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Cervical Spine Injury .

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There is no doubt that serious injuries to the cervical spine is one of the major and most devastating health care problems that besets man, affecting so many body systems and necessitating the involvement of many public services and medical and other specialists. The patient's whole life may quite suddenly become disrupted, with permanent personal, family and employment problems. Maximal vertebral column deformity and associated neural and vascular damage usually occurs at the time of the injury.

The appreciation, organisation and harnessing of proper resources for traumatic tetraplegic patients is indeed a challenge. The study and management of traumatic tetraplegia is a microcosm of the overall scientific and humanitarian progress of man [1], [2], [3], [4], [5], [6].

As noted by Edwin Smith in the medical writings of the Egyptians some 6,000 years ago, there is a phrase concerning spinal cord injuries: "an ailment not to be treated". This was understandable, because death was the immediate or the early outcome of such injuries - how times have changed!

My aim today is to highlight some of the current medical aspects of patients with severe cervical spinal injury. Our interest and responsibility is firstly to try to prevent such injuries from occurring, but having occurred, to ensure that the patient is expertly managed, and this includes maintaining the cervical spinal cord, nerves and vessels in an optimal environment to allow neurological functions to recover maximally, to prevent complications and to permit the best possible future life for the patient.

Epidemiology and Aetiology

Most reported series give an incidence of between 30 and 40 new severe spinal cord injury patients per million of the population per year, and about 10% of such patients will be tetraplegic. The commonest age for such injuries to occur is from 15 to 24 years, with a second peak at about 55 years and increasing as people get older. As is to be expected, the condition is much more common in males than in females [1], [2], [7].

In many countries the commonest cause is a road traffic accident either involving a person in a vehicle, especially the front seat passenger, or a pedestrian and motor cycle accidents are unfortunately notorious resulting in cervical spine injuries and indeed many of these are unfortunately immediately fatal or the patient succumbs soon after the accident. Another common cause is a fall, from a building site or a tree, or in someone's home - especially an elderly person who possibly has poor vision and a poorly lit home. Sporting accidents can unfortunately be the cause, in particularly diving into shallow

water, contact sports and horse-riding. Direct blows to the spine can occur, for example at work, or possibly from an assault, and stabbings occur either with a knife or some other object such as a bicycle spoke. Missile injuries are not uncommon, even outwith a period where there is no major war proceeding. Iatrogenic causes include osteopathic manipulations of the neck, especially in a person who happens to have cervical spondylosis. Another cause is attempted suicide.

Prevention

It must be appreciated that most spinal cord injuries are preventable, and if proper, straightforward and indeed not necessarily expensive care can be promptly instituted, most of the serious complications following cervical spinal cord injury, which can cause awful miseries and cost so much money, may be obviated. Proper education of health workers and the public is necessary, and this is achieved by education and example [1], [2], [3], [8].

Biomechanics, Anatomy and Pathology

The cervical spine is unique from the anatomical point-of-view. It is slender compared to the other parts of the spine, and its construction is such that it is the most mobile part of the spine, thus the facet joints lie almost horizontal, compared to the direction of the facet joints in the lower thoracic and lumbar regions of the spine where they are vertical . Except for the uppermost part of the cervical spine, the spinal cord almost completely fills the cervical spinal canal, and therefore there is little room available for any space-occupying mass, be it an intervertebral disc protrusion or bone fragments, and indeed the cervical spinal cord and nerve roots and vessels can be compromised by even relatively minor distortions of the cervical spinal canal resulting from trauma. The commonest site is at the C5/6 level and the C6/7 or C4/5 or the C7/T1 level. The next common site is the atlanto axial region.

The main forces are flexion and rotation, causing either a unilateral or bilateral dislocation of the cervical spine, or a compression fracture of a vertebral body; extension in older patients for example resulting from someone falling forwards with a blow to the face and forehead and causing acute hyperextension of the cervical spine. Other types and direction of forces can produce certain distinctive cervical spine injuries such as

(a) dislocation at the atlanto axial level or fracture dislocation at this site.
(b) a fracture dislocation at the C2/3 level, causing the so-called Hangman's fracture; and rarely
(c) a closed injury to the back of the neck causing fracture of a lamina which can compress the dorsal aspect of the spinal cord.

The atlanto-axial injuries usually result from combined axial loading and acute neck flexion. In ankylosing spondylitis, and in rheumatoid arthritis, distinctive cervical spine injuries can occur [1], [2], [9].

