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Wagih El Masri(y) and Michael Barnes

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The incidence is increasing in older people, mainly due to falls. Early acute management Appropriate management of the individual at the scene of an

accident is vital to avoid unnecessary worsening of a spinal cord injury. Those who are unconscious should be assumed to have a cervical spine injury, with the head and neck held firmly in a neu- tral position using a semi-rigid collar, and transportation on a spinal board with a head immobilizer. Investigation—spinal cord injury cannot be determined solely by examination, hence radiological investigation is essential. MRI is the best imaging technique. Treatment—injuries to the cervical spine will usually receive skel- etal traction applied through skull calipers; thoracic and lumbar in- juries require simple support of the patient in the correct posture. Surgery may sometime be required (e.g. fusion and internal fixation, anterior or posterior decompression). Steroids are no longer admin- istered routinely. Management in the spinal cord injury centre In the neurologically intact patient, surgery allows the individual to be mobilized and discharged quickly. In the neurologically impaired patient with a multi-system physiological impairment and malfunction the injured cord is physiologically unstable and unable to protect itself from further nonmechanical damage by complications such as hypoxia, hypo- tension, hypertension, ischaemic events, sepsis, or hypothermia, all of which can easily occur due to the sudden autonomic and sensory-motor impairment and loss of blood–brain barrier. There are no studies to demonstrate that surgical

intervention followed by early mobilization is as good as conservative management in terms of short and long-term clinical outcomes (achieving uneventful early mobilization; days spent in recumbence throughout admission; in- cidence of pressure sores, respiratory infections, urinary infections, and other urinary complications; time from injury to completion of particular end points of rehabilitation; incidence of chronic neck or back pain; achieving and maintaining a good painless range of movement of the spine; level of independence and quality of life on discharge) or healthcare costs (days spent in intensive care; period of total hospitalization from injury to first discharge; frequency of readmission and total period of hospitalization during the first five years following first discharge to treat complications). Medical problems during the acute stage include (1) Paralytic Ileus— withhold oral intake until bowel sounds return. (2) Respiratory—regular and frequent chest physiotherapy is vital. (3) Pressure sores—should be preventable.
(4) Bladder—residual urine can predispose to infection or stone formation and contributes to impairment of renal function; failure of bladder emptying requires mechanical drainage, preferably by intermittent clean catheterization; detrusor hyperreflexia is treated with anticholinergics. (5) Bowel care—in the period of spinal shock the bowel remains flaccid and should not be allowed to overdistend. (6) Autonomic dysreflexia—management consists of trying to avoid com- plications and use of antihypertensive agents. (7) Spasticity and con- tractures—passive stretching of the spastic muscles and regular standing regimes can be helpful; antispasticity medication should be used with care because they induce significant tiredness and weakness. (8) Pain and dysaesthesia—usually respond to the use of carbamazepine, tri- cyclic antidepressants, gabapentin, or pregabalin. (9) Risk of venous thromboembolism—prophylactic anticoagulation is advisable. Rehabilitation—a coordinated multidisciplinary team can improve functional outcome, a key element being the setting of realistic goals. Long-term issues A very wide range of medical, physical, emotional, and social issues may need to be addressed. Later medical complications include pressure sores, pathological fractures, vesical and renal complica- tions, post-traumatic syringomyelia and (in those with high cervical cord lesions) respiratory compromise. Prognosis With appropriate management, initial mortality from spinal cord injury is less than 5%. In the acute phase, with expert active physio- logical conservative management (APCM) of the cord injury and all its effects, over 70% of patients presenting with incomplete som- atosensory loss and about 7% of those presenting with complete somatosensory loss will recover to regain ambulation. Most of those with complete somatosensory loss will recover up to three myotomes below the level of the injury, and with ongoing support are able to lead dignified, healthy, fulfilling, enjoyable, productive, and often competitive lives. Life expectancy in paraplegia is modestly reduced, although in- dividuals with tetraplegia still die prematurely, in particular from re- spiratory infection, generalised sepsis and (occasionally) renal failure. Introduction Spinal cord injuries (SCI) are potentially devastating, paralysing life changing events. Below the site of injury, the various systems of the body no longer function normally and become significantly dependent on the reflex activity of the distal spinal cord segments. Function will differ at various stages following injury, especially be- tween the stage of spinal shock and gradual return of reflex activity. Reflex activity can be erratic in the long term, markedly disturbing function further, hence the functioning of the various systems of the body is likely to vary throughout the patient’s life, requiring con- tinued and frequent reviews and intervention. For example, during the stage of spinal shock, poor detrusor activity will cause retention of urine necessitating drainage with catheters. Following the return of reflex activity, the patient will be incontinent of urine and at risk of many complications, including hydronephrosis, renal failure, and autonomic dysreflexia. Management to contain urinary incon- tinence should also ensure safety to the upper urinary tract and to autonomic functions.

section 24 Neurological disorders 6136 The multisystem dynamic physiological impairment and mal- function presents ongoing lifelong challenges to patients and clin- icians. Each of the affected systems of the body becomes a source of disability and a potential source of a wide range of complications. Complications during the first few weeks of injury, when the injured spinal cord is physiologically unstable and vulnerable, can cause fur- ther neurological deterioration. The associated sensory impairment presents ongoing risks to patients and a diagnostic challenge to clin- icians. Conventional symptoms and signs to diagnose associated in- juries or intra-abdominal pathology cannot be relied upon. Pressure sores, fractures of long bones, and burns can remain unnoticed for several days. Mortality because of undiagnosed acute abdominal pathology can occur. The loss of coordinating and modulating influences from the brain usually results in cascading intersystem effects that are rarely seen in other medical conditions. For example, severe constipation in a tetraplegic or high paraplegic patient can result in excess spasti- city, which can involve the pelvic floor muscles causing retention of urine, urinary infections and/or autonomic dysreflexia. The psychological, social, emotional, vocational, financial, envir- onmental, and relationship challenges to the patient, partner and family members are usually at least as devastating as the paralysis and the impairment of bodily functions. Almost all complications following SCI can be prevented or their effects minimized. Coordinated, multidisciplinary holistic care has significantly improved neurological outcome, quality of life, and life expectancy of tetraplegic and paraplegic patients. With expert treatment (Fig. 24.13.2.1) from the first few hours or days of injury, most patients with incomplete SCI recover ambulation. Patients with complete cord injuries who do not recover are able to live dig- nified, enjoyable, productive, and often competitive lives. Epidemiology The annual incidence of traumatic spinal cord injury varies and is reported to be up to 50 cases per million population per annum, but in the United Kingdom the incidence is 10–15/million population/ year. Most injuries occur in males (around 80%), and the commonest cause is road traffic accidents (around 40%) (Table 24.13.2.1). There seems to be a steady increase in the incidence of elderly people who sustain spinal injuries during falls, mainly at home. About 10–20% of spinal injuries are sustained during sporting activities such as diving and rugby. Regrettably, spinal cord injury from violence (ei- ther self-harm or criminal assault) is increasing, and military con- flict is a cause of SCI in some parts of the world. Alcohol intake is a contributing factor to a significant number of spinal injuries from all causes. There is some evidence in the last decade that the incidence of traumatic spinal injury has reached a plateau. However, due to the significant increase in survival and life expectancy, the preva- lence has steadily increased in the last five decades, with a cur- rent estimate of 40 000 paraplegic and tetraplegic patients in the United Kingdom. W.E.M. BRITISH MODEL OF HEALTHCARE MANAGEMENT IN SPINAL CORD INJURIES Healthy Patient Lavyers Nurses Doctors Psychologist Social Worker Physiotherapist Back-up Team Occupational Therapist Soft landing in the community Maintenance of health & independence Outpatients Co-ordinators S.I.C. Hospital CONSULTANT ACUTE CARE POST DISCHARGE Community Rehab Specialists CONSULTANT S O C I A L

W O R K E R

O T S P I N A L

C E N T R E C O N S

G P

N U R S E S

P H Y S I O Fig. 24.13.2.1 Model of service delivery in the United Kingdom (author’s representation).

