the time needed. It takes approximately 20 minutes to complete. For each item, patients are rated on a 5-point scale from 0 (the task cannot be carried out) to 4 (the task is completed without difficulty in the prescribed 20 second timeframe and using the prescribed handgrip of normal quality).

A total score is then computed by adding the scores from the various subtests, from 0 to 80. The higher the score the better the grasping ability. Subjects without functional hand impairment generally achieve a score of 80 with the dominant hand and between 77 and 79 for the non-dominant hand. This generic test has been validated in tetraplegic subjects [21]. Its validity could be improved as it has a weak correlation coefficient with the studied reference test. It is only validated in English, not in French.

#### 4.4. The Standardized Object Test (SOT)

This test was designed to assess tetraplegic patients with an implanted neurostimulation functional prosthesis, the FreeHand System®. The test requires the subject

to grip, carry and release six objects of varying weight, size, and texture (block, disk, videotape, peg, cylinder, and fork) as many times as possible within a 30 second timeframe. The total score corresponds to the number of times each object can be carried within 30 seconds. Sensitivity was strong enough to detect an improvement in hand grip function in tetraplegic patients with an implantable hand neuroprosthesis [22]. Its use is limited to patients with such a device. This test is not translated or validated in French.

#### 4.5. Grasp and Release Test (GRT)

This test is one of the only tests specifically designed to assess grasping in tetraplegic patients [23,24]. It measures the ability to grip and release standardized objects. Originally designed to assess outcomes following implantation of a hand neuroprosthesis in C5 and C6 tetraplegic patients, this test has been mostly discarded from current practice and the literature since the FreeHand System® was abandoned. Easy to use, the material required was rather specific, greatly limiting its use.

This test requires the unilateral manipulation of six objects of varying weights and sizes: three objects using key pinch (peg, paperweight, fork) and three objects using palmar grasp (block, box, videotape). The patient performs a set sequence of movements for each object (grasp, lift, release), as many times as possible within 30 seconds. The score is determined with the mean number of successful completions and the mean number of failures within 30 seconds, for each object, with a 30 second break between each trial.

### 5. Assessment of overall function

The three most used scales are summarized in Table 3.

#### 5.1. The Quadriplegia Index of Function (QIF)

The QIF is a general autonomy scale for tetraplegic patients, considered equivalent to the Functional Independence Measure (FIM) [25,26]. It is a questionnaire to measure activity limitations using 44 items within seven functional categories: feeding, grooming, bathing,

dressing, bed activities, transfers, and wheelchair mobility. Each item is scored from 0 to 4 (0: dependent; 1: requires third party assistance; 2: requires monitoring; 3: independent with technical assistance or specific installations; 4: independent). The test must be completed within 30 minutes. The final score is between 0 and 100. A simplified version of the QIF, with a score between 0 and 24 and including only six items, has also been proposed. This scale shows good reproducibility and good sensitivity, as well as good construct validity with the FIM and AIS scores [26].

## 5.2. Motor capacities scale for the tetraplegic patient

This scale was developed by Fattal et al. [27]. It is used to assess basic motor skills with potential for improvement following tendon transfer. It is made of 31 items divided into six functional categories: transfers, positioning on a Bobath couch, positioning in a wheelchair, locomotion, motor capacities of spatial exploration and motor capacities for grasping and gripping. This scale was designed and validated by a multidisciplinary French team consisting of surgeons, PM&R specialists, occupational therapists, and physiotherapists. The metrological quality is excellent [28], with excellent inter-rater reliability, good sensitivity, and good acceptability. In its final version, the average completion time is 17 minutes (5 minutes to 40 minutes). Only available in French, it is not widely used internationally.