Animal Experimentation

In recent years there has been a resurgence of interest in experimental animal spinal cord injuries studies, in particular showing that immediately following spinal cord injury, and proceeding progressively for up to some 4 hours or so, secondary chemico-vascular changes occurs, usually starting centrally in the injured spinal cord and spreading peripherally [10]. As a result, haemorrhagic necrosis develops. Different therapies have been used in an attempt to delay or indeed to reverse these changes. But it is absolutely essential that careful, controlled, well-planned experimental studies continue. The great hope, of course, is to obtain regeneration of the severely injured spinal cord. Much research is progressing in this field, but we must be aware of "miracle cures" [10], [11], [12].

Clinical Features and Diagnosis

Unfortunately, serious cervical spine injury may either be missed or the diagnosis may be delayed, and there are several reasons for this, including the fact that about 30% of such patients have a significant associated injury, in particular a head injury [13]. Another factor in some countries is the abuse of alcohol so that the patient is difficult to assess clinically. However, a cervical spine injury should be considered as a real possibility in anyone ill enough to be admitted to hospital because of a head injury, and in any patient who has multiple injuries "At risk".

A system for clinical neurological classification is necessary, and the most common one in use is that by Frankel et al [14]. But although this classification is very important and is recommended, other systems are also in use, which stress upon other aspects of the clinical syndromes that may result from spinal trauma, including the Yale Index [15]; and the system recommended by Chehrazi et al [16].

There may be immediate complete loss of spinal cord function, that is tetraplegia, but tetraparesis is fortunately common with reasonable prospects for some useful recovery of neurological function. A partial cervical spine cord traumatic lesion can result in an anterior cord syndrome, especially from an acute flexion rotation injury, a central cord syndrome tends to result from an acute hyperextension injury in an older person who has a degree of cervical spondylosis, a Brown-Sequard syndrome, that is a hemi-cord lesion, is less common, but can occur for example from unilateral facet joint dislocation, although this type of bony/joint injury more often does not result in any neurological disability except for possible nerve root disturbance at the site of the dislocation.

The patient may have an associated injury and, in particular a head injury, and this can make the diagnosis of a spinal cord injury difficult, but it is essential to consider the possibility of cervical spinal injury in any patient referred to hospital because of a head injury. In our Department in Edinburgh, 5% of our head injury admission patients have a significant associated spinal injury, nearly always a cervical spine injury.

A most important aspect of patients who have sustained a spinal injury is that of the psychological effects on the patient. Thus initially the patient wonders "will I live?"; subsequently he becomes concerned about the probable quality of his life. There are very real psychological problems in many of these patients, including sensory deprivation [17], mood swings, depression, anxiety, thoughts of suicide and, at times, anger and frustration [17], [18].

Investigations

A.Radiological

There has been tremendous progress in recent times concerning the radiological studies of patients with cervical spine injuries, including much better plain radiological studies with open mouth, and with oblique views. Cervical myelography is only occassionally indicated, and should only be carried out by a very experienced radiologist after full discussion with the clinician in charge of the patient. Such myelography can be invaluable in patients who have sustained a cervical spine injury and have severe neuralogical involvement, whereas plain radiographs of the cervical spine do not show any significant traumatic abnormalitiy. Thus an acute protrusion of the cervical intervertebral disc can occassionally occur as a result of trauma to the neck, and this pathology may only be defined by a myelogram, but now a days where there are facilities for computerized tomography, this may be a better form of investigation in such patients [4], [19].

Computerized tomography of the cervical spine is providing much information concerning the bone and soft tissue changes that occur in some of these patients, but we have a good deal to learn still, and I am not at all certain myself if this type of investigation is leading to improved management of cervical spine injured patients. Certainly, we can identify trauma that could not be demonstrated by other types of radiological studies, including fragments of bone or intervertebral disc tissue or haematomas in the spinal canals, and including swelling of the spinal cord [20], [21].

Magnetic resonance imaging (M.R.I.) is a wonderful invention and has certain advantages over computerized tomography. Thus no ionizing radiation is involved, the investigation is not invasive, the spinal cord can be visualised in its whole length or in segments, and multiplanar magnetic resonance images can be obtained. We are just beginning to appreciate the possibilities of this new facility, but unfortunately so far it is not possible to distinguish between white and grey matter of the spinal cord. One very practical use of M.R.I. is in the diagnosis of post-traumatic syringomyelia [19], [20].

