Rehabilitation of the patient with chronic critical illness

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Critical illness (CI) or injury has been defined as a medical condition that impairs one or more vital organ system, jeopardizing the patient’s survival. For the physician, CI involves highly complex decision making, extensive interpretation of medical data, and application of advanced technology to stabilize the patient. Patients with CI are usually managed in the Intensive Care Unit (ICU). Unfortunately, not all CI medical problems can be resolved, although many can be managed effectively with modern technology and interventions. Many reasons, primarily financial constraints and demand for ICU beds, often make it necessary to discharge seriously ill patients from the ICU with multiple unresolved medical problems and in need of continuing complex medical care including mechanical ventilation. These are the patients with chronic CI (CCI). Following discharge from the ICU, these patients may be cared for on the medical/surgical wards of the hospital until their death or, if they survive, until they can be discharged, either to long-term acute care facilities or to home. Depending on their exact medical condition, patients with CCI may be in need of renal dialysis, cardiac pacing, parenteral nutrition, gastric intubation, and monitoring of cardiopulmonary functions, hematologic findings, electrolyte status, and so on, in addition to mechanical ventilation. Most of these patients have indwelling urinary bladder or intravenous catheters and a variety of monitoring devices.

Besides life-threatening medical illnesses, patients with CCI experience profound deterioration of function and quality of life [1–4], and their families...
are faced with major emotional and financial burdens. Extended bed rest and immobilization results in well-known adverse physiologic alterations [5,6] and secondary medical complications, which may further jeopardize health, mobility, and self-sufficiency (Table 1). Most patients with CCI have profound functional deficits that interfere with self-care, mobility, and safe discharge to home. These need to be addressed early and managed aggressively, especially when prognosis for survival is good. Several risk factors for mortality among patients with CCI have been identified, that is, advanced age, diabetes mellitus, renal failure, and dependence in mobility and activities of daily living (ADL) before hospitalization [1,3,4,7]. Although life-saving efforts continue, a careful evaluation of prognosis for survival, as well as of the functional potential for each patient with CCI is needed to formulate realistic goals and plans. If the CCI can be effectively managed, sustained rehabilitation interventions may have an important impact on the ultimate function, quality of life, discharge destination, and the burden of care for family and society. Optimal care of the patient with CCI will require early intervention and effective collaboration between the intensivist and the physiatrist, that is, the medical specialist in Physical Medicine and Rehabilitation.

**Rehabilitation medicine process**

The goal of rehabilitation medicine is to achieve the maximum restoration of physical, psychologic, social, vocational, recreational, and economic functions within the limits imposed by the illness and the physical/mental impairment. To address and improve such diverse functions, the input of a well-coordinated and goal-oriented interdisciplinary rehabilitation team is required (Table 2). Due to the uncertain medical prognosis of patients with CCI, rehabilitation interventions primarily focus on preventing complications, maximizing mobility and self-care, as well as providing psychosocial support. Flexibility in setting rehabilitation

<table>
<thead>
<tr>
<th>Organ systems</th>
<th>Conditions</th>
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<tbody>
<tr>
<td>Muscles</td>
<td>Reduced strength, endurance, flexibility and bulk</td>
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<tr>
<td>Joints</td>
<td>Reduced flexibility; joint contractures</td>
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<tr>
<td>Bones</td>
<td>Osteopenia and osteoporosis</td>
</tr>
<tr>
<td>Heart</td>
<td>Reduced stroke volume, cardiac output, and exercise capacity tachycardia</td>
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<tr>
<td>Peripheral circulation</td>
<td>Reduced orthostatic tolerance and venous return; deep vein thrombosis</td>
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<tr>
<td>Lungs</td>
<td>Atelectasis and pneumonia; pulmonary embolism</td>
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<tr>
<td>Gastrointestinal tract</td>
<td>Reduced appetite and bowel motility; constipation</td>
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<tr>
<td>Urinary tract</td>
<td>Urolithiasis, infection</td>
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<tr>
<td>Skin</td>
<td>Pressure ulcers</td>
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<tr>
<td>Endocrine</td>
<td>Reduced endorphin production and insulin sensitivity; reduced lean body mass; obesity</td>
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<tr>
<td>Psychologic</td>
<td>Reduced self image and stress tolerance; anxiety and depression</td>
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Table 1
Adverse effects of immobilization on different organ systems
goals and providing of therapy is important due to the patient’s changing needs, stamina, and medical status.

**Interdisciplinary rehabilitation team**

The exact composition of the interdisciplinary rehabilitation team (Table 2) may vary considerably, depending on each program’s philosophy and size, and the range of disabilities served. The roles of various team members are described below.

The physiatrist directs the rehabilitation team and is its primary link with other treating physicians. To establish realistic goals and prescribe an appropriate rehabilitation program, the physiatrist needs to know the details of the diagnosis, impairment of different organs, the patient’s life expectancy, and the details of the medical–surgical treatment plan. The physiatrist presents this information to the rehabilitation team as the foundation for developing a specific and realistic plan for treatment and discharge. The physiatrist discusses the goals of the rehabilitation team with the patient and family on a regular basis, and coordinates all treatment efforts, considering the patient’s progress and changing needs.

The rehabilitation nurse evaluates the patient’s specific nursing needs and care, identifies needed nursing supplies, educates other nurses, the patient, and the family about different nursing techniques and principles of treatment, facilitates patient and family involvement, and assists in the discharge process.