## 5.3. The SCIM - Spinal Cord Independence Measure

This scale assesses the capacity of SCI patients to perform daily activities. The latest version—the SCIM III—includes 95 items detailing individual tasks divided into three subscales: self-care (feeding, bathing, dressing), respiration and sphincter management (ability to manage breathing and the vesical and anal sphincters) and mobility. The total score varies between 0 and 100. The metrological quality of this scale is excellent for construct validity, reproducibility, internal consistency, and it has better sensitivity than the FIM [29]. There have been three successive versions and several translations that have

undergone transcultural adaptation and validation. The latest version—SCIM III—was translated in French but never validated. It is presented in Fig. 6.

#### 5.4. The Canadian Occupational Performance Measure (COPM)

This semi-structured questionnaire assesses an individual's perceived performance in the areas of self-care, productivity, and leisure. The COPM—or *Mesure Canadienne du Rendement Occupationnel* (MCRO)—offers two self-rated scores: performance and satisfaction. The COPM is a valid, reliable, and clinically useful outcome measure for occupational therapists [30]. Unfortunately, it is not specific to tetraplegic patients, rendering its usefulness in this population very questionable. This questionnaire and its guidelines are not free of charge, thus limiting their usability in a clinical setting.

### 6. Other techniques using precision assessment tools

#### 6.1. Electromyography (EMG)

Electromyography provides a detailed analysis of the injured segment by measuring the intensity of muscle response to stimulation [2,31]. This technique can help refine indications for tendon transfer or thumb arthrodesis, by supplementing clinical examination data which is not always specific enough to assess the extent of injury and the changes in partially denervated muscles. It is also useful to determine whether implanted functional electrical stimulation is indicated by establishing whether the target muscles, such as the radiocarpal extensors or flexor tendons of the fingers or thumb, can be stimulated.

Diagnostic EMG can help monitor muscle recovery within the injured segment, similarly to peripheral nerve injuries. The role of dynamic EMG in the tetraplegic patient's upper limb assessment has yet to be defined. However, it is easy to imagine its potential in monitoring the adaptation of dynamic muscle activation patterns after tendon transfer [32].



## 6.2. Ultrasound

Ultrasound is routinely used to assess the upper limb of tetraplegic patients. In addition to its typical role in assessing microtrauma or non-specific pathologies, at least two specific uses have been described in the literature:

- Ultrasound is useful to confirm muscle activity of the extensor carpi radialis longus (ECRL), whose function is important in the event of tendon transfer [33]
- It can also be useful for the very early diagnosis of para-osteo-arthropathy (elbow, very rarely shoulder, extremely rarely hand).

Eventually, it is possible that ultrasound imaging will help keep track of neurological recovery, especially for the injured segments involved [34].

## 6.3. Kinematic assessment

The 3D upper limb motion analysis of tetraplegic patients has been the subject of several studies since the beginning of the 1990s [7,35]. Kinematics help determine residual motor function, understand the kinetic adaptation mechanisms caused by SCI, and monitor patients during the rehabilitation period or after specific procedures, including surgery. The accessibility of motion assessment systems should contribute to the development of these types of precise, reproducible monitoring methods using precision assessment tools that are valuable adjuncts to the clinical follow-up.

# 7. Summary and discussion

## 7.1. Summary

The AIS classification defines the SCI of the tetraplegic patient within an international and consensual framework. The Giens classification remains the gold standard in the assessment of motor function impairment, especially to determine residual motor function for surgery to restore function. A detailed description of the extent of injury is essential, based on clinical examination and, ideally, completed by EMG or electrodiagnostic techniques. Other

upper limb impairments are assessed with generic, commonly used tools: goniometer, MRC manual muscle testing, Ashworth scale.

Upper limb function can be determined using a clinical assessment, the Jebsen test, which is not specific to the tetraplegic patient and of poor metrological quality, or the Sollerman test, which has yet to be validated in French. The absence of specifically tailored tests leads to patient assessment being undertaken with tools that are poorly adapted, such as the Box and Block Test which is too generic and has a high floor effect [36], or the GRT.