24.13.2 Spinal cord injury and its management 6137 Pathophysiology of spinal cord injury Spinal cord injury results in loss of auto-regulatory mechanisms and disruption of the blood brain barrier. Ischaemia or further bleed ing within the cord can easily develop and cause further damage. Secondary changes (vascular, cellular, electrophysiological, enzym- atic, electrolytic, and metabolic) also occur in and around the in- jured site in the spinal cord. It is therefore not surprising that during the first few weeks of injury, the spinal cord is ‘physiologically un- stable’ and unable to protect itself from nonmechanical damage, such as severe hypotension, hypertension, severe anaemia, electro- lyte imbalance, hypoxia, hypothermia, and sepsis. Oedema of the cord at the site of the injury usually reaches its peak volume at 48–72 hours from injury and can be associated with tem- porary neurological deterioration. Scientists and clinicians have, for several decades, tried to manipulate the post-traumatic changes of the spinal cord in both the laboratory animal and in humans in the hope of improving the neurological outcome. Some improvement following decompression of the spinal cord can be demonstrated in the laboratory animal, when the impact of injury is of subthreshold magnitude and when decompression is carried out within minutes or few hours of injury. Such improvement is difficult to demonstrate in the laboratory above threshold impact or after four hours of in- jury. In the clinical situation decompressive surgery, steroids and a variety of pharmacological agents have been tried and have failed to demonstrate credible evidence of short or long term equality or su- periority of outcomes over that which can be obtained with APCM and without these interventions. Not all injuries to the spine are grossly unstable to the degree that this might cause further mechanical damage. However, once the structure of the bony spine has been disrupted, some degree of micromovement or microinstability is likely to be present at the site of injury, no matter how stable the injury is, and this could be an- other source of pain at the site of the fracture. Bony healing will occur between six to twelve weeks following injury, irrespective of the treatment being conservative or surgical, in most cases of vertebral fracture. In other words, biomechanical instability is time related and the most biomechanically unstable spinal column injuries are likely to become stable within six to twelve weeks of injury. Management at the scene of the accident and in the emergency department The appropriate management of the individual at the scene of an acci- dent is vital in order to avoid unnecessary worsening of neurological damage. If the individual is unconscious, then it should be assumed there is an injury to the cervical spine until proven otherwise. Until this diagnosis can be ruled out, the head and neck should, as far as possible, be held firmly in a neutral position except for patients with ankylosing spondylitis. This is normally achieved at the scene of an accident by immobilization in a semi-rigid collar, but if this is not available alternative improvised methods of stabilizing the head and neck should be initiated. The individual should not be placed in the coma position as this will rotate the cervical spine, but is best placed—if their other injuries allow—in a lateral position with the head kept in line with the spine by the underlying arm. If any move- ment is necessary, the person should be 'log rolled' to ensure that the spine is kept in a straight and neutral position at all times. Usually transportation is on a spinal board with a head immobilizer. Patients with SCIs become poikilothermic and can easily de- velop hypothermia or hyperthermia, depending on the ambient temperature. This is due to the loss of the sympathetically medi- ated thermoregulatory mechanisms. Prevention of hypothermia can save lives since hypothermia can exaggerate the bradycardia, leading to cardiac standstill. Cardiac arrest also readily occurs with hypoxia, especially in patients with cervical cord injuries. The speed of evacuation is important, particularly if there are other life-threatening injuries. The individual with a SCI should preferably be transferred to a specialist spinal injuries centre, but obviously resuscitation and other life-threatening injuries may need treatment at the nearest trauma centre or emergency department. Diagnosis in the conscious patient Following significant trauma, impairment or loss of motor power and of sensation together with absent reflexes are usually the give- away signs of damage to the spinal cord and/or nerve roots. In the absence of neurological signs; pain, tenderness, bruises, or swelling in the region of the cervical, thoracic, or lumbar spine and limitation of range of movement are likely to be indicative of bony or soft tissue damage of the spinal axis. In patients with SCI, the incidence of associated injuries is re- ported to be up to 40%, hence a thorough general examination is essential to exclude associated injuries, some of which can be life- threatening. It is also important to note that up to 20% of patients with spinal injuries are reported to have other noncontiguous in- juries of the spinal axis. The biomechanical stability of the spine requires thorough assess- ment prior to mobilization because neurological deterioration oc- curs mostly when neurologically intact or neurologically impaired patients are sat up in bed or mobilized prematurely, and this often leads to litigation. In the neurologically intact, deterioration is usu- ally caused by mechanical damage caused by an undiagnosed bio- mechanically unstable injury. The spinal cord of the neurologically impaired patient is also physiologically unstable. It cannot protect itself from nonmechanical damage. Neurological deterioration or lack of recovery can occur due to severe postural hypotension, hypertension, hypoxia, and sepsis. Diagnosis in the semi-conscious and unconscious patient Unconscious or semi-conscious patients with head injuries and/or intoxication present particular challenges to the clinician. Delays in diagnosis can have major consequences. It is therefore para- mount that following a significant traumatic event such patients are Table 24.13.2.1 Causes of spinal cord injury—comparison of causes in the United Kingdom and the United States of America Cause UK (%) USA (%) Road traffic accidents 35 43 Violence 7 19 Sports injuries 21 11 Falls (domestic and industrial) 36 19 Other 1 8

section 24 Neurological disorders 6138 managed with the assumption that they have sustained a spinal in- jury until proven otherwise, clinically and radiologically. Further damage to the spinal cord causing further neurological deterior- ation rarely occurs in recumbence, hence it is important that the patient remains in recumbence until a spinal injury has been ruled out. Clear written instructions to keep the patient in recumbence until an injury to the spine and/or the spinal cord has been excluded is likely to prevent neurological deterioration, as well as minimize the risk of litigation. Accurate clinical diagnosis cannot be made until the patient be- comes conscious. The general examination of the semi-conscious and unconscious patient can, however, yield clinical signs which, in combination, can help the clinician detect a neurological im- pairment of spinal cord origin. Things to look for include the following: • Facial or scalp lacerations and bruises—their site can also be in- dicative of whether the cervical injury has occurred in flexion or extension. • Bruising or swelling over the spine—may be apparent at an early stage, but their absence does not rule out an injury to the cervical spine. • Cardiovascular—the combination of hypotension and brady- cardia due to the early loss of sympathetic reflexes and unopposed vagal tone is rarely seen in patients without cervical or upper thoracic spinal cord injury; engorgement of the distal peripheral veins in a hypotensive patient following trauma is one of the most helpful signs of cord damage. • Miosis of one or both pupil(s)—occurs in cervical cord injuries due to the interruption of the sympathetic outflow. • Diaphragmatic breathing (absence of chest expansion during in- spiration associated with increasing abdominal girth and retrac- tion of intercostal muscles)—this is a very useful sign, which in the absence of ankylosing spondylitis is almost diagnostic of a spinal cord injury in the cervical or upper thoracic spine. • Limbs—absence of spontaneous movement in the limbs of a semi-conscious irritable patient; absent tendon reflexes; spon- taneous movement of the upper limbs but not the lower limbs is likely to be caused by a thoracic or thoracolumbar injury; spon- taneous movement of the lower limbs but not the upper limbs is likely to be indicative of a central cord syndrome or a brachial plexus injury; the difference in the response to painful stimuli by pressure over bony prominences, the difference in muscle tone and in tendon reflexes between the upper and lower limbs are also likely to help towards locating a level of neural tissue injury. • Priapism. Radiological investigations All patients with suspected or clinically confirmed spinal injuries will require radiological investigation, but it is important to remember that spinal movement must be minimal during any procedures. Plain X-rays have limited value in the lower cervical and upper thoracic spine. CT scan is the investigation of choice to demonstrate the bony spine longitudinally and cross-sectionally. MRI is the in- vestigation of choice for the neural tissues as well as soft tissues. Most patients who sustain traumatic injuries of the spinal cord and cauda equina therefore require both a CT scan and an MRI scan. Injury to the spinal cord can occur in the presence of normal X-rays and CT scans. SCI without radiological abnormality (SCIWORA) can occur in children and may only become apparent on an MRI scan. This can also occur in older people with underlying cervical spondylosis, when tetraplegia can result from hyperextension injury without fracture or dislocation. Pitfalls in neurological assessment and initial management One of the most common problems encountered is the mis-diagnosis of the level of injury. A neurological examination is essential to de- termine the level and density of the cord lesion, indeed neurological examination and documentation is at least as important clinic- ally and medicolegally as the radiological examination in patients with suspected traumatic spinal cord injury. Fig. 24.13.2.2 illus- trates the myotomes, dermatomes, and reflexes as an aide memoire. Until the diagnosis has been established, and if a biomechanically unstable spinal column injury has been diagnosed, the patient will need to be log rolled with head and neck support during turning, which requires a minimum of four individuals. Cervical injuries have been erroneously diagnosed initially as upper thoracic injuries, even when the patient has been fully con- scious, alert, and cooperative. It is important to remember that the sensory innervation of the subclavicular area is from the fourth cer- vical dermatomes through the supraclavicular nerves, rather than the third and fourth thoracic dermatomes. It is therefore advisable to assess sensation in the upper trunk along the mid-axillary line rather than in the mid-clavicular line of the chest. In a busy emergency department, it is easy to mistake passive movements for active movements. For example, a patient with a C5 lesion in spinal shock will be able to actively move the deltoid and biceps muscles, resulting in active abduction of the shoulder and flexion of the elbow. This active movement will invariably result in passive movement of the wrist and fingers. If active voluntary and reproducible wrist and finger movements cannot be demonstrated, such movements should not be interpreted as normal movements. The same applies to active movements around the hips resulting in passive movement in knees and ankles. An apparently normal plantar response can be seen in patients with complete and incomplete SCI for several days or weeks fol- lowing injury, hence plantar and multisynaptic reflexes should not be relied upon for diagnostic or prognostic purposes in the early stages following injury. A positive bulbocavernosus reflex (internal/external anal sphincter contraction in response to squeezing the glans penis or clitoris) without preservation of sensation and/or voluntary anal contrac- tion cannot be relied upon as indicative of an incomplete lesion. The bulbocavernosous reflex is often found to be positive in complete cord injuries from a very early stage of injury. Weakness or absence of a voluntary anal squeeze is likely to be indicative of a spinal injury in a conscious patient. The presence of anal tone or a positive anal reflex does not exclude a spinal cord injury, as it can be due to early return of sacral reflexes. Reflex detrusor activity is likely to be absent during the acute stage of SCI. Unlike the patient with head injury who is likely to be in- continent of urine on presentation, a patient with spinal cord injury with or without concomitant head injury is likely to be dry and have a distended bladder before developing overflow incontinence.

