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Wagih El Masri *

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Review Article

Traumatic Spinal Cord Injuries: Effects, Controversies in Management and Neurological Outcomes

Wagih El Masri *

* Clinical Professor of Spinal Injuries - Keele University.

Corresponding Author: Wagih El Masri, Clinical Professor of Spinal Injuries - Keele University.

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Abstract

Prior to the second World War (WW) the great majority of patients with Traumatic spinal cord injuries (TSCI) died within two years of injury. Those who survived had an even more miserable short life than death because of a wide range of complications.

Keywords: traumatic spinal cord injuries; hypotension; hypoxia; hypothermia

Introduction

Prior to the second World War (WW) the great majority of patients with Traumatic spinal cord injuries (TSCI) died within two years of injury. Those who survived had an even more miserable short life than death because of a wide range of complications.

During the 2nd WW Guttmann, a neurosurgeon in the UK studied all the effects of cord damage including the pathogenesis of the various complications and how to prevent them. He demonstrated that provided the patient is adequately treated and all the medical and non-medical effects of cord damage are attended to from the very early hours or days of injury the majority of patients survived and lived healthy, long, enjoyable, dignified, productive and often competitive lives. [1] Guttmann condemned laminectomy because of poor outcomes and this was subsequently supported by other groups. [3,4]

Effects of Traumatic Spinal Cord Injuries

Traumatic spinal cord injuries (TSCI) are life-changing events that affect the patient's medical, physical, psychological, social, financial, vocational, environmental condition all of which with dramatic effects on the patient, partner and family members relationships. [2,6]

The combination of consequent effects of cord damage such as: generalised physiological impairment, multi-system malfunction, multiple disabilities,impose immense challenges to patients, their careers as well as health careprofessionals who treat the patient and take responsibility of the outcomes. Fortunately, the incidence of TSCI is small and ranges between 15-50patient/million population per year.

The combination of a low incidence of patients with generalised multi-system physiological impairment and malfunction, sensory impairment or loss, unable to complain or display the usual clinical signs of pathology is a source of multiple challenges to clinicians who are not familiar with the condition. This can result in the development of a wide range of complications almost all of which are preventable.

What is often not generally appreciated is that the acutely injured spinal cord is also Physiologically Unstable and unable to defend itself from systemic complications that can easily develop in these patients as well as from further mechanical damage.

Complications such as severe hypotension, hypoxia, hypothermia, generalised sepsis, significant electrolyte imbalance can cause further physiological destabilisation of the injured cord, further neurological damage manifested as neurological deterioration, delays or prevention of neurological recovery. Irrespective on the neurological outcomes these complications frequently add to the level of disability and the psychological devastation of the patient and family members and increase the cost of treatment.

It is therefore evident that the management of the TSCI and its systemic effects encompass Orthopaedic, Trauma Care and require a wide range of disciplines and health care professionals from various backgrounds from the early hours or days of injury to achieve optimum outcomes.

The characteristics of the condition and the requirements of its management necessitated the development of Specialised Spinal Injury Centres in the UK that took responsibility for these patients from the early hours or days following injury until the end of life.

This also necessitated a specific accredited training in the field of TSCI and its allied specialities which ensures the clinician develops the competences necessary to take responsibility for the day-to-day management of the patient from the early hours or days of injury and on an ongoing basis as well as manage the Centre. This training was accredited by the Royal Colleges of Physicians and Surgeons.

This holistic model of service delivery prevented fragmentation of management of the patient between various disciplines and institutions, ensured continuity of care throughout the patient's life, enabled the Spinal Injury Specialist and supporting team to maintain expertise, monitor the short- and long-term outcomes of management improve treatment and reduce cost significantly. The author had the privilege of obtaining such first

accreditation of training in the field of spinal injuries and general surgery in 1982.

Neurological Recovery following TSCI

Neurological Recovery is not uncommon following traumatic spinal cord injuries. This is provided no further mechanical or non-mechanical damage is inflicted on the injured cord. Early prediction of Neuro-functional recovery in the lower limbs is important to the patient, family members and the community. This is to ensure adequate level of care support, equipment as well as adaptation and alteration of the accommodation.

Frankel et al. observed and documented the clinical prognostic indicators of neurological recovery in 612 patients admitted to Stoke Mandeville Hospital within 14 days of injury. They had all undergone simultaneous Active Physiological Conservative Management (APCM) of their injured spine as well as the multi-system physiological impairment and malfunction consequent to cord damage in the early stage of injury. They demonstrated that neurological recovery can be predicted form the presence or absence of sparing of long tracts as clinically manifested by sensory and sensory-motor sparing distal to the last normal level of injury. Some recovery also occurs in the adjacent spinal cord segments distal to the last normal level which is referred to as the Zone of Partial Preservation (ZPP).