B.Evoked Potentials

Motor and sensory evoked potentials would appear to have a place in the study of spinal cord injury patients, but so far I am not convinced that they are better than a good clinical neurological examination, regarding the degree of completeness of a spinal cord traumatic neural lesion. However, in the unconscious patient, and in a patient who is anaesthetised - for example spinal surgery to reduce by operation a cervical spine dislocation, or when carrying out some other spinal operations such as a procedure for scoliosis, evoked potential studies can be of real practical value. This is a form of investigation which is being intensively studied in many clinical neurophysiological departments in many centres throughout the world [22].

Management

In few circumstances of trauma can the early care given to the patient with a cervical spine injury be so directly related to prognosis. The time factor is of great importance, as spinal cord chemico-patho-physiological changes may develop at an accelerated time scale, with increasing neural damage, resulting in "self-destruction" of the spinal cord.

Thus expert care of the patient at the site of accident is essential; a "second injury" must not be allowed

to occur. Remember that about 30% of patients with a severe spinal injury have a significant associated injury, most often a head injury. A free airway, good ventilation - if necessary aided, and an optimal circulation with a good perfusion pressure are vital. Homeostasis must be achieved. At the site of the accident, use a back board and collar, or some other appliance such as my whole body splint. Communicate promptly with specialists knowledgeable in the care of someone who has sustained a cervical spine injury, and ideally and with the utmost care, transport the patient to the nearest best staffed and equipped hospital, preferably this should be a Spinal Injury Centre, part of an accident service of a general hospital which can provide a high standard of patient care, from every point of view [1], [4].

The first few hours and days following a severe cervical spine injury are the most important ones for the survival and the well being of the patient. I cannot emphasise this too strongly. This is difficult to obtain and to achieve in many parts of many Western countries. Ideally, such patients should be admitted to a Spinal Injury Service, and gradually, in many countries throughout the world, such facilities are becoming available, but there is a very real necessity for more Spinal Injury Services of excellence, because only then is it possible to do all that one should do for such patients who, after all, do not have a progressive disease such as malignancy of the Spinal Cord, and many of these patients are young and have their whole life ahead of them. I know that in India an increasing interest is being taken in the management of patients who have sustained a serious spinal injury and some spinal centres linked with good general hospitals are available and others are now under consideration [23], [24], [25]. Such patients are vulnerable, and susceptible, to urinary, respiratory, gastro-intestinal and other serious disturbances, including deep vein thrombosis and pulmonary embolism. Thus it is essential that appropriate prophylaxis and care of the patient is begun as soon as possible and is maintained. There are many different types of beds and turning frames available, and we prefer the stryker turning frame used along with Gardner Wells tongs with a special modification for the tongs on the frame in the form of supports. A special bridge has been shown to be useful to help to reduce dislocations and fracture-dislocations of the cervical spine and also to provide a firm support for the cervical spine if a decision has been taken to operate on the patient's neck. But I do not like to have my patients spend any length of time on the Stryker turning frame, and for certain patients with dislocations or fractures or fracture-dislocations of the spine, I prefer, once the dislocation or fracture-dislocation has been reduced, to carry out - usually some days or about a week following the reduction, posterior cervical wiring of spinous processes along with a special type of methy methacrylate called Palacos-R (which contains Gentamycin and is radio opaque). This provides internal fixation of the injured spine and then under the same anaesthetic, an anterior operation is carried out, for a dislocation an interbody bony fusion is done;and if there is a comminuted fracture with displacement of disc tissue and bone fragments in the spinal canal, these are removed and a wedge of iliac bone is used as an anterior graft. The patient can then have early mobilisation. Alternatively, the halo head- trunk apparatus may be used to fix the cervical spine, but this is cumbersome and is unpleasent for the patient, especially in countries with hot climates. For patient with atlanto-axial dislocations of fracture-dislocations, other measures may be necessary. A dislocation at this site can be treated by reduction followed by posterior wiring of the arch of the atlas to the spinous process of the axis along with some palocos, but bone grafting of the atlanto-axial region is also required for permanent stability and prevention of redislocation. A problem with wiring is that it may either break, or it can cut through the bone. Alternatively, a trans-oral approach to atlanto-axial region can be used to fuse the atlanto-axial joints on each side [4], [26].