Overall functional assessment is better standardized but has its own challenges. The metrological quality of the SCIM III is excellent and it would be the best suited scale; however, it is time consuming and has only been validated in English and Italian, which limits its use. The motor capacities scale of the tetraplegic patient has excellent psychometric properties but being only available in French considerably limits its use.

In addition to various scales, the upper limb assessment of tetraplegic patients could also rely on instruments taking more accurate measurements, such as EMG, dynamometry, ultrasound imaging, and 3D kinematics. These techniques would provide a more detailed injury profile, help investigate complications and supplement the preoperative assessment, but are rarely or never used.

## 7.2. Perspectives

In this way, it becomes clear that there is a need for international, wide ranging collaborative projects aiming to (1) standardize an array of multidimensional assessment tools for the upper limb in tetraplegia, (2) validate and promote the main tools currently available in various languages whose use are hindered by availability issues, and (3) work to design new, simpler, faster, more reproducible assessment methods, probably based on data collection techniques that rely on precision assessment tools with more accurate measurement methods (kinematics, embedded sensors...)

**Conflict of interest statement:**

The authors declare that they have no conflicts of interest.

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## Figure legends

Fig. 1. C6 SCI patient, "tenodesis grasp": fingers and thumb can close with active dorsal wrist flexion, which is not paralyzed, and the hand is opened via passive wrist flexion using gravity.

Fig. 2. Hook grip of the lower limb allows its mobilization (A). Hooking the arm to the back of the wheelchair helps stabilize the trunk (B).

Fig. 3. C5 SCI patient, AIS grade A with typical flexion-supination deformity of the elbow and wrist extension deformity resulting from muscle asymmetry and the neurological level of injury.

Fig. 4. Dynamometers used to measure grip strength and pinch grip in tetraplegic patients: Jamar dynamometer for grip strength (A) and pinch gauge for pinch strength (B).

Fig. 5. Capabilities of Upper Extremity (CUE), revised version (CUE-Q). In: Principales échelles d'évaluation en Médecine Physique et Réadaptation, J. Pélissier, F. Pellas, C. Benaïm et C. Fattal (éds.) (deuxième édition). Cofemer (Collège français des enseignants universitaires de médecine physique et de réadaptation, 2009.

Fig. 6. Spinal Cord Independence Measure (SCIM) In: Principales échelles d'évaluation en Médecine Physique et Réadaptation, J. Pélissier, F. Pellas, C. Benaïm et C. Fattal (éds.) (deuxième édition). Cofemer (Collège français des enseignants universitaires de médecine physique et de réadaptation, 2009.



**Table captions**

Table 1. Motor function according to the ASIA Impairment Scale (AIS) and corresponding  
Giens classification

Table 2. Assessment scales specific to the upper limb function of tetraplegic patients

Table 3. Assessment scales for the overall functional ability of tetraplegic patients

Fig. 1. Patient tétraplégique C6, "préhension automatique" : la fermeture des doigts et du pouce se fait grâce à la flexion dorsale active du poignet qui n'est pas paralysée, l'ouverture de la main se fait grâce à la flexion passive du poignet sous l'effet de la pesanteur.

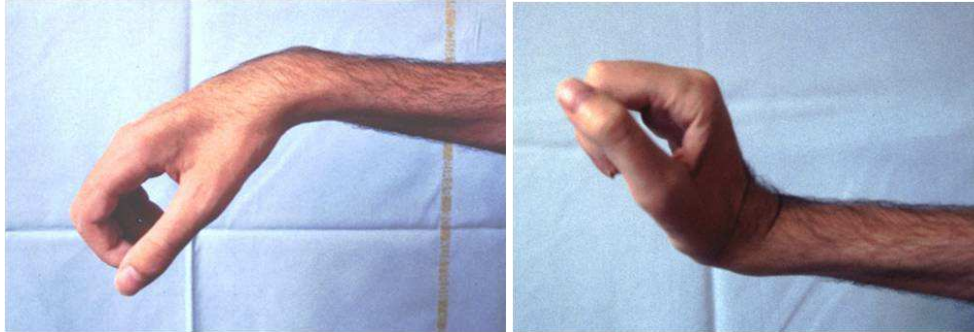


Fig. 2. Crochetage du membre inférieur permettant sa mobilisation (A). Crochetage du dossier du fauteuil permettant la stabilisation du tronc (B).