24.13.2 Spinal cord injury and its management 6139 Although bowel sounds can often be heard in the first few hours of injury, the patient is very likely to develop a paralytic ileus which can last for up to a week and possibly longer. Neurogenic ileus can be aggravated by a retroperitoneal haematoma in patients with thoracolumbar injuries. Oral hydration and feeding should be withheld for at least 24 hours and until the bowel sounds are heard. Ruling out an associated intra-abdominal injury is also paramount before oral intake is commenced. A paralytic ileus usually results in significant abdominal distension: this can interfere with the dia- phragmatic excursion, cause respiratory embarrassment, and has resulted in death of tetraplegic and high paraplegic patients. Patients with SCIs become poikilothermic and can easily develop hypothermia or hyperthermia depending on the ambient tempera- ture. This is due to the loss of the sympathetically mediated thermo- regulatory mechanisms. Prevention of hypothermia can save lives as hypothermia can exaggerate the bradycardia and cause cardiac standstill in patients with spinal cord injury. Further management General aims Initial management will consist of resuscitation, treatment of as- sociated injuries, containment of the biomechanical instability of the injured bony spine by either conservative or by surgical means and containment of the physiological instability of the injured cord. Whenever possible, treatment should be carried out in a specialized spinal injury centre as soon as possible. The ultimate goals of management are to ensure maximum neuro- logical recovery; maximum independence in activities of daily living, personal care, and hygiene; a biomechanically stable, pain-free, flexible spine with a good range of movement; safe and convenient functioning of the various systems of the body; and prevention of complications at all stages during the lifetime of the patient. It is equally important to enable patients to make informed choices about treatment, regain assertiveness, take control of their own lives, re-engage in employment and/or any activity of their choice, and whenever possible compete in some sphere of life. The importance of education in the condition and ongoing supervision of all the ef- fects of paralysis and support of the patient to maintain health and independence following discharge cannot be overemphasized. There is clear evidence that outcome is maximized medically, physically, and psychologically, if individuals are managed in spinal injury centres as opposed to a fragmented, less coordinated, and less experienced approach in general hospital settings. The ultimate goals of these centres is to softly land healthy well-functioning pa- tients in the community, maintain their health and maximum level of independence, minimize the cost of living in the community, and minimize the need for rehospitalization with medical and non- medical complications. The aims of active physiological conservative management (APCM) and of surgical management are to prevent neurological deterioration from further mechanical and nonmechanical damage of the neural tissue, allow maximum neurological recovery, prevent or minimize chronic pain, and preserve the range of movement at the site of the fracture. Reduction of the period of hospitalization and a reduction of cost is becoming increasingly necessary. There is, unfortunately, no evidence to suggest that any treatment (vaso-pressor medication, surgical, biological, pharmacological, cellular, or other) can improve neurological recovery in humans or reduce cost of treatment. The favourable natural history of neurological recovery following spinal cord injury is sadly poorly appreciated and grossly under- rated. Most patients who present with incomplete injury in the first 72 hours of injury will recover sufficiently neurologically to walk again. Most patients with a complete spinal cord injury will exhibit some recovery for up to four dermatomes and myotomes below the initial level of injury (zone of partial preservation). Such outcomes are achieved when the injured cord is protected from further mech- anical damage as well as from nonmechanical damage by hypoxia, C8 Myotomes Muscle group Diaphragm Shoulder abductors Elbow flexors Supinators/pronators Wrist extensors Wrist flexors Elbow extensors Finger extensors Finger flexors Intrinsic hand muscles Hip flexors Hip adductors Knee extensors Ankle dorsiflexors Toe extensors Knee flexors Ankle plantar flexors Toe flexors Anal sphincter Reflexes Nerve supply C(3), 4 (5) C5 C5, 6 C6 C6 C7 C7 C7 C8 T1 L1, 2 L2, 3 L3, 4 L4, 5 L5 L4, 5 S1 S1, 2 S1, 2 S2, 3, 4 Biceps jerk C5, 6 Supinator jerk C6 Triceps jerk C7 Abdominal reflex T8-12 Knee jerk L3,4 Ankle jerk S1, 2 Bulbocavernosus reflex S3, 4 Anal reflex S5 Plantar reflex L2 S2 S3 C7 S5 C2 T2 T1 C4 T7 C6 T10 T4 T2 T1 T12 L1 C7 L2 L3 L4 S1 L5 C5 S4 Fig. 24.13.2.2 An aide memoire to examination—summary of the dermatomes, myotomes, and associated reflexes.