The physical therapist instructs and assists the patient to perform specific exercises to strengthen muscles, to increase endurance, and to maintain or improve joint range of motion and trunk flexibility. Training often involves improvement of balance, gait, and coordination, and most important, of functional skills, that is, bed mobility, transfers in and out of bed, wheelchair propulsion, and safe ambulation with or without assistive devices. The physical therapist may employ various physical modalities to reduce pain, for example, superficial and deep heat, cold, electrical stimulation and massage, but the most important therapeutic modality is physical exercise.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>The interdisciplinary rehabilitation team</th>
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<tbody>
<tr>
<td>Physicians (physiatrist; consultants)</td>
<td>Rehabilitation nurse</td>
</tr>
<tr>
<td>Physical therapist</td>
<td>Occupational therapist</td>
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<tr>
<td>Speech–language pathologist</td>
<td>Social worker</td>
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<tr>
<td>Psychologist</td>
<td>Psychologist</td>
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<tr>
<td>Vocational counselor</td>
<td>Recreational therapist</td>
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<tr>
<td>Physical therapist</td>
<td>Nutritionalist</td>
</tr>
<tr>
<td>Speech–language pathologist</td>
<td>Prosthetist/orthotist</td>
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<tr>
<td>Social worker</td>
<td>Respiratory therapist</td>
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<tr>
<td>Psychologist</td>
<td>Patient and family</td>
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</table>
The occupational therapist emphasizes upper extremity exercises and training in self-care activities. These exercises are designed to improve strength, coordination, and skills in the various ADLs (Table 3). Different adaptive equipment, both low tech and high tech, may be provided to make the patient more skillful in ADL and communication. When indicated, the therapist may fabricate simple orthotic devices, such as hand splints for immobilization or compensation for weak muscles. When brain dysfunction is present, the therapist performs gross assessment of cognitive and visual perceptual skills, and provides therapy to compensate for deficits in these areas. Frequently, the therapist evaluates the home and makes recommendations to make it more accessible and more conducive to self-sufficiency and productivity.

The speech–language pathologist assesses and provides interventions for impaired oral communication, and works closely with the occupational therapist and nutritionist in the evaluation and management of swallowing disorders.

The social worker evaluates the patient’s support system, counsels patients and families during discharge planning, and helps them to identify financial resources, including health insurance coverage, social security and disability compensation, and authorizations or payments for necessary devices and services. The social worker will facilitate a smooth transition from the hospital to the home or a long-term care facility, ensuring continuity of care and appropriate follow-up services.

The psychologist evaluates the patient’s cognition and behavior, including motivation and coping skills. The psychologist counsels the patient and the family, and helps them to manage emotional reactions.

A vocational counselor participates in the rehabilitation of those patients who have the potential to return to school or work, which would be less likely for patients with CCI. The vocational counselor evaluates, counsels, and tests patients for their abilities and explores and assists in planning for vocational activities.

A recreational therapist evaluates the needs and interest of the patient who participates in different vocational activities to enhance socialization, leisure time activities, and positive attitudes.

The nutritionist evaluates the patient’s nutritional condition, metabolic demands, and total calorie intake required, and recommends the optimal diet considering the specific clinical condition.

<table>
<thead>
<tr>
<th>Activities of daily living</th>
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<tr>
<td>Moving in bed</td>
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<tr>
<td>Transferring in and out of bed</td>
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<tr>
<td>Bathing and grooming</td>
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<tr>
<td>Dressing and undressing</td>
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<tr>
<td>Eating and drinking</td>
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<tr>
<td>Toileting for bladder and bowel functions</td>
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<tr>
<td>Walking, wheeling, and climbing stairs</td>
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The prosthetist/orthotist may be requested to make artificial limbs (prostheses) or special braces (orthoses) for patients who need them for increased function or comfort, and are able to use such devices.

The respiratory therapist will provide the primary care responsibilities for all respiratory care treatment. In addition, the respiratory therapist may be involved with teaching the patient and family about their respiratory care needs.

Rehabilitation in the ICU

Rehabilitation interventions should be initiated as early as possible after the critically ill patient is admitted to the ICU. Interventions should include exercises to maintain joint range of motion and muscle strength, proper bed positioning to prevent pressure ulcers and compression neuropathies, and pulmonary care. Provision of more complex rehabilitation interventions in the ICU may be limited by the patient’s medical condition, surgical procedures, monitoring and intravenous lines, various tubes or drains, staff shortage, the patient’s ability to participate, etc.

Proper positioning in bed, frequent changing of position, and thoughtful selection of a bed mattress can reduce the risk of pressure ulcers. When the patient is kept lying in the supine position for long periods, the following areas are at increased risk for developing pressure ulcers: occiput, rim of ears, dorsal thoracic area, elbows, sacrum, coccyx, and heels, with the last three areas of greatest risk. When lying on the side, the following areas are at increased risk for developing pressure ulcers: side of head, shoulders, perineum, ischium, trochanter, anterior knee, and lateral malleolus, the trochanteric region being at greatest risk [8].

Patients with CCI are at risk for developing compression neuropathies. The two most common compression neuropathies involve the ulnar nerve at the elbow’s retrocondylar groove and the peroneal nerve as it winds superficially over the fibular neck. Involvement of the ulnar nerve is associated with sensory deficits on the volar and dorsal surfaces of the fourth and fifth digits and weakness of the palmaris brevis, abductor digiti minimi, and flexor digiti minimi muscles, resulting in weakness of finger adduction and abduction. Involvement of the peroneal nerve is associated with weakness of ankle dorsiflexion and eversion and numbness of the lateral aspect of the leg and dorsum of foot [9]. Because patients in the ICU are often sedated or have decreased cognitive awareness, the motor and sensory deficits from these compression neuropathies may not be apparent for some time. Proper bed positioning and frequent turning may limit the incidence and severity of these neuropathies.