Type.

1. Fracture of the dens is stable.
2. Fracture, that is at the base of the dens where it adjoins the body of axis. This is the commonest dens fracture and tends to be unstable and the incidence of non-union if appropriate operative treatment is not carried out is high.
3. Fracture of the dens is more stable and more likely to fuse satisfactorily with simpler surgical measures.

We must always remember the importance of an osodontoideum. The so-called "Hangman's fracture" usually heals well and there are no neurological or minimal neurological deficits, and the treatment is to apply a suitable firm collar. It should be appreciated that the halo-thoracic orthosis should not be used if the patient has cutaneous sensory loss over the upper part of the trunk and the shoulders because of the danger of the development of pressure ulcers.

The controversy regarding early operation on patients with severe spinal injuries continues. Theoretically certain operations can make patient handling safer and easier, and may permit earlier mobilisation of the patient, but all operations may only very occassionally result in neurological improvement, and they can cause complications, especially if they are not carried out expertly by those quite familiar with the management of such patients.

Probable absolute indication for early spinal surgery are:
(1) An increasing neurological lesion.
(2) An open injury.
(3) Delayed onset of a neurological lesion.
(4) Un-reduced dislocations and fracture dislocations.

And delayed indications to be considered are [1], [4], [10], [27], [28]:
(1) An incomplete neurological lesion.
(2) If recovery of the neurological lesion is halted.
(3) Vertebral column instability.
(4) Permanent serious malalignment of the vertebral column.
(5) To decompress nerve roots [3], [4], [12], [15], [30].

Local cord cooling; hyperbaric oxygen, and pharmacological therapies, are unfortunately, not proven regarding their possible benefit in treating patients with severe spinal cord injury. Urinary tract management-intermittent catheterisation of the bladder is strongly recommended; Urodynamic studies will become necessary for many of these patients; some eventually will require a transurethral bladder neck resection. Later on, self catheterisation is proving to be most useful for many of these patients both male and female; sometimes a fine supra-pubic catheter is used in some centres. For male patients a condom sheath catchment system can be practical and valuable. In more recent times, sacral anterior nerve root electrical simulation is proving to be a practical, although complex and expensive procedure for certain patients with neuropathic bladders [29], [30]. For some patients, a penile prosthesis is indicated, really to facilitate the wearing of a sheath. A portable real-time ultrasonic scanner is invaluable for the estimation of urinary bladder volume, obviating the necessity for catheterisation to check this volume [31], [32], [33].

Concerning the respiratory system in patients with severe spinal cord injuries, early death from respiratory problems has been considerably reduced in the last 15 years for mid or higher cervical cord

lesions artificial ventilation will most likely, but significant spontaneous improvement can occur after some weeks or months. However, some of these patients with high cervical lesions will require either permanent artificial ventilation, or require phrenic nerve electrical stimulation. The multi-disciplinary care of the high tetraplegic at C4 and above is a tremendous challange in medicine and can only really be carried out satisfactorily in Spinal Centres where all the expertise is available. Such patients cannot be treated on a Stryker turning frame because they cannot manage to lie prone as this greatly restricts ventilation. Another innovation for those patients with high cervical lesion is the use of a pneumobelt. This is an abdominal corset which, by inflation, and deflation assists ventilation [1], [34], [35], [36], [37].

Functional electrical stimulation for the spinal paralysed is an exciting new technique which is being studied in a few centres in certain countries, and although it may have the potential in permitting some form of standing and even "ambulation" in the paraplegic patient, at present it has a very limited place in helping the tetraparetic or tetraplegic patient. By electrically stimulating such groups of muscles as the quadraceps and the dorsi-flexor muscles by surface or implanted electrodes, practical benefits can be obtained in a few patients who are paraplegic. One important problem is the fatigue that occurs in such stimulated paralysed muscles, and sequential stimulation is required and this involves multichannel control for the antigravity and the propulsive muscles. Indeed function electrical stimulation is still in its early days of intense study in a relatively small number of centres in different countries, and it would be quite wrong to raise the hopes of the spinal paralysed and, unfortunately, publicity in the press and media has been premature [38], [39], [40].