Figure 2A



Figure 2B

Fig. 3. Patiente tétraplégique C5 AIS A présentant une déformation classique en flexion-supination du coude et extension du poignet liée à une asymétrie musculaire en rapport avec son niveau neurologique.



Fig. 4. Dynamomètres utilisés pour la mesure des forces de préhension du patient tétraplégique : dynamomètre de Jamar pour la force de poigne (A) et dynamomètre de mesure du de la force de pince (pinch) (B)



Figure 3A



Figure 3B

Fig. 5. Capabilities of Upper Extremity (CUE) ou questionnaire des capacités du membre supérieur du tétraplégique (CMS), présentation en version simplifiée (CUE-Q).

In : Principales échelles d'évaluation en Médecine Physique et Réadaptation, J. Pélissier, F. Pellas, C. Benaïm et C. Fattal (éds.) (deuxième édition). Cofemer (Collège français des enseignants universitaires de médecine physique et de réadaptation, 2009.

	Membre supérieur gauche	Membre supérieur droit
1 Atteindre un objet et le soulever vers l'avant	<input type="text"/>	<input type="text"/>
2 Atteindre un objet et le soulever vers le haut	<input type="text"/>	<input type="text"/>
3 Atteindre un objet et le soulever vers le bas	<input type="text"/>	<input type="text"/>
4 Tirer un objet léger vers soi	<input type="text"/>	<input type="text"/>
5 Tirer un objet lourd (5 kilos) vers soi	<input type="text"/>	<input type="text"/>
6 Pousser un objet léger loin de soi	<input type="text"/>	<input type="text"/>
7 Pousser un objet lourd (5 kilos) loin de soi	<input type="text"/>	<input type="text"/>
8 Étendre le poignet vers le haut (extension)	<input type="text"/>	<input type="text"/>
9 Tourner le poignet, paume de la main vers le bas (pronation)	<input type="text"/>	<input type="text"/>
10 Prise de force (par exemple un marteau)	<input type="text"/>	<input type="text"/>
11 Pince termino-terminale	<input type="text"/>	<input type="text"/>
12 Pince termino-latérale	<input type="text"/>	<input type="text"/>
13 Prise d'ouverture (ouvrir un bocal)	<input type="text"/>	<input type="text"/>
14 Manipuler un petit objet	<input type="text"/>	<input type="text"/>
15 Presser avec l'index (par exemple sonner à la porte)	<input type="text"/>	<input type="text"/>
Sous total A :	<input type="text"/>	B : <input type="text"/>
Les 2 membres supérieurs		
16 Soulever un poids de 2,5 kg au dessus de la tête	<input type="text"/>	<input type="text"/>
17 Pousser vers le bas pour se soulever de la chaise (push-up et transfert du poids)	<input type="text"/>	<input type="text"/>
Sous total C :	<input type="text"/>	<input type="text"/>

Fig. 6. Spinal Cord Independence Measure (SCIM) ou mesure d'indépendance des blessés médullaires. In : Principales échelles d'évaluation en Médecine Physique et Réadaptation, J. Pélissier, F. Pellas, C. Benaïm et C. Fattal (éds.) (deuxième édition). Cofemer (Collège français des enseignants universitaires de médecine physique et de réadaptation, 2009.