Based on their observation they neurologically classified the patients on admission and on discharge and published their results in 1969 in what has been known as the Frankel Classification. [5]

The majority of patients presenting in the first two weeks of injury without manifestation of any clinical sparing of long sensory or sensory-motor long tract function distal to the ZPP (Frankel A, clinically complete injuries) are unlikely to recover below the level of injury but many will recover or improve motor power within the ZPP. A minority of these patients recover below the ZPP and are assumed to have anatomical sparing but not electrophysiological conduction during the stage of spinal shock.

Over 60% of patients who exhibit manifestation some long tract sensory sparing only (without motor sparing) below the ZPP (Frankel B), recover significant sensory and motor functions. Many of these patients become able to stand and walk.

Folman and El Masri in 1989[7] found that the preservation of pin prick sensation without motor power preservation below the ZPP in the first 72 hours following injury was predictive of motor recovery in over 70% of patients. This observation was subsequently confirmed by others [8,9] and the pin prick sensation was introduced in the assessment of presentations and outcomes.

Patients who present with initial sparing of sensory as well as motor long tracts are likely to recover even more irrespective of how weak the motor power at presemtation was.

Surprisingly, this recovery was achieved irrespective of the severity of the radiological presentations and without any intervention on the injured spine other than an attempt at closed postural reduction which often failed. The outcomes however were determined by the injured cord being well protected from further mechanical insults as well as further non-mechanical physiologically systemic complications that further destabilise the Spinal cord.

The Frankel findings were repeatedly confirmed by other groups of the international community and of spinal cord injury specialists in the field and the Frankel Neuro-functional Classification is still used by clinicians to exchange information about the neuro-functional presentation of patients on admission,discharge and long term outcomes[13-17,29,30,31,33,35,39,40,42,50]

Biomechanical Instability of the Injured Spinal Column

Biomechanical Instability (BI) causes concern because of the potential displacement of the fractured elements at the site of the injury which can damage further damage of neural tissue. The diagnosis of BI is usually based on radiological investigations at the time of the presentation of the patient. Unfortunately, the function of the soft tissues (muscles and ligaments) and the natural history of the repair process that follows are often not taken into account. It is perhaps worthwhile noting that most vertebral fractures heal within 6-12 weeks from injury. Ligamentous injuries however can take much longer to heal.

In the majority of patients, the Biomechanical Stability (BS) of the spine is usually restored once the healing of bone and/or ligament occurs. In other words, Biomechanical Instability is Time related. There is no evidence to suggest that surgical stabilisation enhances the speed of healing or achieves earlier BS. Surgical stabilisation should therefore be regarded as an option of Containment of the BI until natural healing occurs. Biomechanical stability can be at least equally well achieved with active Conservative treatment.

The advantages of natural healing is the achievement of the shortest fusion that allows maximum flexibility of the spine and minimal pain without further damage to vascular, soft tissue or bony structures.

Non-Surgical and Conservative Management

Unfortunately, the terms non –surgical treatment and conservative treatment are frequently liberally inter-changed.

Conservative treatment consists of a necessary period of bed rest until both the neurogenic and spinal shock have resolved. This period can range between four to six weeks. During this period the injured spine is contained non-surgically, attention to all the impaired systems of the body is given in order to prevent the range of complications, psychological and monitored peer support is provided and education of the patient about the condition is commenced [1,2,6,13-17]. This period is followed by a similar period of bracing during which the patient is mobile, in active rehabilitation and continuing his/her education.

Non-surgical management rarely include such a period of treatment in recumbence and the details of management of the systemic effects of cord damage are often lacking.

Moreover, it is difficult to contain the BI of the spine by non-surgical means when the patient is mobilised prior to complete bony healing and a kyphotic deformity tends to recur.