section 24 Neurological disorders 6140 marked hypotension, marked hypertension, severe anaemia, sepsis, marked electrolyte imbalance, and hypothermia, all of which can easily occur. In other words, both the physiological instability of the spinal cord and the biomechanical instability of the spinal column will require ‘containment’ during management, until biomechanical stability of the bony injury and physiological stability of the spinal cord are achieved. Several classifications have been developed in the last few decades to assess the mechanism and severity of the biomechanical instability in the acute stage, and to help orientate the spinal surgeon to an op- timum surgical approach. Some classifications are more popular than others, and some are more elaborate and more time consuming to use. Surgeons differ in their choice of classification, but what is common to all is that none of these classifications has been validated as to its predictive value in assessing instability once natural healing occurs following APCM. The classifications are rarely used by those who manage patients with APCM as the most unstable fractures of the spine can be contained with APCM and become stable without surgical intervention. Active physiological conservative management Up to the early 1980s, APCM had been the standard of care of pa- tients with SCI. It had been established that there was no correlation between the severity of the vertebral injuries on X-rays and the neurological picture on presentation to the emergency department or the neurological outcome. Improvement of radiological imaging with the introduction of CT & MRI, improvement in the design of instrumentation and the increasing safety of anaesthesia, have all resulted in a change of standard of care, unfortunately without evi- dence of equality or superiority of outcomes, or reduction in cost. The rationale of APCM is based on observations made over the last seven decades and on the published excellent outcomes for neuro- logical and functional recovery. Further arguments for APCM are: • The complications that can cause nonmechanical damage of the spinal cord are easier to prevent with APCM than with surgery. • The risk of these complications is higher with surgery and postoperatively than with APCM. • The biomechanical instability of the injured spine can be con- tained easily and safely by nonsurgical means in recumbence for 4–6 weeks followed by bracing for a further 6 weeks. • The natural fusion at the site of the fracture leads to the shortest length of fusion that maintains the architectural segmentation of the spine, prevents the spine becoming rigid and prevents poten- tial instability above and/or below a longer rigid fusion. • Further damage to soft tissue, including nerve endings is pre- vented by avoiding surgery. The great majority of patients treated with APCM will have a painless spine with good range of movement. Most importantly, with APCM spinal canal encroachment, cord compression and malalignment re- sulting from trauma do not correlate with the degree of neurological deficit and do not prevent neurological recovery. Most patients who present within the first 72 hours from injury with incomplete spinal cord injury and are treated with APCM will make a signifi- cant neurological recovery to ambulate, irrespective of the degree of malalignment, canal encroachment, or cord compression (please see online case 24.13.2.1, 24.13.2.2, 24.13.2.3). A period of 4–6 weeks in recumbence is required with APCM. During this period simultaneous management of the injured spine and each of the impaired systems of the body will be carried out, ensuring prevention of further damage to soft tissues and complica- tions. Tilt table studies are carried out prior to mobilization to en- sure safety. Following mobilization, the patient is likely to require a cervical collar or a brace for a further period of 4–6 weeks. Nonsurgical management without an adequate period of immo- bilization in recumbence has often been erroneously described as conservative management and its outcomes compared with the out- comes of surgical management, leading to understandable conclu- sions. Adequately designed studies to compare outcomes of good APCM with good surgical management are long overdue. Outcome and prognostic indicators of recovery with active physiological conservative management In the late 1960s, Frankel et al. demonstrated at Stoke Mandeville Hospital that most patients with incomplete injuries of the spinal cord and cauda equina will recover significantly to ambulate without surgical or any other intervention (Table 24.13.2.2a). Between 5.9% and 8.9% of patients with complete cord injury will recover to ambulate. Many more will recover motor power and sen- sation within their grade or improve in grade, but not enough for ambulation (Table 24.13.2.2b). These results have been repeatedly confirmed by other groups, irrespective of the degree of canal sten- osis, canal encroachment, malalignment, or cord compression. The prognostic value of pin- prick sensory sparing in the 48–72 hours from injury was established in the late eighties and con- firmed by other groups. With optimum APCM, over 70% of pa- tients who present 48–72 hours from injury with no motor power, but with preservation of pin-prick sensation down in the S2/S3 dermatomes (Frankel B), will recover to walk again within a year from injury. Patients with any distal flicker of movement (how- ever weak and/or patchy) in the first 72 hours from injury have an even better chance of recovery. This recovery is achieved irre- spective of the degree of canal encroachment, cord compression, or severity of malalignment, and without any vasomotor medica- tion, surgical, pharmacological, cellular, or other intervention on the spinal cord. Patients with complete cord injury (Frankel A) and pin-prick sen- sory sparing in the zone of partial preservation where no movement is detected will recover useful motor power in the equivalent myo- tomes without intervention. A neurological level higher than the bony level of the fracture is another good prognostic indicator of zonal recovery. Over two hundred individuals with various degrees of biomech- anical instability, cord compression and initial paralysis who were treated with APCM and who recovered to walk irrespective of the radiological presentation have given their consent to have their clin- ical, radiological, photographic documentation and videos available to study. The debate about early mobilization Early mobilization of the neurologically impaired is regarded by some as potentially hazardous, indeed early mobilization during the stage of spinal shock is usually associated with significant postural hypotension. The sympathetic nervous system fails to maintain the

24.13.2 Spinal cord injury and its management 6141 blood pressure, and a drop of BP can result in reduction of spinal cord perfusion pressure and possibly further cord damage from is- chaemia. Temporary neurological deterioration in association with postural hypotension has been reported, with recovery occurring as soon as the patient is back to recumbence. Close monitoring of neurological state during tilt table studies prior to mobilization re- vealed an incidence of about 8% in our population. Early mobilization of patients with complete cervical and upper thoracic cord injuries also causes reduction in vital capacity, and an associated drop of oxygen saturation can further impair cord func- tions and result in neurological deterioration or limited recovery. The incidence of patients who deteriorate permanently and those with a potential for recovery who do not recover when mobilized during the stage of spinal shock, the so-called ‘silent deterioration’, is not known and is poorly documented in the literature. Pooling of the blood in the lower limbs is more marked during the stage of spinal shock due to sympathetic areflexia. Patients who are mobilized early are likely to be at higher risk of developing deep venous thrombosis and pulmonary emboli. The risk of ischial and sacrococcygeal sores is high during early mobilization because of the poor perfusion of the insensate skin during the stage of spinal shock and the loading of the weight of the patient on the ischial tuberosities and sacrococcygeal bony area. It remains to be proven that patients with paralysis, postural hypotension, and reduced vital capacity can benefit psychologically and otherwise from early mobilization. These patients usually feel weak, easily tire, and exhibit even lower mood. Often the patient has to go back to bed because of feeling faint and unwell. Surgical approaches Stabilization Surgical stabilization is most beneficial for patients with injuries to the spine without spinal cord damage. The spinal cord is physio- logically stable and unlikely to be damaged by nonmechanical insults. The patient does not require multisystem management or rehabilitation and can, therefore, be discharged home within days of surgery. Pure ligamentous injuries with displacement without bony injury to the vertebrae are unlikely to stabilize before 6–8 months following injury and are likely to require surgery. The surgical ap- proach depends on the mechanism of injury, the source of spinal compression (front or back), and the preference of the surgeon. The belief by some that in humans surgical stabilization and/or de- compression of the neurologically impaired is likely to improve the biological changes (vascular, cellular, electrophysiological, enzym- atic, electrolytic, and metabolic) thus improving neurology is not supported by clinical evidence. The injured spinal cord is at risk of sustaining further mechanical and nonmechanical damage during anaesthesia, the surgical procedure and postoperatively, with the reported incidence of complications from surgery and parasurgical procedures being about 3%. Complications, including neurological deterioration, following surgery are believed to be underreported. The commonly claimed benefits of surgical stabilization of pa- tients with cord injury are psychological benefit from early mobil- ization, earlier completion of rehabilitation, shorter hospitalization, and a reduction of the cost of treatment. Some surgeons also believe that surgical stabilization of the patient facilitates nursing. Some claim that the incidence of

post-traumatic syringomyelia is reduced following surgery. However, there is no evidence that early mobil- ization of patients with cord injury following surgery reduces the incidence of complications, number of days the patient spends in bed, or that equal end points of rehabilitation are achieved within a similar period or earlier, or that the total period of hospitalization from injury to discharge home with equal levels of independence, safety and convenience of bodily functions is shortened. Indeed, a significant number of unventilated patients with cervical spinal cord injury may require postoperative ventilation for days or weeks, cannot be mobilized early, and have their rehabilitation delayed and hospitalization prolonged. There is no evidence to suggest that sur- gery makes nursing easier, nor is there evidence to support equal or lower incidence of short- and long-term pain following surgery. It is hoped that data collected nationally from all spinal injury
Table 24.13.2.2 (a) Percentages of patients in Frankel gradesa A—C improving to Frankel grades D or E (able to walk again) Site of cord lesion Cervical T1–T10 T11–12-L1 Lumbar Frankel A 8.9% 5.9% 7.9% 44.4% Frankel B 57.6% 46.7% 70.8% 66.7% Frankel C 76.2% 50.0% 80.0% 75.0% (b) Percentage of patients improving to Frankel Grade C (improved but not functionally useful for ambulation) Cervical T1–T10 T11–12-L1 Lumbar Frankel A 25% 9.6% 11.1% 11% Frankel B 6% 13.3% 8.3% 33.3% a Description of the neurological sparing of patients in the various Frankel grades:

1. Complete (A). ‘This means that the lesion was found to be complete, both motor and sensory, below the segmental level marked.’
2. Sensory only (B). ‘This implies that there was some sensation present below the level of lesion but that the motor paralysis was complete below that level.’
3. Motor useless (C). ‘This implies that there was some motor power present below the lesion, but it was of no practical use to the patient.’
4. Motor useful (D). ‘This implies that there was useful motor power below the level of the lesion. Patients in this group could move the lower limbs and many could walk, with or without aids.’
5. Recovery (E). ‘This implies that the patient was free of neurological symptoms, i.e. no weakness, no sensory loss, no sphincter disturbance. Abnormal reflexes may have been present.’ After Frankel HL, et al. (1969) The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. Paraplegia 7, 179–92.