Dates	
SOINS PERSONNELS	
1.	<i>Alimentation (couper la viande, ouvrir une boîte, tenir un gobelet plein, verser du liquide, porter les aliments à la bouche)</i>
0	Nutrition parentérale, gastrostomie ou assistance totale pour alimentation orale
1	Assistance partielle pour manger et/ou boire, ou pour aliments coupés, assiette et couverts adaptés, incapable de tenir un gobelet
2	Indépendant pour manger, besoin d'AT ou assistance seulement pour couper les aliments et/ou verser et/ou ouvrir une boîte)
3	Indépendant dans toutes les tâches sans assistance ou AT
2.	<i>Toilette (utiliser le savon, manipuler les robinets, se laver, se sécher le corps et la tête)</i>
	<i>A. Partie supérieure du corps</i>
0	Assistance totale
1	Assistance partielle
2	Indépendant avec AT ou installation spéciale
3	Indépendant sans AT ni installation spéciale
	<i>B. Partie inférieure du corps</i>
0	Assistance totale
1	Assistance partielle
2	Indépendant avec AT ou installation spéciale
3	Indépendant sans AT ni installation spéciale
3.	<i>Habillage (préparation des habits, habillage, déshabillage, chaussage, mise en place des orthèses permanentes)</i>
	<i>A. Partie supérieure du corps</i>
0	Assistance totale
1	Assistance partielle pour avec les vêtements sans boutons, fermetures éclair ou lacets (vsbfl)
2	Indépendant pour vsbfl ; besoin AT et/ ou installation spéciale
3	Indépendant pour vsbfl ; pas besoin AT et/ou installation spéciale sauf pour bfl
4	Indépendant (pour tout type de vêtement) sans AT et/ ou installation spéciale
	<i>B. Partie inférieure du corps</i>
0	Assistance totale
1	Assistance partielle pour avec les vêtements sans boutons, fermetures éclair ou lacets (vsbfl)
2	Indépendant pour vsbfl ; besoin AT et/ ou installation spéciale
3	Indépendant pour vsbfl ; pas besoin AT et/ou installation spéciale sauf pour bfl
4	Indépendant (pour tout type de vêtement) sans AT et/ou installation spéciale



**4 Soins d'apparence (se laver les mains et le visage, se coiffer, brossage des dents, rasage, maquillage)**

0 Assistance totale

1 Assistance partielle

2 Indépendant avec AT

3 Indépendant sans AT

**Sous total (0-20)**

**RESPIRATION ET CONTROLE SPHINCTÉRIEN**

**5. Respiration**

0 Sonde trachéale (ST) et ventilation assistée (VA) permanente ou intermittente

2 Respire spontanément avec ST; besoin oxygène, assistance pour tousser et soins trachéaux

4 Respire spontanément avec ST + peu d'assistance pour tousser ou soins trachéaux

6 Respire spontanément sans ST + besoin d'oxygène et soins importants pour tousser, un masque ou VA

8 Respire sans ST; besoin d'un peu d'assistance mécanique pour tousser

10 Respiration normale sans aide ou AT

**6. Contrôle vésico-sphinctérien - Veste**

0 Sonde urinaire à demeure

3 Résidu post mictionnel (RPM) > 100 cc, pas de sonde, pas de SI

6 RPM < 100 cc, ou auto sondages intermittents, aide nécessaire pour vidange vésicale

9 Auto sondages intermittents < 100 cc, utilise une AT pour vidange vésicale sans assistance

11 Auto sondages intermittents, continent entre les sondages, sans AT

13 RPM < 100 cc, vidange vésicale externe uniquement sans aide

15 RPM < 100 cc, totalement continent sans vidange vésicale

**7. Contrôle sphincter anal**

0 Évacuation des selles inappropriées, ou irrégulières, ou fréquence < à 1 fois/3j

5 Évacuation régulière et adaptée avec assistance (ex : mise du suppo), rares fuites (< 1 fois/mois)

8 Évacuation régulière et adaptée sans assistance, rares fuites (< 1 fois/mois)

10 Évacuation régulière sans assistance pas d'accidents

**8. Utilisation des toilettes (hygiène périnéale, désabillage, rhabillage, utilisation de couches ou de serviettes périodiques)**