For the paralysed upper limb, in selected patients certain orthopaedic procedures, and now-a-days sometimes in conjunction with functional electrical stimulation with the implantation of electrodes, can be invaluable. Thus to produce elbow extension, the posterior third of the deltoid muscle may be transfixed into the triceps tendon. If the patient has wrist extension, the ECRL muscles can be transferred to the FDP; and for independent thumb flexion the brachioradialis muscle can be transferred to the FPL [41], [42]. Moberg [41] is most likely the most distinguished orthopaedic surgeon in this field, and he obtained key pinch grip, with a tendonesis of the FPL into the lower end of the radius with stabilisation of the interphalangeal joint of the thumb. Certainly functional electrical stimulation will strengthen wasted muscles and will help to restore bones that are osteoporotic.

Regarding sexual aspects from an early stage following injury, it becomes very important, especially when patients are young. Proper counselling should begin within the first few weeks following the spinal injury. In recent years the management of the sexual aspects of the spinal paralysed patient has become much better understood and more scientific, both for the male and for the female patient [43]. For the male patient with a high cervical cord lesion there is no genital sensation, but emotional aspects of sex are normal, and such patients can usually get reflex penile erections but not ejaculation, except possibly retrograde into the urinary bladder. The female patient will have amenorrhoea initially for upto about a year, and then becomes fertile and can become pregnant.

Social re-adaptation should be well planned and be realistic. There are very many aspects to this, including modification of the patient's home, the use of orthoses of micro-switches, a wheelchair which may be required to be electrically propelled. Education of the patient and members of his family and close friends is essential. Community resources are vital. A nurse coordinator is a very important person from the spinal paralysed patient's point-of-view [1], [2], [5], [6].

Outcome and Functional Expectations

A very small percentage of patients who have a complete neurological lesion initially, or apparently initially, can make some recovery but rarely of any practical value. However patients with partial cervical spinal cord lesions usually show definite recovery of cord functions, but rarely excellent recovery and much depends on the type of neurological disability that the patient has. Thus those with central cord lesions will have good recovery of motor power and sensation in their lower limbs, but usually very poor recovery of the hands and digits. There is no conclusive evidence that direct treatment of the spinal lesion by closed or open means has any significant influence on the outcome of neurological recovery, although this remains an area of great controversy. It is obvious that more precise, and if this is ever possible, control studies are necessary [1], [3], [10], [28], [44], [45], [46], [47].

Regarding functional expectation, for patients with spinal cord lesions from C7 to T1, complete independence is possible, and hopefully there will be an automatic urinary bladder which responds to supra-pubic tapping. Self-catheterisation is not possible in such patients because of their weak hands. Such patients are wheelchair bound, and may require an electrically propelled wheelchair. They can often manage to drive a hand controlled motor car.

Patients with a lesion at C6 level will require orthoses. Few such patients will be completely independent. It is unlikely that they will drive a hand controlled motor car. If the patient has a lesion at C5, assistance will be necessary for most activities. Such a patient can use a special electric wheelchair. A person with a lesion above C5 will be totally dependent and ventilation care is necessary. Even so, some of these patients will manage to use an electrically driven wheelchair.

Delayed Complications

Delayed spinal column deformity with possible neurological deterioration can occur. Possible excess callus formation at the site of vertebral injury; arachnoiditis; or post-traumatic syringomyelia may also cause delayed, progressive neurological deterioration. Autonomic dysreflexia is very important in a significant number of patients with a cervical spinal cord traumatic lesion. There is dissociation between hypothalamic control from the sympathetic spinal reflexes that are still active caudal to the spinal cord lesion, and certain efferent impulses may cause vaso-constriction and hypertension. Provoking factors include a full urinary bladder or rectum or a pressure ulcer or even an ingrowing toenail. This can be a most dangerous, even fatal, condition and requires serious attention as it can be controlled and it can be treated by sub-lingual glycerine trinitrate; or the patient may be given Clonidine, or Guanethidine. In the urinary system, in patients who have not had proper care, infection and indeed recurrent infections may ensure, calculi tend to form in the bladder and in the kidneys and eventually renal failure will develop. This should not happen now-a-days.