section 24 Neurological disorders 6142 Centres in the United Kingdom will shed some light on this debate, but for now the benefits of surgical stabilization for early mobiliza- tion (before 4–6 weeks) of injury remain to be proven. Decompression Opinion is divided among surgeons about the value of surgical decom- pression, which is not carried out routinely when the injured spine is surgically stabilized. However, patients who exhibit clinical signs of neurological deterioration with evidence of further mechanical neural tissue compression may benefit from spinal decompression. Claims were made in the early 1980s that early decompression was necessary to prevent neurological deterioration and enhance neuro- logical recovery. However, studies since the early 1990s to determine the significance of canal encroachment have revealed no correlation between the magnitude of canal encroachment, the neurological deficit, and the degree of neurological recovery. The majority of patients who present within 48–72 hours of injury with incomplete cord and cauda equina injuries and canal encroachment recover neurologically sufficiently to walk without surgical decompression or any other intervention. A recent multicentre study suggested that surgical decompression in the first 24 hours from injury resulted in relatively better neurological outcomes than decompression car- ried out after 24 hours, but unfortunately there was no comparison with APCM. Furthermore to date no attempts have been made to compare the incidence of complications including pain, the range of movement at the site of injury, or the quality of neurological re- covery, between patients who are surgically managed and those who are treated with APCM and in recumbence for 4–6 weeks. Complications and their management Respiratory problems Paresis or paralysis of the intercostal muscles results in a reduc- tion of vital capacity. Paresis or paralysis of the abdominal muscles results in poor forced expiratory volume and impairment of the patient’s ability to cough. The higher the level of cord injury, the lower is the vital capacity and the poorer the ability to cough and expectorate especially during the stage of spinal shock. In the early hours and days following injury, respiratory function should be monitored carefully. Ventilation is likely to be required in patients with C3 cord lesions and above, but with adequate respira- tory management those with lesions at C4 and below are unlikely to require ventilation unless they have associated chest injury or a history of chronic chest disease. Regular chest physiotherapy to in- clude deep breathing exercises, vibration and percussion of the chest wall to loosen secretions, postural drainage and assisted coughing is vital since the most common cause of a decline in respiratory function is the retention of secretions. Assisted coughing with the patient in recumbence and head of the bed tilted down 10–15o is likely to be necessary to get rid of bronchial secretions effectively. Assisted coughing against gravity during the stage of spinal shock, when the abdominal muscles are flaccid, is more effort-consuming and less effective. With the return of reflex contractions of the ab- dominal muscles, forced vital capacity and the ability to generate a reasonably good cough by triggering a spasm of the abdominal muscles improve significantly. Cardiovascular problems The loss of sympathetic activity is likely to result in hypotension and bradycardia due to an unopposed vagal tone, both of which are more marked during the stage of spinal shock and with higher levels of cord injury. Patients cannot increase their heart rate in response to a drop of blood pressure such as will invariably occur during mobil- ization of the tetraplegic and high paraplegic patient in the stage of spinal shock. Tracheal suction, hypoxia, and hypothermia can also result in drop of heart rate and cardiac standstill. Atropine is often life-saving and should always be readily available to administer to tetraplegic or high paraplegic patients when the heart rate drops below 45 beats/minute. Although vasopressor drugs are often administered to raise the blood pressure, there is no convincing evidence of benefit in terms of neurological benefit or otherwise. It is also possible that raising the blood pressure when spinal cord auto-regulatory mechanisms are impaired could lead to further bleeding in the spinal cord to the detriment of neural tissues and neural function. Venous thromboembolism Pooling of blood occurs in the lower limbs particularly during the stage of spinal shock. This is due to loss of vasomotor sympathetic reflexes and the absence of pumping muscle action. It is advis- able to keep the legs elevated to 10–15o during the stage of spinal shock to minimize such pooling. Deep venous thrombosis (DVT) remains a significant complication after spinal injury, and the in- cidence of death from pulmonary embolism (PE) in patients who are not prophylactically anticoagulated is about 15%. The risk of PE is highest in the first three weeks after cord injury, and low mo- lecular weight heparin or warfarin are usually used for prophylaxis for about 12 weeks following injury. Some centres also use external pneumatic calf compression in addition to prophylactic anticoagu- lants. With the return of sympathetic and motor reflex activity the risk of DVT is slightly reduced. Autonomic dysreflexia Autonomic dysreflexia is a potentially fatal problem if inadequately managed. It is most commonly seen in those with cervical cord in- juries above the sympathetic outflow, but can occur in those with thoracic lesions above T6. It is characterized by an exaggerated autonomic response to a stimulus below the level of the lesion. Stimuli can include distension of the pelvic organs such as bladder, colon, and rectum, which induces sympathetic activity resulting in vasoconstriction and hypertension. Other stimuli include cath- eterization, urinary infections, sexual intercourse, discitis, pressure sores and even tight clothing, and surgical procedures can also induce autonomic dysreflexia. The problem occurs in around 50–80% of those at risk, typically beginning 2–12 months after injury and persisting long term. Patients with incomplete lesions are at less risk of developing this complica- tion. Symptoms and signs include anxiety, severe pounding head- aches, nasal obstruction; sweating, vasodilatation, and flushing above the level of the lesion; paraesthesia and significant hypertension. Good education and awareness of the patient, together with regular follow up to prevent and detect early and/or treat complications that can trigger autonomic dysreflexia, are paramount to minimize the occurrence of this complication. Once automonic dysreflexia

24.13.2 Spinal cord injury and its management 6143 occurs, attention is directed to the reduction of the blood pressure. Sitting the person upright is usually helpful. Sublingual nifedipine can be used or, in more severe cases, parenteral antihypertensives. Hydrallazine, chlorpromazine, nitroprusside, and diazoxide have all been used. Occasionally the sympathetic reflex activity may have to be blocked by spinal epidural anaesthetic. All these are temporary measures until the precipitating cause is found and treated. Pressure sores Regrettably, the development of pressure sores still occurs, but really ought to be preventable. The patient is at highest risk during the stage of spinal shock when skin perfusion is at its poorest. The risk, however, persists for life. Sores are commonest where there are bony prominences near the skin such as the scapula, ischial tuber- osity, greater trochanter, sacrum, heel, and at the back of the head. A key to prevention is awareness of the potential problem, vigilance, and regular changes of position in bed and regular lifting in the wheelchair. There are many commercial mattresses and wheelchair cushions that help distribute the patient’s mass over a wide area of the skin. When lifting or positioning, shear forces should be avoided as far as possible, and the injured person should never be dragged over sheets or from the wheelchair. The skin should be kept clean (but not with alcohol), and particular care should be taken to avoid any urine or faecal soiling. If a sore does occur, the area must be kept clean and any dead tissue removed. There should be complete relief of pressure from that area until it is fully healed. Occasionally surgery is indicated for larger or deeply infected sores which otherwise will take too long to heal. Primary excision and direct closure remains the preferred surgical method of covering a sore when required. This allows the anatomy of the vascular supply to remain intact and hence repeated surgical closure can be carried out with good results if and when required. Education of the injured patients and their family is essential. Pressure sores are likely to cause excess spasticity, anaemia, higher risk of urinary infections, septicaemia, low mood and problems with relationships. The management of pressure sores should also include assessment of the level of haemoglobin, plasma protein, and zinc, as the patient may require replacement therapy. Bladder problems Before the Second World War, renal failure from infections, hydronephrosis, and stag horn calculi were the main causes of death within two years of those patients who survived a SCI. The develop- ment of dedicated spinal injury centres led to better understanding and management of the neurogenic bladder. The work of Sir Ludwig Guttmann and Hans Frankel in the middle of the last century is rele- vant to this day, having demonstrated that death from renal causes can be prevented, although unfortunately it remains a significant cause of mortality in developing countries. Early management In the period of spinal shock the bladder is usually noncontractile, and during the first 48–72 hours after injury, when oliguria is ex- pected, a fine bore indwelling urethral catheter (g14) should be in- serted to monitor urine output. However, urethral catheterization beyond 72 hours is likely to result in colonialization of the bladder with bacteria, hence it is important that the indwelling catheter is removed, and intermittent catheterization commenced by a nurse or other trained assistant. The patient is likely to develop polyuria a few days later, and restriction of fluids below two litres/day is likely to be required to avoid bladder distension. During this period the frequency of intermittent catheterization may have to be increased. Alternatively, a fine bore urethral catheter may be inserted for a few hours at a time during the period of the day or night when max- imum polyuria occurs. Later management Detrusor hyperreflexia often develops when the period of spinal shock wears off. This usually gives rise to frequent passage of small quantities of urine. Detrusor sphincter dyssynergia, with simultan- eous reflex contraction of the detrusor and sphincter muscles, occurs in most patients with suprasacral lesions of the spinal cord and can result in hydronephrosis and renal embarrassment if unmonitored. Detrusor hyporeflexia will tend to occur when there is damage to the sacral nerves S2, 3, and 4. A urodynamic study is recommended prior to discharge from hospital to determine the exact nature of the underlying bladder and sphincter functions. The management of urinary system following the acute stage of in- jury should not restrict the paralysed individual’s ability to socialize, work, and pursue hobbies. Four-hourly intermittent catheterization remains the preferred method of drainage throughout the patient’s life, as it is associated with minimal risk of recurrent infections, vesical calculi, bladder autonomic dysreflexia, urethral strictures, and bladder cancer. Patients who can self-catheterize should be en- couraged to do so: tetraplegic male and female patients may or may not wish to depend on an attendant to catheterize them every four hours. Occasionally anticholinergic drugs such as propantheline, oxybutynin, or imipramine may help to reduce detrusor activity and incontinence between intermittent catheterizations. Injection of botulinum toxin into the detrusor muscle of the bladder is effective when oral medication fails and has revolutionized the management of the overactive neurogenic bladder and neurogenic incontinence, minimizing the need for surgical intervention. Male patients who void reflexly must be closely monitored to ex- clude poor drainage (residual more than 100 ml), recurrent urinary infections, recurrent attacks of autonomic dysreflexia, or early signs of upper tract dilatation. Should they present with any of these symptoms and signs they will require repeat urodynamic studies, as some who wish to continue to void reflexly may require α-blockers or bladder outlet surgery (sphincterotomy) to minimize resistance from the bladder outlet, enhance drainage, and reduce vesical pres- sure during voiding. Following sphincteroromy reflex erections may be affected. Unfortunately, botulinum toxin injections in the sphincter muscles of the bladder have not always been successful in significantly reducing resistance to urine flow. Male tetraplegic patients should be able to void reflexly in an in- continence appliance consisting of a penile sheath attached to a leg bag, and some paraplegic male patients may also prefer to void re- flexly rather than be catheterized. Tetraplegic female patients who do not wish to be dependent on someone to catheterize them should be given an informed choice between absorbent pads or the inser- tion of a suprapubic catheter. Advice from a specially trained con- tinence nurse should be sought if absorbent pads are chosen to discuss the risks of skin irritation, inflammation, and pressure sores. Suprapubic catheters are much preferable to indwelling urethral