0 Besoin d'assistance totale

1 Assistance partielle, ne peut se laver seul

2 Assistance partielle, peut se laver seul

4 Indépendant dans toutes les tâches, nécessite AT ou installation spéciale

5 Indépendant sans AT ni installation spéciale

**Sous total (0-40)**

**MOBILITÉ (Chambre et Toilettes)**

**9. Mobilité dans le lit et prévention des points d'appui**

0 Besoin d'assistance totale dans toutes les activités : tourner le haut et bas du corps dans le lit, s'asseoir, push-up en fauteuil, avec ou sans AT, mais sans aides électriques

2 Peut accomplir une de ces activités sans aide

4 Peut accomplir deux ou trois activités sans aide

6 Totalement indépendant pour toutes les activités de mobilité dans le lit et prévention des points d'appui



**10. Transferts lit-fauteuil roulant** (bloquer le fauteuil, soulever les appuis-pieds, enlever et ajuster les repose-bras, transfert, lever les pieds)

- 0 Besoin d'assistance totale
- 1 Besoin d'assistance partielle et/ou surveillance et/ou AT (ex : planche de transfert)
- 2 Indépendant (ou n'a pas besoin de fauteuil roulant)

**11. Transferts fauteuil roulant-W.C.** (bloquer le fauteuil, soulever les appuis-pieds, enlever et ajuster les repose-bras, transfert, lever les pieds)

- 0 Besoin d'assistance totale
- 1 Besoin assistance partielle et/ou surveillance ou aménagement (ex : barre d'appui)
- 2 Indépendant (ou n'a pas besoin de fauteuil roulant)

#### **DÉPLACEMENTS (à l'intérieur et à l'extérieur, sur surfaces planes)**

**12. Déplacements à l'intérieur (courtes distances)**

- 0 Assistance totale
- 1 A besoin d'un FRE ou d'une aide pour déplacer le FRM
- 2 Se déplace seul avec un FRM
- 3 Surveillance pour la marche (avec ou sans AT)
- 4 Marche avec déambulateur ou cannes anglaises (swing)
- 5 Marche avec 2 cannes anglaises ou cannes simples (marche réciproque)
- 6 Marche avec 1 canne simple
- 7 Utilise seulement une orthèse
- 8 Marche sans AT

**13. Déplacements sur distances moyennes (10 - 100 m)**

- 0 Assistance totale
- 1 A besoin d'un FRE ou d'une aide pour déplacer le FRM
- 2 Se déplace seul avec un FRM
- 3 Surveillance pour la marche (avec ou sans AT)
- 4 Marche avec déambulateur ou cannes anglaises (swing)
- 5 Marche avec 2 cannes anglaises ou cannes simples (marche réciproque)
- 6 Marche avec 1 canne simple
- 7 Utilise seulement une orthèse
- 8 Marche sans AT

**14. Déplacements à l'extérieur (> 100 m)**

- 0 Assistance totale
- 1 A besoin d'un FRE ou d'une aide pour déplacer le FRM
- 2 Se déplace seul avec un FRM
- 3 Surveillance pour la marche (avec ou sans AT)
- 4 Marche avec déambulateur ou cannes anglaises (swing)
- 5 Marche avec 2 cannes anglaises ou cannes simples (marche réciproque)
- 6 Marche avec 1 canne simple
- 7 Utilise seulement une orthèse
- 8 Marche sans AT

**15. Escaliers**

- 0 Incapable de monter ou descendre des escaliers
- 1 Monte et descend au moins 3 marches avec aide ou surveillance d'un tiers
- 2 Monte et descend au moins 3 marches avec appui d'une rampe et / ou canne
- 3 Monte et descend au moins 3 marches sans aucun appui ni surveillance