Proper bed positioning and frequent change of position may also help to limit the number and severity of joint contractures. Any patient who requires prolonged bed rest is at risk for developing joint contractures. The most frequently involved areas of the body include: neck in flexion, shoulders in adduction and internal rotation, elbows in flexion, wrists in flexion, fingers in flexion, hips in flexion and
external rotation, knees in flexion, and ankles in plantarflexion [9]. Joint contractures may be painful, and often make nursing care and proper bed positioning difficult. If there is any degree of recovery from the acute medical illness, such contractures will limit the patient’s mobility and self-sufficiency.

If the medical and surgical condition can be stabilized and the patient with CCI becomes free of major medical complications, a more comprehensive rehabilitation approach may be indicated.

Rehabilitation after ICU

The next phase of the rehabilitation process depends on each hospital’s capabilities and referral options, as well as on the medical condition of the patient. Hospitals today face great economic pressures to reduce length of stay in the ICU and overall in the hospital. When a patient with CCI is judged able to be moved from the ICU, transfer may occur to a general medical ward, a respiratory care unit, an acute inpatient rehabilitation facility, a subacute rehabilitation facility, or a long-term nursing care facility [3].

Some acute inpatient rehabilitation facilities accept patients who are ventilator dependent, provided they meet other admission criteria; such patients should be generally medically stable and physically and mentally able to participate in different individual or group rehabilitation therapies for a minimum of 3 hours per day, at least 5 days per week. The facility must be able to provide respiratory care, and facilitate weaning off the respirator. It must have physicians capable of managing a host of complex medical conditions and an easy 24-hour access to a range of diagnostic and interventional services. This type of rehabilitation facility is more likely to be within a hospital than a free standing unit.

An acute inpatient rehabilitation facility provides the most comprehensive and intensive services, and generally has most of the disciplines represented on the interdisciplinary rehabilitation team (Table 2), most of whom will participate in the care of each patient. The team sets rehabilitation goals for each patient, considering both prehospital and current functional level as well as the medical condition of the patient. A treatment plan is developed in an initial team conference and adjusted on a weekly basis according to the patient’s progress, which must be measurable to justify continued stay. Specific rehabilitation goals are established, equipment needs are assessed, and a discharge disposition and date are predicted. For example, goals for a patient with CCI could include independence in transfers to and from bed, independence in powered wheelchair mobility with a portable ventilator, independence in ADL, and/or weaning from the ventilator.

Subacute inpatient rehabilitation facilities will provide less comprehensive and intense services, but will have at least 24 hours of nursing care and 1 hour of rehabilitation therapies daily. Such facilities are usually housed within free-standing skilled nursing facilities, and therefore, patients must be medically stable, even if still ventilator dependent. Although the team must set specific
rehabilitation goals, progress towards these goals does not need to be as rapid, as in an acute inpatient rehabilitation facility and the length of stay can be longer. Home rehabilitation therapies can be provided for the few persons with CCI who are discharged from institutions to home [3]. A visiting nurse will evaluate the patient in the home and arrange for various services in conjunction with the referring physician, for example, a home health aide, physical, occupational, and/or speech therapies, etc, two to three times per week for 30 to 60 minutes each session. Goals for home-care patients depend on each patient’s condition, but especially on the respiratory status and functional level.

Orthoses (splints) can be applied to ensure proper joint positioning and provide pressure relief when a patient is unable to actively move a joint through its full range of motion. Orthoses can be custom made from a variety of plastics and cloth materials by the therapist or an orthotist, or prefabricated and used off the shelf. The most common splints for the upper extremity are for the wrist and finger joints. The conventional resting splint keeps the wrist in a neutral or slightly extended position (15 degrees), and the fingers flexed (20–40°), with the thumb placed in opposition to the other four fingers [9]. The ankle joint is the most commonly splinted joint in the lower extremity, with the foot and shin usually positioned at 90° to each other to prevent a plantarflexion contracture. Pressure relief is simultaneously provided for the heel. Such orthosis may also have a derotation bar attached to prevent external rotation of the extremity from the hip, which may increase the risk for developing peroneal nerve compression neuropathy or pressure ulcers of the greater trochanter or lateral malleolus.

For any patient with CCI, it is important to maintain functional range of motion of all joints. Joint capsules, muscles, tendons, and ligaments must be moved regularly to maintain their pliability. If a joint is immobile for any length of time, the surrounding connective tissues will stiffen quickly, and a contracture may easily develop [9]. If a patient is unable to actively move, physical and/or occupational therapists, nursing staff, and even family members can provide active assistive or passive range of motion exercises in the ICU or another setting. However, the amount of such exercises needed to prevent contractures is not known [9]. In general, for daily exercise sessions each joint should be moved through its full range of motion 10 times. These exercises do not usually affect vital signs, such as heart rate and blood pressure [10]. Ventilator tubes, intravenous catheters, drains, and monitoring devices may limit the therapist’s ability to provide range of motion exercises to all joints.