 catheters because of less contamination from the perineum, as well as mitigating the risk of urethral strictures and fistulas. Cystoscopy and other surgical procedures Cystoscopy may be required in patients who complain of recurrent urinary infections. Regular cystoscopic surveillance of patients with suprapubic and urethral indwelling catheters is not generally re- garded as necessary. Advocates of cystoscopic surveillance quote the increased incidence of radiolucent urinary calculi and mucus ma- terial (which often block the catheter and cause urinary infections and autonomic dysreflexia), the increased incidence of metaplastic changes and cancer of the bladder, and the absence of sensation to alert the patient and the clinician, as legitimate reasons for a regular procedure. In the long term, in paraplegia and tetraplegia, bladder augmen- tation with an ileocystoplasty can be useful to increase bladder capacity. Artificial urinary sphincters can be inserted for the treat- ment of neuropathic incontinence, but caution should be exercised in patients with sensory loss due to the high rate of complications in such cases. Sacral anterior nerve root stimulators can be con- sidered in some individuals with suprasacral cord lesions: a radio- linked implant is inserted to stimulate the S2, S3, and S4 anterior nerve roots, and by activating the implant the bladder can be emp- tied. Often the same implant can also be used to assist in defecation and in obtaining penile erection. Urinary diversion procedures are, fortunately, now needed less frequently. Follow-up Long-term follow-up and timely intervention are essential for sig- nificant reduction in long-term risks and maintenance of a good quality of life. All patients with neurogenic bladder from SCI require annual clinical follow up, an ultrasound scan of their urinary tract with or without a plain abdominal X-ray, blood tests including cre- atinine (eGFR), as well as urine culture and sensitivity, irrespective of the method of management of the urinary tract. This is to ensure adequate drainage with a residual urine of less than 100 ml in the patients who void reflexly, as well as good renal function free from urinary tract infections, urinary calculi, and upper urinary tract dilatation. Residual urine can predispose to infection, stone forma- tion, and contributes to impairment of renal function. The risk of these complications developing is particularly high if the failure to empty is associated with high intravesical pressure and back pres- sure to the kidneys. Bowel care In the initial period of spinal shock, the bowel remains flaccid and should not be allowed to overdistend with the risk of constipation and overflow incontinence. Manual evacuation is usually carried out until bowel activity returns. Eventually reflex emptying can occur in those with predominant upper motor neurone lesions, or the bowel can remain flaccid in those with lower motor neurone in- volvement. In the former, bowel evacuation can usually be triggered by glycerine suppository and/or by anal digital stimulation. In those with flaccid bowel there is a continuing need to evacuate manually or by straining using abdominal muscles. Advice on a proper diet is also required. Natural aperients, such as senna, and a good quality high-fibre diet together with a high fluid intake are recommended. Colostomy should be considered as a last resort because, in the absence of sensation, the potential skin problems around the stoma and the diagnosis of acute abdomen is more difficult to manage than in the neurologically intact. Spasticity and contractures Spasticity can occur in an upper motor lesion with intact spinal reflex arcs below the level of the lesion. It is usually worse in those with incomplete lesions. Spasms can be functionally useful and the individual can sometimes use flexor or extension spasms as an aid to standing transfers and dressing. Acute excess spasticity in pa- tients with complete cord injury should be regarded as a symptom of an underlying irritating factor or pathology. Excess spasticity usually produces functional problems as well as causing pain, and in the long term there is a significant risk of muscle contractures, hence aggressive early management of spasticity is important to maximize the use of any neurological recovery and prevent un- necessary complications. Initial management focuses on removing any unnecessary exacerbating factors such as pressure sores, constipation, tight cath- eter leg bags, or urinary infection. Treatment should always involve the use of an expert neurological physiotherapist who will advise on appropriate positioning and seating. In the early stages, passive stretching of the spastic muscles and regular standing regimes can be helpful, and in the longer term these can often be carried out by the disabled person and their carers. Antispastic drugs should always be used with care as they induce significant tiredness and weakness, but they can provide some useful background antispastic effect. Baclofen, dantrium, and tizanidine are the most commonly prescribed. Oral cannabis (or at least 50:50 ratio of tetrahydrocannabinol (THC) and cannabidiol—Sativex) may also be helpful, and positive trials have been undertaken, but the agent is not yet licensed (except in Canada for neuropathic pain management). Nerve blocks with phenol and alcohol can be used, but intra- muscular botulinum toxin is probably most useful. This is injected directly into the muscle and blocks the release of acetylcholine from the nerve endings, producing muscle relaxation over three or four days which lasts about three months. Occasionally more severe spasticity will need other measures, such as intrathecal baclofen. If contractures have resulted, then surgical correction by tenotomy, tendon lengthening, or muscle division is often the only method that will get the limb back into a functionally useful position. Heterotopic ossification The term heterotopic ossification is used when calcification develops in an abnormal anatomical position in soft tissues. Its prevalence in spinal cord injury is reported to vary between 5 and 50%. The patho- genesis is not entirely known, but there is some evidence that it may be due to excessive stretching of muscle fibres, resulting in bleeding and calcification within the muscle. It commonly occurs around the hips and knees and can mimic an abscess in the acute stage of its development, causing a decreased range of movement as well as lo- calized swelling and joint effusion. Treatment is difficult: etidronate disodium (Didronel) is probably most useful. In severe cases sur- gical intervention can be required, but is usually unsatisfactory. Some centres now use prophylactic etidronate disodium for about a year, although this is not universally accepted.

