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SPECIAL COMMUNICATION

Rehabilitation After Surgical Reconstruction to Restore Function to the Upper Limb in Tetraplegia: A Changing Landscape

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Abstract

Upper limb reconstructive surgical procedures for individuals with tetraplegia are performed in many centers internationally. Most recipients of surgery return to local communities and nonsurgical centers for postoperative rehabilitation and long-term follow-up. This supplement focuses on the clinical significance of upper extremity reconstruction, addressing issues related to the availability and choice for surgery, preoperative assessments, postoperative training paradigms, and appropriate outcome measures. Comprehensive intervention protocols are described in terms of dose, timing, specific activities, modalities, and related outcomes. Shared knowledge of current rehabilitation practice, as it relates to reconstructive surgery, can expand treatment options communicated to patients, increase the availability of postoperative muscle reeducation programs, and motivate long-term follow-up assessments.

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Restoring upper limb function is rated among the highest priorities for individuals with cervical spinal cord injuries (SCIs).[1,2] Reestablishing active grasp and pinch strength to the hand has a profound effect on independence, the ability to return to work, participation in society, and quality of life. Even small improvements can be the difference in whether an automated teller machine card can be retrieved or a mobile device can be accessed. Health care providers address this challenge with innovative strategies that include both surgical and nonsurgical approaches. Therapies that aim to restore or reorganize spared neural circuitry with physical activity and practice, either alone[3,4] or in combination with sensory stimulation,[5] robotic-assisted training,[6,7] or repetitive transcranial magnetic stimulation,[8] are exciting possibilities for those individuals with incomplete injuries. For those with motor complete classification of SCI, reconstructive surgery (eg, tendon or nerve transfer) and implanted neuroprostheses are the primary methods for reanimating motor function in the upper limb.[9-13] Postoperative therapy is critical to achieving a successful functional outcome; therefore, the availability of rehabilitation expertise is an important criterion for surgery. Even though functional outcomes are due to the combined effects of surgery and postoperative therapy, descriptions of surgical techniques (see references in Dunn et al[14]) and outcome measures dominate the literature.[15,16] Specific guidelines for postoperative training paradigms are not available.

Reconstructive surgery is often perceived as a specialized area of expertise dominated by knowledge of surgical techniques and advanced through biomechanical research. In centers where surgical expertise does not exist, enthusiasm for integrating upper limb surgery into the plan of care for patients with tetraplegia is also less likely to exist. Nonetheless, many recipients of surgery return to local communities and nonsurgical centers for postoperative care and long-term follow-up. After surgery, voluntary strength is restored to muscles distal to the injury level that were paralyzed or weak when the level and severity of SCI was classified. Reestablishing strength to select muscle groups enables surgical recipients to participate in interventions that incorporate similar activity and task-specific training techniques under investigation for those with incomplete injuries. The collection of articles in the *Archives* supplement is an opportunity for clinicians who partner directly with surgeons to communicate current trends

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in practice associated with surgical procedures. With this shared knowledge, we hope to expand the treatment options communicated to patients, increase the availability of postoperative muscle reeducation programs for surgical recipients, and motivate long-term follow-up assessments of upper limb function for individuals with cervical SCI.

The society of professionals who specialize in surgical restoration of hand function share clinical and research experience at the International Conference on Surgical Rehabilitation of the Upper Limb in Tetraplegia. The conference brings together multiple disciplines, including surgeons, biomedical engineers, physicians, and therapists, every 3 years. The programming encompasses advancements in surgical procedures, applied biomechanics, evaluation procedures, and clinical outcomes. At the 2013 meeting in Hong Kong, presentations from the therapist symposium highlighted emerging themes for improving preoperative assessments, postoperative training, and multicenter collaborations as they relate to surgical reconstruction. Findings from the work presented in the symposium are reported in this supplement. There was also broad recognition that without documentation of current treatment protocols and associated outcomes, it would be impossible to demonstrate the benefits of new treatment approaches. The need to document the accumulated experience in pre- and postoperative aspects of care related to surgical intervention inspired collective enthusiasm for disseminating site-specific information of postoperative therapy protocols. This effort will contribute to advancing upper limb rehabilitation practice by enabling objective evaluation of novel treatment approaches, interpreting outcomes from multicenter studies, and comparing tendon transfer outcomes with nonsurgical approaches to upper limb rehabilitation.