During the period of bedrest, physical and/or occupational therapists can assist the patient to perform various strengthening exercises as tolerated, teach proper breathing techniques, facilitate bronchial drainage, encourage proper bed positioning, secure skin pressure relief, and educate the family and nursing staff on these matters. When the patient is permitted to get out of bed, therapists will teach techniques for bed mobility, transfers between bed and chair, and ADL as permitted by the medical condition and in collaboration with the ICU nurses aiming to have the patient return to the premorbid functional level as quickly as possible.
Common complications of critical illness may affect the rehabilitation process. Some of these, such as critical illness polyneuropathy (CIP) and pressure ulcers are covered in other chapters. Here we address specifically the rehabilitation implications of those conditions, as well as other conditions not separately discussed.

Critical illness polyneuropathy (CIP) affects predominantly motor, rather than sensory, axons and is often felt to be the result of a systemic inflammatory response to sepsis [11], although other causes exist [12]. Cytokines and free radicals released during sepsis are known to have an adverse effect on the microcirculation of the peripheral and central nervous system, damaging the myelin of the peripheral nerves [11].

This is to be distinguished from the effect on nerves found in muscles with disuse atrophy alone. It is known that polyphasic potentials account for as much as 25% of all action potentials during disuse. This is in contrast to the 1–3% polyphasic potentials in normal muscle [13]. Spontaneous activity is not seen with disuse atrophy without superimposed denervation of the muscle.

Electrodiagnostic studies are useful in differentiating etiologies of muscle weakness due to either nerve or muscle pathology. Physiatrists or neurologists can perform these studies at the bedside. Electrodiagnostic studies have two main components, nerve conduction studies and electromyography. Nerve conductive studies are performed by stimulating various motor and sensory nerves and recording their electrical responses for analysis. During nerve conductive studies, compound muscle action potentials and sensory nerve action potentials (SNAPs) are recorded and compared to known norms. Electrodiagnostic studies at the bedside may be limited by electrical interference from various devices, accessibility to the patient, and the patient’s ability to cooperate. Electromyography consists of inserting tiny recording needle electrodes into skeletal muscles and recording their electrical activity during rest and voluntary muscle contraction for analysis. Because CIP usually involves an axonal motor and sensory polyneuropathy, findings usually include reduced compound muscle action potentials, SNAPs, as well as denervation potentials. Because SNAPs may be deceivingly low in patients with significant tissue edema, certain techniques must be performed to attribute the low SNAPs to CIP. Phrenic nerve conduction and needle electromyography of the chest wall and diaphragm muscles may be helpful to identify CIP as a cause of difficulty weaning from the ventilator. If the inflammatory response to sepsis can be treated effectively, a degree of recovery from CIP can be expected, lasting from weeks to months, during which the patient would benefit from rehabilitation therapies [11]. Initially, these therapies should concentrate on preventing contractures by using range of motion exercises, proper positioning, and splinting. As the condition improves, the patient can participate in a strengthening program. Care should be taken to avoid overworking these muscles before they are able to function at greater than antigravity strength. The patient can then be progressed to more advanced training in their activities of daily living and ambulation.
Disuse also causes a decrease in muscle strength along with a decrease in cross-sectional area in the muscle fibers. This results in a decrease in maximal attainable muscle tension and loss of muscle weight [14,15]. This muscle wasting is due to a decrease in muscle protein synthesis rather than an increase in muscle breakdown [16]. As a result of this decrease in muscle mass and maximal attainable muscle tension, the muscles fatigue easily with work.

Critical illness myopathy (CIM) is an acquired disorder of muscles that has become more prevalent with increased survival of patients with CI [17]. The clinical symptoms are symmetrical muscle weakness, greater proximally than distally, but sensation is not affected. Major risk factors for CIM include administration of intravenous corticosteroids, neuromuscular junction blocking agents [17,18], and sepsis, which may cause a generalized reduction in membrane excitability. Besides limb muscles, CIM may affect the diaphragm muscle and cause difficulty with weaning from the ventilator [19].

Clinically, CIM may be difficult to differentiate from CIP and prolonged neuromuscular junction blockade. Electrodiagnostic studies are important to differentiate these three disorders. Nerve conductive studies on patients with CIM will show low amplitude compound muscle action potentials but relatively preserved SNAPs. However, the patient’s medical condition, including the presence of edema, may reduce the amplitude of the SNAPs. Analyses of motor unit potentials by electromyography in a patient with CCI may be difficult due to a patient’s inability to cooperate and move the muscle to be studied. As with other myopathies motor unit potentials will be of low amplitudes and durations, while recruitment of motor units occurs early.

Cardiovascular conditions

Patients with prolonged CI may develop significant changes in cardiovascular function as a result of physical deconditioning caused by prolonged bed rest and immobility. These changes include tachycardia, decreased stroke volume, cardiac output and maximal oxygen uptake, orthostatic hypotension, alterations in the body fluid balance, and venous stasis with increased risk for deep vein thrombosis [20]. Many of these changes may be reduced or reversed by effective rehabilitation interventions. Much of the following data has not been derived from studies of CCI populations; some differences may be seen among those patients with CCI, who are typically elderly and often have multiple chronic and acute comorbid conditions, including cardiovascular disease.