Other complications include spasms of the affected limbs and trunk, and contractures. Another complication is that of intractable pain, and this can certainly be a real problem. Then some of these patients, even if they have been well educated and indeed indoctrinated concerning the care of their skin, may develop pressure ulcers once they have left the hospital. An important delayed complication that requires early recognition, investigation and management, is post-traumatic syringomyelia. In the past few years it has been realised that this complication, especially in patients with cervical spine trauma and spinal paralysis, is not very uncommon and indeed one major series reported an incidence

of 4.5%. What happens is that, after a period of months up to several, sometimes many years, the patient begins to show neurological symptoms and signs above the level of the original spinal cord lesion, and these in particular consist of numbness and pain and motor weakness and are progressive. The condition required clinical evaluation and radiological studies, including CT Scan and, even better, magnetic resonance imaging. It is appreciated that such facilities are only available in a few hospitals that admit spinal cord injury patients. Myelography can, in these circumstances, be helpful in coming to a diagnosis of the condition. The best treatment would appear to be a syringoperitoneal shunt [48], [49], [50].

Ethics

The ethical aspects of patients with traumatic cervical spinal cord lesions are of paramount proportions. There is an obvious problem of the best utilisation of scarce resources, and problems related to the immediate management of a patient who requires artificial ventilation and subsequent care of such a patient. Throughout medicine we, as doctors and other workers looking after the sick and injured, can learn a great deal from our own patients. Recently Gardner et al [34] published an interesting and important paper on "Ventilation or dignified death for patients with high tetraplegia". The conclusion from this study was that in nearly all instances, the patients and indeed also their close relatives preferred to proceed with all that could be done for them, and in particular to remain on ventilation. As I have already mentioned, some of these patients after some months may be able to be weaned off the ventilator. However such patients do present tremendous problems.

Conclusion

In conclusion in this brief outline of "Cervical Spinal Injury", I have attempted to cover some of the main features of such injuries and in particular to express some of the more important aspects of the mechanism behind such injuries, the symptoms that may occur and their investigation and management.

One cannot think of any condition occuring in man that involves so many disciplines in medicine and in the allied health professions, as in a patient with a severe cervical spine injury. The spread of knowledge concerning such conditions is necessary for medical students and for those undergoing training in nursing and in other health professions.

Most fortunately by no means all patients with cervical spine injuries have high level injuries that are complete, and many of these patients have incomplete neurological lesions that tend to recover, certainly to a degree.

I would conclude by quoting from Tolstoy who, in his book "War And Peace", states that "The most difficult but most essential thing is to love life, to love it even when one suffers because life is all".

1.Bedbrook G M, *The Care and Management of Spinal Cord Injuries. Springer Verlag, New York*
2.Guttmann Sir Ludwig, *Spinal Cord Injuries Blackwell Scientific Publications, Oxford*1973
3.Harris P, Acute spinal cord injury patients-who cares?

Paraplegia Page: 23: 1, 1985
4.Harris P, The spine
In: Hamilton Bailey's Emergency Surgery (Ed) H.A.F. Dudley, 11th Edn. John Wright and Sons Ltd., E
Page: pp.139-150,
5.Rogers M, *Paraplegia-A Handbook of Practical Care and Advice. Faber & Faber London*
6.Rogers M, *Living with Paraplegia. Faber & Faber London*1986
7.Kraus J F, A comparision of recent studies on the extent of the head and spinal cord injury problem in the United States
Journal of Neurosurgery Page: Suppl. S. 35-43, 1980
8.Donowan W H, Carter R E, Bedbrook G M, Young J S & Griffiths E R, Incidence of medical complications in spinal cord injury: Patients in specialised compared with non-specialised centres
Paraplegia Page: 22: 282, 1984
9.Dohrman G J, Punjabi M & Banks D, Biomechanics of experimental cervical spinal cord trauma
Journal of Neurosurgery Page: 48: 993, 1978
10.Collins W F, A review and update of experimental and clinical studies of spinal cord injury
Paraplegia Page: 21: 204, 1983
11.Allen A R, Surgery of experimental lesion of spinal cord equivalent to crush injury of fracture dislocation of spinal column
JAMA Page: 57: 878, 1911
12.Hughes J T, Regeneration in the human spinal cord: A review of the response to injury of the various constituents of the human spinal cord
Paraplegia Page: 22 :131, 1984
13.Harris P, Associated injuries in traumatic paraplegia and tetraplegia
Paraplegia Page: 5: 215, 1968
14.Frankel H, Hancock D O & Hyslop G, et al, The value of postural reduction in the initial management of injuries of the spine with paraplegia and tetraplegia
Paraplegia Page: 7: 129, 1969
15.Bracken M B, Webb S B & Wagner F C, Classification of the severity of acute spinal cord injury: Implications for management
Paraplegia Page: 15: 319, 1978
16.Chehrazi B, Wagner F C, Collins W F & Freeman D H, A scale for evaluation of spinal cord injury
Journal of Neurosurgery Page: 54: 310, 1981
17.Harris P, Patel S S, Greer W & Maughton J A L, Psychological and social reactions to acute spinal paralysis
Paraplegia Page: 11: 132, 1973
18.Treischman R B, Ed:, *Spinal Cord Injuries: Psychological, Social & Vocational Adjustment. Pregamon Press, New York*1980
19.Perovitch M M, Application of Contrast agents in M.R.Imaging, In:
Proc. of the International Conference for Clinical Neuroimaging. Weiner, Medizuische Academia, Wie
Page: pp 44-46, 1986
20.Perovitch M M, Neuroradiology of the sequelae of the spinal cord trauma
In Trauma and Regeneration (Ed.) J.Hume Adams. Acta Neurochir, Suppl. 32.Springer, Wien
Page: pp.91-94, 1983
21.Post M J D & Green B A, The use of computed tomography in spinal trauma
Radiological Clinics of North America Page: 21: 327, 1983
22.Bowed D W, Mclean J A & Tator C H, Somatosensory evoked potentials in acute spinal cord injury: Prognostic value