**16. Transferts fauteuil roulant - voiture** (accéder à la voiture, bloquer le fauteuil roulant, enlever les appuis-pieds et repose-bras, transfert fauteuil roulant-voiture, mettre / sortir le fauteuil roulant)

- 0 Besoin d'assistance totale
- 1 Besoin d'assistance partielle et / ou surveillance et / ou aide technique
- 2 Indépendant sans aide technique

**16. Transferts fauteuil roulant-sol**

- 0 Besoin d'assistance totale
- 1 Indépendant pour les transferts avec ou sans AT

**Sous total (0-40)**

**TOTAL (sur 100)**

Table 1. Motor function according to the ASIA Impairment Scale (AIS) and corresponding  
 Giens classification

Giens Classification	Muscles active below the elbow (4 or more on the MRC scale)	AIS motor function
0	No muscle function below the elbow	
1	BR (brachioradialis)	C5: elbow flexion
2	ECRL (extensor carpi radialis longus)	
3	ECRB (extensor carpi radialis brevis)	
4	PT (pronator teres)	C6: wrist extension
5	FCR (flexor carpi radialis)	
6	Finger extensors	C7: elbow extension
7	Thumb extensor	
8	Finger flexors	C8: finger flexion
9	Intrinsic muscles	T1: finger adduction/abduction
10	Exceptions or atypical	

Table 2. Assessment scales specific to the upper limb function of tetraplegic patients

Name	Metrological quality	Test duration	Maximum score	Validated in French
Capabilities of Upper Extremity (CUE)	<p>Validity: proven by significant correlation with other scales (UEMS, SCIM, CUE-Q)</p> <p>Fidelity/reproducibility: excellent (ICC 0.94)</p> <p>Internal consistency: excellent (Chronbach's <math>\alpha = 0.96</math>)</p> <p>Harmlessness: yes</p> <p>Cost: free</p>	30 minutes	224	No
Jebsen-Taylor Test	<p>Validity: weak correlation with other scales (MHQ, ADL)</p> <p>Fidelity/reproducibility: excellent inter-rater reproducibility</p> <p>Cost: test kit approximately 300 \$</p>	15 minutes	Test duration (in seconds)	No
Sollerman Hand Function Test	<p>Validity: weak correlation coefficient with other tests</p> <p>Cost: Low, basic materials needed</p>	20-25 minutes	80	No
Standardized Object Test	<p>Sensitive for detecting improvement in hand function of tetraplegic patients with a neurostimulation functional prosthesis</p>	15 minutes	Total number of times each object is moved in 30 seconds	No
Grasp and Release Test	<p>Excellent reliability for each object</p> <p>Excellent predictive value for FIM scores</p> <p>Convergent validity with ADL scale and Van Lieshout</p> <p>Cost: low, basic materials needed</p>	90 – 150 minutes	30	No

Table 3. Assessment scales for the overall functional ability of tetraplegic patients

Name	Metrological quality	Test duration	Maximum score	Validated in French
Quadriplegia Index of Function (QIF)	<p>Validity: very good correlation with other scales (FIM, AIS, UEMS)</p> <p>Fidelity/reproducibility: excellent inter-rater reproducibility</p> <p>Cost: Free</p>	<p>30 minutes max</p>	100	No
Motor capacities scale for the tetraplegic patient	<p>Fidelity/reproducibility: excellent inter-rater reproducibility</p> <p>Good sensitivity to change</p> <p>Good acceptability</p> <p>Cost: free</p>	<p>20 – 40 minutes</p>	233	Yes
Spinal Cord Independence Measure (SCIM)	<p>Convergent validity and inter-rater validity</p> <p>Acceptable internal consistency (Chronbach's <math>\alpha &gt; 0.7</math>)</p> <p>Satisfactory correlation coefficient with FIM</p> <p>More sensitive to change than FIM</p> <p>Validity needs to be confirmed with bigger samples</p> <p>Cost: free</p>	<p>30 minutes</p>	100	Translated in French, but not validated