Altered cardiac function

Historical studies, typically in young healthy men, indicated that the heart rate at rest increases by one beat every 2 days during the first 4 weeks of immobilization [21–23]. After 6 weeks of bed rest, the increase in heart rate in response
to head up tilt from supine position may be as much as 89%, apparently related to imbalance of the autonomic nervous system [22,24]. After prolonged bed rest, there is a higher heart rate during any given level of submaximal exercise, although the maximum heart rate is unchanged or only slightly increased. The heart rate response to submaximal exercise may be as much as 30 to 40 beats per minute greater than expected after only 3 weeks of bed rest. With faster heart rates, the diastolic filling period and absolute systolic ejection time of the cardiac cycle are shortened, stroke volume is reduced, and myocardial perfusion is decreased, which may precipitate angina in patients with pre-existing coronary artery disease [22,24,25].

The decrease in stroke volume associated with physical deconditioning at submaximal and maximal exercise averages 30%, but due to increased heart rate the cardiac output declines only slightly at submaximal exercise, but more significantly, (average 26%) at maximal exercise [22,24]. Maximal oxygen uptake (VO$_{2\text{max}}$), an indicator of general aerobic fitness, is reduced by bed rest, as is the submaximal VO$_2$ [23,26]. Physical deconditioning produces an increase in the arteriovenous oxygen difference with submaximal, but not with maximal, exercise [22]. There is no significant change in the total peripheral resistance and mean arterial pressure at rest or during exercise after bed rest. In the deconditioned person, it takes longer for the heart rate to return to the resting state after a period of exercise than in an able bodied person [5].

The ideal treatment of cardiovascular deconditioning is prevention. Avoiding prolonged bed rest and complete immobility, to the extent possible, is important. Even sitting daily in a chair helps prevent the decreases of stroke volume, cardiac output, and VO$_{2\text{max}}$ as well as orthostatic intolerance that occurs with bed rest. Isometric exercises have also been shown to minimize the decline of VO$_{2\text{max}}$ as well as the loss of plasma volume [26,27]. Leg ergometer exercise has been shown to maintain VO$_{2\text{max}}$ and to reduce the decrease in plasma volume and red blood cell volume while on bedrest. Supine exercise does not appear to prevent orthostatic intolerance, even when plasma volume is maintained [25,28].

The effects of cardiovascular deconditioning can be reversed by progressively increasing activity and regaining the upright posture. This can be done initially with passive and active range of motion exercise in bed and with a tilt table. Later, more aggressive activity is promoted [9].

A number of studies, of previously active male subjects, have assessed the effects of training on cardiovascular function following prolonged bed rest. In general, it takes at least twice as long to recover from disuse as it did to deteriorate, for example, to reverse the decline in VO$_{2\text{max}}$ caused by 20 days of bed rest in previously active subjects by intensive retraining [29]. In a study by Dietrick et al [5], resting heart rate returned to near normal levels with training during a time period approximately equal to the duration of disuse. After 3 to 4 weeks of immobilization, heart rate recovery after exercise is only 50% of normal by 16 days, but becomes normal by 36 days. Submaximal VO$_2$ recovers to normal between 16 and 36 days [5,22].
Orthostatic hypotension

In a healthy individual, immediate peripheral vasoconstriction and a rise in heart rate and systolic blood pressure occur with head-up tilt, compensating for the effects of venous pooling. After prolonged bed rest, a person loses this adaptation and develops an orthostatic intolerance. Blood pools in the legs, venous return decreases, stroke volume is diminished, heart rate rises, and the systolic blood pressure is not maintained in the erect position. This may be due to an altered carotid baro-reflex and autonomic balance [23,28,30]. Clinically, this is accompanied by the common signs and symptoms of orthostatic hypotension, that is, a feeling of light-headedness, nausea, dizziness, sweating, pallor, tachycardia, and hypotension [23].

Neurovascular deconditioning appears to occur mostly during the first 4 to 7 days of bed rest [31,32], and even more rapidly in the elderly and the medically frail. With resumption of physical activities, it may take twice as long to reverse these changes as it took for them to develop [23].

Although it may be difficult or impossible in the care of the chronically critically ill patient, the most effective way to counter orthostatic hypotension is early mobilization, which should include passive and active range of motion exercises, strengthening exercises in supine and upright positions, and progressive ambulation. Abdominal strengthening and isotonic–isometric exercises involving the legs are optimal for reversing venous stasis and pooling. Elevating the leg rests and reclining the back rests on wheelchairs can be used to assist patients during the reconditioning process. Occasionally placing the patient on a tilt table may be necessary, with the goal being the toleration of 20 minutes at 75° of tilt. Supportive garments, such as elastic bandage wraps, full-length elastic stockings, and a variety of abdominal binders may be helpful [33]. Maintaining an adequate salt and fluid intake is important, and will prevent worsening of hypotension secondary to blood volume contraction [34].

Fluid imbalance

As a result of prolonged bed rest, there is a shift in blood volume to the thorax and a delayed shift of extravascular fluid into the circulation. This causes a compensatory diuresis, which leads to a decreased plasma volume. Because red blood cell mass remains unchanged, hematocrit initially rises and blood viscosity increases. Over the course of 2 to 4 weeks, red blood cell mass decreases and hematocrit begins to fall. During this time period, the loss of plasma volume is proportionally greater than the loss of red blood cells. Later, red blood cell losses will exceed plasma losses [35,36]. Again, one must be cognizant of the fact that many CCI patients have renal dysfunction, hypoalbuminemia, and other factors that may alter their physiology.