Although the macro BI of the injured spine can be contained by surgical stabilisation and the spinal cord is likely be safe during mobilisation prior to healing, instrumentation hardly contains and prevent micro-instability at the site of the injury which can be a source of short and long term pain and discomfort

RATIONALE, AND ARGUMENTS FOR APCM

The range of cellular, molecular, chemical and metabolic changes as well as the disruption of the blood brain barrier in response to trauma, the injured spinal cord is also physiologically unstable. This Physiological Instability renders the cord vulnerable to and unable to defend itself from complications such as Hypoxia, Anaemia, Hypotension, Septicaemia, significant Hypothermia or Electrolyte imbalance [6,10]. These complications can easily develop and cause further neurological damage with delay or prevention of recovery if the malfunctioning and physiologically impaired systems of the body are not well managed [6,10,11,12,13,14,15,16,17]

In other words, the physiological instability of the injured spinal cord in patients whose multisystem malfunction is poorly managed is probably more threatening to the injured cord than the biomechanical instability (BI) of the spinal column. The latter can be easily managed by conservative containment until natural healing and Biomechanical Stability are achieved or indeed by surgery.

The controversy between Conservative and Operative management of the spine is currently almost two centuries old and still ongoing [18-50]

The Conservative school argues that none of the systemic complications of TSCI that can damage the spinal cord further, can be prevented by surgery without attention to the medical consequences of cord damage and prevention of systemic complications. Moreover, the added risks of further damage to neural tissues from anaesthetic or surgical mishaps and post-operative complications cannot be dismissed.

Interestingly bony healing seems to be time related and is not expedited by surgical stabilisation.

Permanent neurological deterioration with APCM is extremely rare.

Although up to 9% of closely and frequently monitored patients can exhibit temporary loss in the first 72 hrs from injury to probably coincide with the development of cord oedema; recovery of this loss to initial level and beyond is the rule and the great majority of patients make significant spontaneous neurological recovery.

Some of the added advantages of APCM are: the prevention of further disturbance to nerve endings, soft and bony tissue; the achievement of the shortest fusion that preserves the highest degree of flexibility of the spine and a low incidence of short-, medium- and long-term pain and more effective attendance to the systemic effects of cord damage is given during the period of recumbence.

The required total period of hospitalisation from injury to discharge to achieve the expected neurological recovery, optimum neurological and functional recovery as well as maximum level of independence within the limitations of the density and level of cord damage rarely exceeds three to four months for the patient with incomplete cord damage and six months for those with complete cord damage.

The APCM School asserts that any claim/s of a potentially useful intervention/s have to demonstrate evidence of added value to the neurological and all other relevant outcomes of APCM prior to its introduction as an option of treatment.

GOALS OF ACTIVE PHYSIOLOGICAL CONSERVATIVE MANAGEMENT (APCM) IN THE ACUTE STAGE

The goals of holistic APCM from the first hours or days after injury are to:

- Containment of the BI of the spinal axis until natural healingat the fracture site occurs & the shortest fusion that helps maintain biomechanical stability, a pain free and flexible spine with an excellent range of movement.
- Prevention of systemic complications or their early detectionand treatment in order to prevent morbidity, delays in activephysical rehabilitation or limitation of its benefits and prolong hospitalisation.
- Protection the physiologically unstable injured cord from systemic complications as well as per-operative and post-operative surgical complications.
- Achievement of maximum spontaneous neurological and functional recovery
- Mitigation of admission to ITU of patients withoutassociated life threatening injuries unless the patient has pasthistory of chronic respiratory disease and patients with corddamage above C4 level.
- Establishment of safe and convenient functioning of the various systems of the body in the short, medium and long term.
- Early provision of adequate psychological and emotional support to patients and family members to minimise impact,ensure and enhance their ability to cope, maximise cooperation of patients in a demanding physical rehabilitation program and improve confidence in their ability to become independent.
- Ensure adequate education of patients and prospective carersin methods of prevention of complications in order to reduceneed and frequency of post discharge readmissions.
- Ensure a gradual building up of confidence and assertivenessto enable patients to contribute and compete in life matters when they return to their community.

RATIONALE, AND ARGUMENTS FOR SURGICAL STABILISATION

The main indications for Surgical stabilisation are to prevent further mechanical damage to the cord and neurological deterioration and to enable patients to be mobilised early, commence and complete rehabilitation and shorten the period of hospitalisation.

There is undoubtedly an advantage in mobilising neurologically intact patients with spinal injuries considering that their spinal cord is physiologically unimpaired, they do not have a multisystem malfunction that requires attention to throughout the stages of spinal shock, return of reflexes and subsequent stages and they can be discharged to their own homes a few days walking a few days following injury.

The same does not apply to patients with acute cord damage, a multi-system physiological impairment and malfunction and a significant number of non-medical problems that require the cooperation of the patient and energy to engage in arduous physical rehabilitation as well as a great deal of support to return to the community with a disability.