24.13.2 Spinal cord injury and its management 6145 Pain and dysaesthesia Localized pain is quite common in the early weeks after injury. Peripheral burning pain can also develop and continue for some months. This usually responds reasonably well to the use of carba- mazepine, tricyclic antidepressants, gabapentin, or pregabalin. Pain from other sources such as osteoarthritis or nerve root compression can also occur. It should be remembered that individuals with spinal cord injury do not always appreciate pain, which is often manifested in different ways, such as autonomic dysreflexia or worsening of spasticity. Adequate pain relief during the acute stage of spinal injuries is essential to minimize long-term chronic pain. Transcutaneous nerve stimulation, acupuncture, and psychological techniques, such as relaxation and hypnotherapy, or alleviation of depressive illness can help in some cases. Spinal cord stimulation or dorsal root entry zone radiofrequency coagulation can also be used, with variable outcomes. Rehabilitation Rehabilitation is an active and dynamic process that requires a con- centrated effort in addressing the pathophysiological, psychological, social, physical, vocational, and related effects of cord damage sim- ultaneously and effectively. Rehabilitation enables the individual to minimize the effects of impairment and maximize functional ac- tivity and participation. Psychological support is necessary throughout the period of hospitalization and often beyond. The great majority of patients with spinal cord injury will experience anxiety, low mood, resent- ment, and anger. Some will exhibit signs of reactive depression. Psychological support is also necessary to help a neurologically im- paired patient with a low energy level cope with a demanding en- ergy and effort consuming rehabilitation process. This support is best provided by trained members of staff with whom the patient feels most comfortable. There is ample evidence that a coordinated multidisciplinary, patient-oriented, and goal-oriented effort by a knowledgeable, well- trained, and experienced team can minimize medical, physical, and psychosocial complications of paralysis and improve functional outcome, participation, and quality of life for the individual with SCI. It is essential that the rehabilitation process commences in the first few hours or days after injury, and equally important that the team ensures functional outcomes are maintained throughout the individual's life. This can be achieved by regular monitoring and oc- casional timely intervention. Acute stage following injury During the resuscitation period and for the first 4–6 weeks following injury, the purpose of rehabilitation is to prevent complications that can easily develop in patients with SCI. Regular and frequent vibra- tion and percussion of the chest wall, together with assisted coughing by an experienced member of staff is required to prevent chest infec- tions. Regular and frequent passive movements of paralysed muscles and splinting can prevent contractures of paralysed muscles. The choice of an adequate mattress and regular turning of the patient in bed will prevent pressure sores. Prophylactic anticoagulation, with or without external pneumatic calf compression, reduces the risk of DVT and PE. Retraining the reflex activity of the physiologically impaired and malfunctioning systems of the body to function safely and conveni- ently should commence from the first few days of injury. This is an essential component of the rehabilitation process for individuals with SCI. Failure to do this, and/or allowing complications such as pressure sores, contractures of muscles, constipation, DVT, recur- rent urinary or chest infections to develop, will probably prolong the subsequent stages of rehabilitation, prolong hospitalization, and in- crease the cost of treatment. Moreover, inadequate prevention or in- adequate management is likely to significantly limit the outcomes of physical, psychological, vocational, and social rehabilitation, as well as the quality of life of the paralysed individual. Fortunately, most of the complications following spinal injury are preventable, and when complications occur their effects can be minimized and limited. Collection of relevant information about the patient in terms of past medical history, education, employment, marital status, ac- commodation, hobbies, and personal habits should start from an early stage to enable the team to plan for the subsequent stages of rehabilitation. Reassurance and support to the patient and the family members is paramount for building trust for the subsequent stages of rehabilitation. Carefully selected and supervised peer support is of immense value to the newly injured. Subacute stage until discharge Safe mobilization Following the acute stage of injury, it is important to ensure that mo- bilization of the patient is safe, particularly to the vertical position. Tilt table studies should be carried out by a trained physiotherapist, who measures the blood pressure and monitors the neurological condition of the patient with every 10° increment of head-up tilt. Should there be neurological deterioration in association with a drop of blood pres- sure, then the process should be aborted. Repeated tilting in bed and monitoring to the safe angle previously achieved and cautiously be- yond, with further increments of 10°, will eventually result in safe mo- bilization without neurological loss. Elastic stockings and abdominal binders may have to be used to prevent severe postural hypotension. Education Before embarking on the all-consuming rehabilitation process, the clinician should impart accurate information and advice, give guid- ance on prognosis and natural history, and help the individual estab- lish realistic goals in an appropriate social context. Education of the patient to become expert in all aspects of his/her condition, in the absence of cognitive or behavioural difficulties, is likely to facilitate the rehabilitation process, help maximize outcomes, and prevent complications in the short, medium, and long term. Table 24.13.2.3 describes the expected residual functional ability according to the level of the spinal cord lesion. Planning Adequate planning of the rehabilitation process, with agreement on the short and long-term goals to be achieved, is undertaken with active involvement of the patient. What can be achieved will depend on a multitude of factors that include the level and completeness of the injury (Table 24.13.2.3), age, pre-accident state of health and section 24 Neurological disorders 6146 level of activity, pre- accident education, employment, accommoda- tion, and personal habits. A psychological assessment of cognitive functions is likely to save unnecessary expenditure of time and effort in pursuing unachiev- able goals. Psychological support through the periods of anxiety, low mood, resentment, and anger is essential to buffer the impact of a demanding energy and effort consuming rehabilitation process. Goal-oriented patient-centred rehabilitation Active physical and locomotor rehabilitation will commence once the patient has achieved safe mobilization. A series of multidis- ciplinary goal setting meetings that include the patient and (pref- erably) also a family member is necessary to achieve incrementally what is realistically possible, without overwhelming the patient. The goals set in each of these meetings should be Specific, Measurable, Achievable, Relevant and Time limited (SMART). Training in skills of independence within the level of disability, self-care of bladder and bowels, dressing, undressing, balancing, safe transfers, use of assistive devices, wheelchair mobility, standing, and ambulating with or without orthoses, will all need to be addressed physically, psychologically, and emotionally by the patient. Supervised peer support from a patient with similar level of in- jury and disability who has succeeded in returning to a useful life has immense value. Demonstration by a peer that there is ‘light at the end of the tunnel’ is likely to be as valuable as the support given by members of staff. It is essential that the patient’s worries about the practicalities of life are minimized if energy and concentration are to be devoted to the rehabilitation process. The Spinal Cord Independence Measure is a validated tool to assess and document the progress made by the patient in self-care, respiratory and sphincter management, as well as mobility. It is used in many spinal injury centres as an outcome measure throughout the goal-oriented rehabilitation process, on discharge and at follow-up reviews. Liaison with the community services from an early stage is im- portant if suitable accommodation and adequate care support in the community are to be ready at the time of discharge. Brief trial home visits are usually carried out before discharge and are particularly important to ensure that accommodation is appropriately adapted. Interim placement in a half-way house or a residential home is sometimes necessary. Counselling Patients may not express their concerns about the effects of the spinal injury on their sexuality, fertility, employment, accommo- dation, partner, and family members, and about coping outside the hospital set-up. These are nevertheless important issues that cause anxiety to almost all patients. Ongoing counselling by the clinician from the first few days of injury, enhanced by education of the pa- tient and reinforced by peer support, is an essential component of the rehabilitation process, helping to minimize anxiety and gen- erate confidence and realistic hope. Counselling and support of the partner is equally important, considering it is usually the partner who must deal with the brunt of the practicalities of life, certainly while the patient is in hospital and often beyond. Sexuality and fertility Self-image and self-confidence can be severely affected. Individuals should be counselled about the totality of sexuality as there is a tendency for discussions to focus on penetrative sexual intercourse. In both sexes, absence of genital sensation can be compensated for by use of other erogenous zones such as the breasts, neck, and mouth. Orgasm has been reported, even in complete spinal cord lesions. Table 24.13.2.3 Expected residual functional ability according to the level of spinal cord lesion Level of injury—complete lesions Lesion below C3 Dependent on others for all care Diaphragm paralysed, needs permanent ventilation or diaphragm pacing Chin-, head-, or breath-controlled electric wheelchair Lesion below C4 Dependent on others for all care Can breathe independently using diaphragm Can shrug shoulders Can use electric wheelchair with chin control Can type/use computer with a mouth stick Environmental control system operated by shoulder shrug or mouthpiece Lesion below C5 Can move shoulders and flex elbows Can eat with a feeding strap/universal cuff Can wash face, comb hair, clean teeth—using

feeding strap/ universal cuff Can write using individually designed splint and wrist support Can help in dressing upper half of body Can push manual wheelchair short distances on the flat provided that pushing gloves are used with capstan rims on the wheels May be able to transfer across level surfaces using sliding board and a helper Electric wheelchair needed for functional mobility Lesion below C6 Can extend wrists Still needs strap to eat and for self-care Can write using individually designed splint but may not need wrist support Can dress upper half of body unaided Can help in dressing lower half of body Can propel wheelchair up gentle slopes Can be independent in bed, car, and toilet transfers Can drive with hand controls Lesion below C7 Full wrist movement and some hand function, but no finger flexion or fine hand movements Can do all transfers, eat, and dress independently Can drive with hand controls Lesion below C8 All hand muscles; expect intrinsics preserved Wheelchair independent, but difficulty in going up and
down kerbs Can drive with hand controls Lesion below T1 Complete innervation of arms Totally independent wheelchair life Can drive with hand controls