Plasma volume loss is approximately 10% after 1 week of bed rest and 15% by 4 weeks. The decrease in plasma and blood volume continues and most likely plateaus around 70% of normal plasma volume and 60% of normal blood
volume. It is accompanied by a proportionate loss of plasma proteins. There also appears to be a loss of albumin, creatinine, chloride, phosphorus, calcium, potassium, and glucose. Urea nitrogen, globulin, sodium, and osmotic concentration are increased, while uric acid is decreased [28,36].

**Thrombotic disease**

It is well known that immobility causes venous stasis due to reduced muscular pumping of the blood from leg and pelvic veins. Increased blood viscosity may also occur with immobility, which increases the intrinsic predisposition of the blood to clot. Platelet aggregation may be stimulated and blood fibrinogen may be increased as well. Therefore, bed rest is a well-known and significant risk factor for developing thrombotic disease and pulmonary embolism, which may be fatal [37,38].

Simple lower extremity exercises, leg elevation, and active contractions of calf muscles may help prevent deep venous thrombosis. A Cochrane review including both medical and surgical patients, showed that the use of graduated compression stockings was associated with an odds ratio of 0.34 (95% CI, 0.25–0.46) in reducing incidence of deep venous thrombosis [39], although anticoagulation with warfarin or heparin is more effective in preventing deep venous thrombosis than external compression. Typically, the patient with CI has multiple medical comorbidities in addition to immobility. A combination of therapies may be necessary in these patients to prevent thrombotic disease.

**Pulmonary conditions**

Apart from underlying disease conditions compromising pulmonary status, prolonged bed rest may cause serious impairment of respiratory function. The work of breathing is increased in the slumped or supine position due to increased mechanical resistance. As blood pools in the thorax, there is an immediate decrease in total lung and residual volumes. There is a tendency for pooling of mucus in the lower parts of the airway, while upper segments tend to dry out, which predisposes the patient to mucous plugging, atelectasis, and pneumonia. This is aggravated by a decrease in respiratory activity and an impaired cough mechanism [9]. After prolonged bedrest, pulmonary function tests often show increased ventilation and perfusion mismatch. Beckett et al [40] have shown that there is an increase in forced vital capacity and total lung capacity, whereas residual volume, functional residual capacity, maximal ventilatory volume, and maximal minute volume are relatively unchanged. A study on middle-aged men placed on 10 days of bed rest found that ventilatory volume was elevated during maximal and submaximal exercise, and that the exchange ratio was significantly increased during upright submaximal exercise, suggesting that orthostatic stress, not pulmonary function, was the main limiting factor for exercise tolerance after bed rest [28]. Craig et al [41] have shown that a change in position from upright to supine results in a 2% reduction of vital capacity, a 7% reduction of total lung capacity, a 19% reduction in residual volume, and 30% reduction in functional residual capacity. Possible
explanations for these changes include diminished diaphragmatic movement in the supine position, decreased chest excursion, progressive decrease in range of motion of costovertebral and costochondral joints, and shallower breathing with subsequent increase in respiratory rate [41]. The ability to clear secretions is more difficult in a recumbent position. The dependent, usually posterior chest walls, accumulate more secretions, whereas the upper parts usually become dry, rendering the ciliary lining ineffective for clearing secretions and allowing the secretions to pool in the lower bronchial tree. The effectiveness of coughing is impaired both because of ciliary malfunction and respiratory muscle weakness. Regional changes in the ventilation–perfusion ratio in dependent areas occur when ventilation is reduced and perfusion is increased. This may lead to significant arteriovenous shunting with lowered arterial oxygenation. Atelectasis and pneumonia may be the ultimate result of these alterations [33].

The pulmonary deterioration induced by bed rest can be prevented to some extent by frequent changes in position, incentive spirometry, deep breathing, coughing, pulmonary toilet, and aggressive mobilization of the patient [9]. An incentive spirometer, chest percussion, and postural drainage with oropharyngeal suctioning may prevent aspiration and atelectasis [33].

**Metabolic and endocrine conditions**

Often unrecognized in the patient with CCI are multiple metabolic and endocrine changes that occur in response to immobilization and bed rest [42]. A separate chapter of this volume is dedicated specifically to many of these issues. Here, we focus on the potential impact of the immobilization itself, which may be associated with particular changes in body composition, mineral exchange, carbohydrate metabolism, and hormone production. There is a reported 2.3% decrease in lean body mass and 12% increase in body fat in healthy subjects after 5 weeks of bed rest [43]. Energy absorption from food is unchanged, but appetite and water intake is decreased.

Calcium metabolism is normally in a state of dynamic equilibrium with respect to its absorption and excretion. Within 2 to 3 days of bed rest, there is an increase in urinary calcium excretion, reaching maximum in 3 to 7 weeks [44,45]. It is estimated that there is a 0.5% loss of total body calcium that occurs per month during immobilization [46]. Simultaneously, there is loss of phosphorus that parallels calcium loss, beginning in the first week and reaching maximum at 2 to 3 weeks [47]. The increased calcium and phosphorous excretion may lead to hypercalciuria and urolithiasis. Nitrogen loss occurs via urinary excretion and parallels the loss of muscle bulk. Sulfur, sodium, potassium, magnesium, and zinc balances are all affected by bed rest as well [48,49].

Immobility also influences carbohydrate metabolism. Hyperglycemia occurs [50,51], as a result of 50% decrease in peripheral muscle sensitivity to circulating insulin, occurring within 2 weeks of bed rest [52]. Consequently, there is a rise in serum insulin levels, but it is not adequate to reduce the hyperglycemia.
Additional effects on the endocrine system during bed rest are seen in the adrenocortical steroid pathways, with changes in circulating glucocorticoids. Examples of these changes include an increase in urinary hydrocortisone excretion, increased plasma renin activity, altered growth hormone production, and an alteration in the circadian rhythm [53–55].