Patients with paralysis, general physiological impairment and multisystem malfunction do not benefit from early mobilisation. Early mobilisationbefore recovery from the neurogenic and spinal shock can be deleterious in more than one way to patients. [6,14,15,50]

To-date there is no evidence that surgical stabilisation and early mobilisation result in achieving equal neurological and other outcomes or shorten period of rehabilitation and hospitalisation compared with of patients with similar levels and densities of cord damage and who have achieved equal optimum results. Furthermore, there are real potential risks to the injured spine with early mobilisation during the stage of neurogenic and spinal shock.

Hazards of early mobilisation in the stage of neurogenic and spinal shock:

Early mobilisation during the stage of spinal and neurogenic shock results in profound hypotension which can reduce cord perfusion.

Individuals with spinal cord injury exhibit reduced lung volumes and flow rates as a result of respiratory muscle weakness. These features have been investigated in relation to the combined effects of injury level and posture. Values of forced vital capacity and forced expiratory volume in one second (FEV1) were repeatedly and consistently shown to be larger in recumbence compared to the seated posture. [52,55]

Early mobilisation of patients with spinal neural tissue injury is associated with a reduction of vital capacity and a potential drop of oxygen saturation. During the stage of neurogenic and spinal shock, early mobilisation of the tetraplegic and high paraplegic results in further marked impairment in the patient's ability to cough. Additionally, it is more difficult to implement postural drainage and provide assisted coughing to get rid of bronchial secretions against gravity when the patient is sitting in a wheelchair than when the patient is recumbent.

Individually, or in combination, these respiratory and vascular pathophysiological mechanisms can potentially cause further impairment of cord functions.

Furthermore, it is more difficult to carry out intermittent catheterisation, bowel evacuation or manage episodes of urinary or bowel incontinence of a patient of a wheelchair than in recumbency.

During the stage of neurogenic and spinal shock, when the vasomotor controls are deficient skin perfusion is markedly diminished below the level of injury and the skin over the ischial sacral and coccygeal bony prominences is at its peak of vulnerability from pressure sores over these prominences while sitting in a wheelchair as opposed to the patient's weight being spread across all the bony prominences of the body

To date there are no comparative studies between surgical and non-surgical management and no evidence to demonstrate added value of surgical intervention over APCM in: saving days spent in Intensive Care Unit, achieving uneventful early mobilisation, reduction of total bed days in recumbence throughout the first admission, superiority of neurological outcome, reduction of the time from injury to completion of equivalent end points of rehabilitation, reduction of the period of total hospitalisation from injury to first discharge, reduction of the incidence of ischial and sacral pressure sores, respiratory infections, urinary infections and other urinary complications, reduction of the incidence of chronic back pain, maintenance of the flexibility of the spine, frequency of readmission or total period of

hospitalisation during the first five years following first discharge to treat complications. [6,14,15,50]

Possible Mechanisms that can Potentially Damage the Spinal Cord Further in During the per-operative period in Patients with SCIs:

Hypotensive or Hypoxic during anaesthesia
Clamping of a major spinal feeder to achieve haemostasis
Increase CSF pressure and Reduction of Cord Perfusion Pressure during Decompression
Clumsy porter, sleepy assistant, inexperienced surgeon
Post-operative epidural or subdural bleed
Early post-operative failure of implant prior to achieving Biomechanical Stability
Post-operative sepsis
Early mobilisation during the spinal and neurogenic shock

The influence of CT & MRI

Following the development of CT and MRI, the last decade in particular has witnessed an aggressive promotion of early surgical intervention within a window of opportunity (WOO) of 24 hours of injury. This WOO is based on the laboratory animal findings that if decompression is carried out within four hours from injury in animals whose spinal cord has sustained subthreshold force of impact to damage the spinal cord completely better recovery is demonstrated than with decompression after 4 hours from injury. The same was not demonstrated in animals who sustained higher forces of impact. The WOO of 24 hours in humans was determined by a post hoc analysis of outcomes in humans. Assumptions by extrapolation were subsequently made that surgical decompression within 24 hrs of injury must therefore give better result than APCM.

A change of the outcome assessment tool from the Frankel neuro-functional Classification to a numerical tool the ASIA Impairment Scale (AIS)) seems to have facilitated the support for the assumptions if not assertions that the spinal cord should be decompressed within 24 hours of injury to obtain best results. Unfortunately, these claims have been perpetuated when the validity and reliability of an accurate motor power assessment and documentation so soon after the injury in suddenly paralysed invariably anxious patients, in pain, under heavy analgesia, sedation and often with associated injuries have yet to be determined for a meaningful subsequent numerical assessment of gain.