24.13.2 Spinal cord injury and its management 6147 In men there are various techniques and devices to restore erectile capacity. Most individuals with complete upper motor neurone lesions will have reflex but not psychogenic erections, but these are often not sustained or strong enough for intercourse. In those with parasympathetic sacral lesions reflex erections are usually not possible. Satisfactory erection can often be achieved by the use of intracavernosal drugs or mechanical means such as vacuum erec- tion aids and compressive retainer rings, although the introduction of sildenafil and similar pharmacological agents has reduced the need for mechanical or injected assistance. External ejaculation is rare following spinal cord injury. Retrograde ejaculation occurs in some patients. External ejaculation can be in- duced by vibro-ejaculation or by electro-ejaculation. Caution should be exercised during vibro-ejaculation in patients with injuries above T6 as they are at risk of developing autonomic dysreflexia during the procedure. Patients who have sparing of sensation will require a gen- eral anaesthetic during electro-ejaculation. Fertility is generally re- duced in men who have low sperm counts with diminished motility, but this has improved significantly in the last two decades with the introduction of the modern assistive conception techniques such as in vitro fertilization and intracytoplasmic sperm injection. In women problems can result from lack of vaginal lubrication. Fertility is not reduced, although some can go through a period of amenorrhoea after SCI. Women with SCI who become pregnant re- quire monitoring throughout pregnancy. Their ability to transfer may be affected by a gravid uterus, and they may require the use of a transfer board. The management of their bladder may need to change, and their kidneys may be at higher risk. They may develop autonomic dysreflexia during labour, but spinal cord injury is not by itself an indication for caesarean section. Tetraplegic and paraplegic women will usually give birth to healthy babies. Employment Overall, between 25 to 35% of people with spinal cord injuries re- turn to work, either in their original occupation or after a period of retraining into a new job. The chances of employment are higher in younger patients and in those who already had a job at the time of injury. There is also positive correlation with the number of years in education. Employment should become more prevalent as the ability to work at home becomes more readily achievable. The process of re-employment or vocational retraining is usually started while the patient is in hospital. It is good practice for there to be a supported meeting (e.g. organized by the patient’s occupational therapist) with the patient and their employer to discuss the possi- bility of the individual resuming employment in the same or a dif- ferent capacity, the alterations that may need to be made to facilitate access, and to inform the employer about the statutory help and sup- port that can be obtained (in some countries) by reemploying the patient. Where available, a disablement employment advisor should be involved, providing further advice and help about return to work, or—in other instances—careers advice, including discussion of fur- ther education or retraining to obtain new qualifications. Leisure pursuits A wide variety of leisure pursuits are possible for those with spinal cord injury. Integration into able-bodied clubs and pursuits is ob- viously to be encouraged, but there are also a reasonable range of sports and other clubs for those with spinal injuries. Wheelchair skills can be finely tuned to develop expertise in a variety of sports. Slowly, physical access is improving to leisure and social outlets. Recent legislation, such as the Disability Discrimination Act in the United Kingdom, should further improve the situation. Driving Access to a motor vehicle is almost essential in modern society. Driving should be entirely possible for people with C5 spinal cord in- jury and below. Automatic transmission is needed and hand controls are usually necessary, enabling the individual to control the acceler- ator and brake functions from a lever or other device near the steering wheel. A variety of infra-red devices to control secondary functions such as windscreen wipers, lights, and horn are now available. Very light power steering makes life easier for those with a weak grip. There are several techniques to stow wheelchairs safely for those with paraplegia, and for those with higher lesions there are several mechanical wheelchair stowage devices. It is also possible to adapt a suitable vehicle to enable people to drive from their wheelchair. Advice is often required on the range and type of suitable vehicles and adaptations, and on financial costs. Holidays Travelling on holiday, both inland and overseas, is now possible for individuals with all levels of injury. The Spinal Injury Association has a good database to provide advice about suitable and accessible accommodation in most holiday resorts. Information A key to independence is access to good quality information. In most countries there are now voluntary organizations that can pro- vide this. These can also act as pressure groups, and many have been instrumental in promoting increased awareness better accesss and improved legislation for disabled people. The internet now provides an excellent source of information and advice. Training in computer literacy should certainly be encouraged by the rehabilitation team. Discharge and post discharge Liaison with the community services is essential prior to discharge to ensure accessibility of the patient to their own home or other suit- able accommodation as well as adequate support. Most spinal injury centres in the UK provide an ongoing monitoring service for individ- uals with SCI following discharge. A one stop full outpatient review of the neurological, medical, psychological, social, and physical status is offered to the individual with SCI annually, or on alternate years. Some blood and urine investigations and an ultrasound scan of the urinary tract are carried out during the same outpatient review. This is to ensure continuing safe and convenient functioning of the various systems of the body, absence, or early detection of established compli- cations of which the sensory impaired patient is unlikely to be aware, and maintenance of the level of independence. A full neurological examination annually and an MRI of the spinal cord every 3–5 years are important to rule out clinically manifest and clinically silent post- traumatic syringomyelia, which can cause neurological deterioration. Most problems detected during outpatient review can be attended to during the same appointment, and such a patient-centred service is believed to significantly minimize the time spent by the patient at- tending different clinics on different days, address any problem and its effects holistically in a coordinated manner, reduce frequency of hospitalization, and reduce the cost of living to the paraplegic and tetraplegic patient.

section 24 Neurological disorders 6148 Access by phone or in person to the spinal injury centre following discharge is offered to most individuals with spinal cord injury in the United Kingdom, whereby patients who have a crisis can seek advice from the members of the team. Liaison with the local Rehabilitation Centre and with the community services is often necessary when top up rehabilitation is required and a psychological or social crisis occurs. If medical complications develop while the patient is in the community, the patient is usually readmitted to the spinal injury centre for investigations and treatment. This reduces the burden on district general hospitals, which are not equipped to deal with the spinal injury patient. It also reduces the cost of management since all the information about the patient is available at the spinal injury centre. Patients who require a specialist expertise that is not avail- able in the spinal injury centre should be managed in the appropriate specialist centre with an outreach input from the spinal injury centre to advise about prevention of potential complications that can occur because of the paralysis, and methods of prevention. Equipment Equipment and assistive devices should be provided following dis- cussion with the team in the spinal injury service. Environmental control equipment will enable an individual to control simple aspects of life around the house, such as a door intercom, turning lights on and off, turning the pages of a book, controlling the televi- sion and telephone, and using a computer. These devices can now be controlled, even by those with high tetraplegia, using mouth sticks or breath control. The occupational therapist will often be involved in such advice, particularly at the time of discharge back into the home environment. Conclusion and future prospects Spinal cord injury presents a range of challenges to patients, family members, and the multidisciplinary rehabilitation team. A holistic approach to the various medical and nonmedical effects, from the early hours or days of injury through to liaison with the commu- nity, has demonstrated success in generating good outcomes at a relatively low cost. There is a current tendency to fragment the man- agement of the patient, with an overemphasis on the management of the injured spine surgically at the expense of all other effects of the injury. Evidence that resources are being targeted appropriately is still awaited. Considering the relatively low incidence of the condi- tion and its high complexity, and considering the increasing claims that new treatments improve outcomes, it is vital that patients with spinal cord injury are managed by experienced teams able to provide a fit for purpose service, and also able to adequately and objectively assess the added value of new interventions. At the present time we cannot repair the injured spinal cord in clinical practice, but developments in basic neuroscience are begin- ning to translate. Repair of the spinal cord, for example by transplant of glial cells cultured from stem cells or the adult olfactory system, may be possible in the near future. There is also progress in the use of neuroprotective agents in the acute phase. Other modalities, such as the use of anti-NOGO monoclonal antibodies to augment plas- ticity and regeneration, chondroitinase and other pharmocological agents may also have a role to play in the future. It is therefore para- mount that the management of the spinal injury does not hinder the assessment of cord tissue regeneration using advanced radiological techniques such as PET scan and Tractography. However, our cur- rent inability to influence neuronal recovery should certainly not in- hibit active and dynamic rehabilitation in order for the spinal cord injured person to resume as normal a life as possible. Significant im- provements to overall survival and quality of life have been achieved in the last seven decades with the application of a knowledge based holistic coordinated approach to management that includes expert rehabilitation, as well as greater social awareness and understanding. FURTHER READING Bedbrook GM (1981). The care and management of spinal injuries. Springer-Verlag, New York, NY. Bickenbach J, et al. (2013). International perspectives on spinal cord injury. 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Oxford University Press, Oxford. Useful addresses Spinal Injuries Association, SIA House, 2 Trueman Place, Oldbrook, Milton Keynes MK6 2HH Web: https://www.spinal.co.uk The association for spinal cord injured people—a good source of fur- ther information and advice.

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