There are obvious benefits to preventing and treating whenever possible the mineral, carbohydrate, and endocrine changes associated with immobility and bed rest. With resumption of normal physical activity [56], mineral metabolism requires twice the length of the period of immobilization to return to normal. Carbohydrate metabolism will improve with aerobic exercise by increasing peripheral sensitivity to insulin, resulting in increased cellular uptake of glucose [5]. In type II diabetes mellitus, isotonic and isometric exercises can improve glucose uptake at the end organs. However, the effects on type I diabetes mellitus are not via the peripheral muscle, but lower insulin requirements by utilizing circulating glucose [57,58]. These are important facts to remember during physical rehabilitation when patients will require less insulin than during their acute illness.

Skin conditions

As mentioned previously, the patient’s position will determine where pressure ulcers develop. Pressure ulcers are preventable, but prevention requires a comprehensive care plan, which includes taking a careful history and performing a detailed physical examination, especially of the skin. The Braden or Norton scales have been developed to predict pressure sore risk [59,60]. The Braden Scale uses seven items (mobility, activity, moisture, sensory perception, nutrition, friction, and shear) and the Norton Scale uses six items (physical condition, mental condition, activity, mobility, and incontinence) to calculate a score to help identify those at greatest risk. The Braden Scale has been tested and validated in diverse populations, although not specifically among chronically critically ill patients, and has been found to have high inter-rater reliability [59,60]. These scales can be used by members of the health care team to anticipate risk and plan treatment; with the patient and the family playing an active role; for example, family members can help with turning the patient and inspecting the skin. Some patients can be taught to use mirrors to inspect their own skin and provide pressure relief, but the CCI patient will not usually have this capacity.

Pressure relief consisting of proper positioning of the patient in bed to permit comfort, and to avoid excessive pressure over bony prominences is of paramount importance, and is the responsibility of all who care for the patient. If patients are able to participate in their own care, they should be taught proper positioning techniques. While in bed, the patient with CCI should be moved off areas of pressure at least every 2 hours, and every 30 minutes while sitting [61]. Pressure relieving devices, for example, special mattresses or wheelchair cushions, are available for use in those patients unable to provide adequate pressure relief.
However, these may give a false sense of security, and do not obviate the need for periodic change of position for pressure relief. Once a pressure ulcer has developed, it is imperative to treat it aggressively by surgical or nonsurgical means. The staging and surgical treatment are discussed elsewhere in this volume.

**Genitourinary**

Prolonged bed rest affects the urinary system in many ways, but most significant are increased incidence of urolithiasis and urinary tract infections. Both of these conditions are related to several similar factors [62,63]. Hypercalciuria occurs frequently in persons who are immobilized. Urinary flow is impaired in those on bed rest, and bladder emptying is incomplete, leading to stagnation of urine. In the supine position, urine flows from the kidneys to the bladder, and voiding becomes more difficult than in the sitting or upright position. Bladder distention may lead to overflow incontinence or urethral reflux. In such an environment stones may easily form and bacteria grow. Prevention and treatment consists of securing adequate fluid intake and bladder evacuation. Most CCI patients require indwelling urinary catheters.

**Gastrointestinal**

Bed rest and immobility mechanically affect the gastrointestinal tract as the passage of food is slowed in the supine position. It has been shown that nonviscous, but not viscous materials, pass through the esophagus more rapidly in the upright position than supine [64], and the transit time through the stomach is 66% slower in the supine position than when standing. Bed rest also results in decrease of appetite, reduced peristalsis, slower rate of absorption, and an increase in symptoms of gastroesophageal reflux [32,65]. An obvious side effect of bed rest is the potential embarrassment and discomfort associated with soiling the bed or using the bedpan, which may lead the patient to delay defecation and contribute to constipation, a common complication of bed rest, and ultimately to fecal impaction.

The patient with CCI at bed rest should have an adequate intake of fluids and a fiber-rich diet, which help to assure softness and proper bulk of the stools. Stool softeners may be helpful, but long-term use of laxatives and enemas should be avoided. Patients should be encouraged to use bedside commodes and the bathroom toilets when medically feasible. This will not only assist with bowel evacuation, but may increase the patient’s sense of dignity.

**Psychologic conditions**

Patients with CCI in the ICU may develop various psychologic reactions, such as anxiety, depression, altered cognition, and delirium [66,67]. Management of these conditions are discussed in another article.
## Functional Independence Measure (FIM)

<table>
<thead>
<tr>
<th>Levels</th>
<th>Description</th>
<th>NO Helper</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Complete Independence (Timely, Safely)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Modified Independence (Device)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Supervision</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Minimal Assist (Subject = 75%+)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Moderate Assist (Subject = 50%+)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Maximal Assist (Subject = 25%+)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Total Assist (Subject = 0%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complete Dependence</td>
<td>HELPER</td>
</tr>
</tbody>
</table>

### Self Care
- A. Eating
- B. Grooming
- C. Bathing
- D. Dressing: Upper Body
- E. Dressing: Lower Body
- F. Toileting
- G. Bladder Management
- H. Bowel Management

### Mobility
- I. Bed, Chair, Wheelchair
- J. Toilet
- K. Tub, Shower

### Locomotion
- L. Walk/wheel Chair
- M. Stairs

### Communication
- N. Comprehension
- O. Expression

### Social Cognition
- P. Social Interaction
- Q. Problem Solving
- R. Memory

Total FIM

NOTE: Leave no blanks; enter 1 if patient not testable due to risk.