Moreover, the definition of the various classes in the AIS depends on the presence or absence of sensation in the S4/S5 dermatomes. This is irrespective of the presence or absence of long tract sensory sparing above the S4/S5 dermatomes level in injuries of a cervical or dorsal or upper sacral injury. Furthermore, the definition of the various classes of the new assessment tool have been updated and redefined at least eight times to ensure uniformity of design or demonstration and interpretation of outcomes. Crucially to date no comparison of early or late decompression with the outcomes on APCM have been made.

The Role of the Robert Jones & Agnes Hunt Orthopaedic Hospital (RJAH)

By the mid-eighties increasingly popular claims of benefits from surgical intervention were being made based on the radiological findings revealed by CT & MRI scanning.

We had to choose between continuing to manage patients by APCM (a method of known & predictable outcomes) while testing the significance of the radiological changes or to change to a surgical method of management of the spine relying on CT and MRI findings

The institution had the advantage of having on site excellent internationally acknowledged spinal surgeons and a team of health care professionalstrained in the management of patients with TSCI treated conservatively and surgically when indicated. We were encouraged by the published findings by Bedbrook in 1982[38] and Tator et al's in 1986 [28] of a lack of differencein neurological outcomes between patients conservatively treated and surgically treated [28] patients and early publication on remodelling of the spinal canal [43]

Considering the lack of evidence of any superiority of outcome from either APCM or Surgery, the predictable spontaneous neurological recovery following APCM from the Frankel class of the patient on presentation and considering the fact that the radiological findings wouldon the balance of probabilities have been present but not accurately demonstrated by Xrays; we decided it would be paramount to study the significance of the radiological features seen on the CT and MRI scans. We decided to initially treat 51 patients admitted within one week of injury with APCM; closely monitor and correlate the neurological progress with the radiological features irrespective of the degree of malalignment and biomechanical instability, canal encroachment and cord compression. Being able to monitor our patients annually or on alternate years for life enabled us to also familiarise ourselves for the medium and long outcomes of these patients.
We have been monitoring published some of our first case reports in 1992 [6,29] and subsequently over the years in [13,14,15,16,17,29,30,31,32] demonstrating a complete lack of correlation between the degree of canal encroachment neurological presentation and neurological recovery. Similar results were confirmed by other groups [33,34,35,36,37,38,39,40,41,42] Furthermore early reports of resorption of osseous material and remodelling of the spinal canal had already been published [43]

INDICATIONS FOR SURGERY AT THE (RJAH):

- Neurologically Intact Patients with Biomechanical Instability
- Pure Ligamentous Injuries with no bony spinal injury
- Mentally Challenged Patients
- Patients with Uncontrolled Epilepsy
- Patients incapable of complying with conservative treatment and accept the unknown outcomes of surgery compared to those of APCM
- Neurological Deterioration is extremely rare in patients treated with APCM and the neurological outcomes of surgery remain unknown. In our experience if the pin prick sensation is still appreciated recovery invariably occurs

All patients with TSCI are offered an informed choice between APCM & Surgical management with full knowledge of the benefits, limitations, hazards and outcomes of both methods of treatment.

Conclusions

To date, other than a fit for purpose model of service delivery that simultaneously and holistically attends to the spinal cord injury and all its systemic effects, there is no evidence of equality or superiority of outcomes with any method of treatment of the injured spine.
On the balance of probabilities what seems to determine the neurological outcome is the force of the impact that damages the spinal cord at the time of the accident, the adequacy of protection of the spinal cord from mechanical and non-mechanical damage. The success of protection is determined by the quality of the simultaneous management of the injured spine together with the multi-system malfunction to prevent complications.
Further damage to the injured neural tissues by mechanical and systemic non-mechanical insults during the early stages of injury remain the main cause of neurological deterioration, delays or lack of expected recovery following TSCIs.
The author strongly recommends that if surgery is to be considered, this should be carried out by knowledgeable and experienced surgeons and anaesthetists, in a set up capable of adequately coping with both the

multi-system physiological impairment and malfunction as well as the surgical, Para-surgical and post-operative requirements of patients.

The author asserts that the two-century old controversy in the management of the injured spine is likely to be perpetuated unless adequately designed prospective studies are carried out in centres wherethe patient's spinal cord injury and all its systemic effects can be equallywell managed from the early hours of injury and patients can be adequately matched for level and density of the cord damage.

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