General principles of surgical rehabilitation

The series of articles in this supplement is introduced with an overview of the general principles that guide surgical rehabilitation. The article by Dunn et al[14] is a brief description of the process for identifying surgical candidates, a description of functional goals of surgery, and a summary of common procedures, postoperative rehabilitation strategies, and expected outcomes. These topics outline the focus of subsequent articles that describe surgical rehabilitation practice in greater detail and reduce the need to restate general principles in each article. Dunn brings attention to both surgical and nonsurgical aspects of the rehabilitation process based on clinical experience and international published literature.

Making the choice for surgery

Health care providers have a key role in assisting patients to make informed decisions that fit with their individual needs. Previous studies have reported an underutilization of surgeries to restore upper limb function in tetraplegia.[17,18] That is, individuals who are candidates to receive surgery do not undergo the procedure.

List of abbreviations:

FES **functional electrical stimulation**
SCI **spinal cord injury**

Two articles in the supplement direct attention to eliminating unnecessary barriers in the delivery of care and empowering patients to make informed choices. In a special communication, Punj and Curtin[19] identify patient, provider, and health care system barriers, shown to influence an individual's choice and the availability of resources to receive surgical intervention. Overcoming the existing barriers through interdisciplinary collaboration and timely patient education can make surgical options available to all patients who are appropriate candidates.

A conceptual framework of the decision-making process for upper limb surgery follows in an article by Dunn et al.[20] This work uses a semistructured interview of persons with chronic tetraplegia to explore the decision-making process and the issues affecting their choice to undergo surgery. The significance of Dunn's work is to deepen our awareness, from the patient's perspective, of the complex and often competing priorities that challenge individuals with tetraplegia as they consider their options. Greater awareness of the patient's concerns will assist health care providers to more effectively guide patients in developing their personal strategy for upper limb rehabilitation.

Matching the patient to the intervention

Treatment paradigms (surgical and nonsurgical) for improving upper limb function vary according to the level and severity of the SCI. In particular, the classification of injuries as complete or incomplete has a profound effect on what options are under consideration for upper limb rehabilitation. Because of the heterogeneity of this patient population, methodology that helps to identify specific mechanisms of paralysis has the potential to improve individualized treatment plans and to identify patients with similar characteristics for comparing treatment interventions.

Differentiating upper versus lower motor neuron damage results in a more complete characterization of functional changes after SCI with objective criteria to stratify individuals within a broader classification. Bryden et al[21] report the advantages of including an early assessment of lower motor neuron integrity with surface electrical stimulation. Examples of surgical and nonsurgical interventions that benefit from assessment of the lower motor neuron include functional electrical stimulation (FES), task-based therapy, and nerve transfer. Implementing methods for stratifying patients according to neurologic characteristics will accelerate the process of selecting the optimal intervention and understanding the determinants of therapeutic outcome.

After surgery: current postoperative treatment practices

Three international multicenter studies detail therapy protocols after tendon transfer procedures to restore pinch,[22] grip,[23] and elbow extension.[24] In a separate article, Wangdell and Fridén[25] describe therapy after tendon lengthening and release procedures that aim to reduce the effects of spasticity and improve the ability to open the hand. The articles state unpublished comprehensive descriptions of the timing, dose, specific activities, progression, and follow-up care related to specific surgical procedures. Each article also reports functional measures (postoperative strength and a self-reported activity measure) to quantify the outcome of surgery and postoperative therapy protocols. The multicenter studies exemplify the benefits of using equivalent postoperative