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Fig. 1.
Evaluation of functional performance

A medical treatment is not indicated if no measurable benefits will result. Unlike some other fields of medicine, the outcome of rehabilitation treatments is not judged mainly by survival or by the elimination of symptoms. The effectiveness of rehabilitation treatments is measured by the patient’s improvement in functional performance. To evaluate and monitor function accurately, the performance in the various ADLs (Table 3), mobility and communication must be numerically rated according to the patient’s level of independence. Although several functional evaluation scales have been used, the scale that has gained the widest acceptance is the Functional Independence Measure (FIM) (Fig. 1). The FIM focuses on six main areas of functioning: self-care, sphincter control of bladder and bowel, mobility (especially the ability to transfer), locomotion, communication, and social cognition. Each of these six areas of functioning has its own subfunctions, for a total of 18 functions. Each of these 18 functions is evaluated and rated using a seven-point scale with respect to independence or dependence, for example, from 1, when total assistance is required, to 7, when complete independence has been achieved. Consequently, a higher score signifies better function. The sum of the performance of these 18 functions represents the FIM total score, which gives a good idea of the cost of the disability in terms of safety, the person’s dependence on others, and need for assistive devices. The FIM score is recorded both on admission and on discharge to the rehabilitation unit, and in some instances periodically in between.

Payments for inpatient rehabilitation

Inpatient rehabilitation services have traditionally been reimbursed on a per diem basis, but on January 1, 2002, the Federal Government implemented a new inpatient Rehabilitation Facility Prospective Payment System (IRF-PPS), for Medicare Part A beneficiaries. This payment system, which will be phased in over 2 years, may also be used for Medicaid beneficiaries, and ultimately many private insurances may follow suit. As in the case with other PPSs, the IRF-PPS will pay hospitals per discharge, but not for the actual number of days spent in an inpatient rehabilitation facility. A Federal standard payment rate of $11,838 per discharge has been set, but this rate is adjusted by case mix and facility level. The IRF-PPS uses a patient-specific assessment tool known as the IRF-Patient Assessment Instrument to score the ADLs using the FIM (Fig. 1). Completion of this assessment establishes a patient-specific payment case-mix group based on rehabilitation impairment category (Table 4), the patient’s motor and cognitive functions, comorbidities, and age. The exact impact of IRF-PPS on delivery of rehabilitation services is unknown, although it is clear that accurate documentation of the patient’s impairment, function and comorbidities is essential, that effectiveness in delivery of rehabilitation interventions must be ensured, and that
length of stay must be closely monitored and kept to a minimum, to avoid financial loss to the institution.

Summary

Patients with CCI have continuing profound medical needs, poor prognosis for significant functional recovery, and a high mortality rate. Nonetheless, some survive for months or years, but unfortunately, often with functional skills and quality of life lower than need be. Careful evaluation of each patient’s medical condition and potential for functional improvement, early involvement of the rehabilitation team, prevention and treatment of medical conditions associated with prolonged bed rest and immobility, reduction of the emotional and financial burden of family members, and establishment of reasonable goals can increase self-sufficiency and quality of life regardless of discharge destination.

References


Table 4
Rehabilitation impairment categories

<table>
<thead>
<tr>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Stroke</td>
</tr>
<tr>
<td>2 Traumatic brain injury</td>
</tr>
<tr>
<td>3 Nontraumatic brain injury</td>
</tr>
<tr>
<td>4 Traumatic spinal cord injury</td>
</tr>
<tr>
<td>5 Nontraumatic spinal cord injury</td>
</tr>
<tr>
<td>6 Neurologic, eg, multiple sclerosis, Parkinsonism, polyneuropathy, etc</td>
</tr>
<tr>
<td>7 Fracture of lower extremity</td>
</tr>
<tr>
<td>8 Replacement of lower extremity joint</td>
</tr>
<tr>
<td>9 Other orthopaedic conditions</td>
</tr>
<tr>
<td>10 Amputation, lower extremity</td>
</tr>
<tr>
<td>11 Amputation, other (upper extremity)</td>
</tr>
<tr>
<td>12 Osteoarthritis</td>
</tr>
<tr>
<td>13 Rheumatoid and other forms of arthritis</td>
</tr>
<tr>
<td>14 Cardiac impairment</td>
</tr>
<tr>
<td>15 Pulmonary impairment</td>
</tr>
<tr>
<td>16 Pain syndromes</td>
</tr>
<tr>
<td>17 Major multiple trauma without brain or spinal cord injury</td>
</tr>
<tr>
<td>18 Major multiple trauma with brain and spinal cord injury</td>
</tr>
<tr>
<td>19 Guillian-Barre syndrome</td>
</tr>
<tr>
<td>20 Miscellaneous</td>
</tr>
</tbody>
</table>


[27] Birdhead NC, Blizzard JJ, Daly JW, et al. Cardiodynamic and metabolic effects of prolonged bed
rest with daily recumbent or sitting exercise and with sitting inactivity. Ohio Aerospace Medical Research Laboratories: Wright-Patterson Air Force Base (OH), AMRL-TDR-64-61; August 1964.