Surgical Neurology Page: 9: 203, 1978
23.Amara D, Yagoubi Z, Benbakhma M & Ouali O A, Traumatic paraplegia in Algeria: Orientation of early management
Paraplegia Page: 23: 16, 1985
24.Chacko V, Joseph B, Mohanty S P & Jacob T, Management of spinal cord injury quadriplegia
Journal of Bone & Joint Surgery Page: 57A: 196, 1975
25.Shanmugasundaram T K, The care of spinal cord injury patients in the developing nations-can we stem the rot?
Paraplegia (in press)
26.Harrris P, Anterior cervical spinal operations
In: Operative Surgery: Neurosurgery(Ed) L. Symons 3rd Edn Page: pp.447-462.4th Edn., 1986 (in press)
27.Anderson L D & D'Alonzo R T, Fractures of the odontoid process of the axis
Journal of Bone & Joint Surgery Page: 56A: 1663, 1974
28.Ducker T B, Russo G L, Bellegarique R & Lucas J T, Complete sensorimotor paralysis after cord injury: Mortality, recovery, and therapeutic implications
Journal of Trauma Page: 19: 837, 1979
29.Brindley G S, Polkey C E & Rushton D N, Sacral anterior root stimulators for bladder control
Paraplegia Page: 20: 365, 1982
30.Cardozo L, Krishnan K R, Polkey C E, Rushton D N & Brindley G S, Urodynamic observations on patients with sacral anterior root stimulators
Paraplegia Page: 22: 201, 1984
31.Grundy D, Swain A & Russel J, A.B.C. of spinal injury. Early management and complications. II.The urinary tract
British Medical Journal Page: 292: 123, 1986
32.Guttmann L & Frankel H L, The value of intermittent catheterisation in the early management of traumatic paraplegia and tetraplegia
Paraplegia Page: 4: 63,
33.Wyndele J J, Desywa & Classens H, Evaluation of different methods of bladder drainage in the early care of spinal cord injury patients
Paraplegia Page: 23: 18, 1985
34.Gardner B P, Theocleous F, Watt J W H & Krishnan K R, Ventilation or dignified death for patients with high tetraplegia
British Medical Journal Page: 291: 1620, 1985
35.Glenn W W L, Diaphragm Pacing: Present Status
Pace Page: 1: 357, 1978
36.Glenn W W L, Hogan J F & Phelps M S, Ventilatory support of the quadriplegic patient with respiratory paralysis by diaphragm pacing
Surgical Clinics of North America Page: 60: 1055, 1980
37.*Multicentre Conference on the Multidisciplinary Care of the High quadririplegic C4 and above. Houstan, Texas, USA*November, 1985
38.Beresford R, Development of Functional Stimulation using an adaptive Electrode
Ph.D. Thesis, University of Southampton, England
39.Kralj A, Bajd T & Turk R, Electrical stimulation providing functional use of paraplegia muscles
Medical Programme Technology Page: 7: 3, 1980
40.Marsolais E B & Kobetric R, Functional walking in paraplegic patients by means of electrical stimulation

Clinical Orthopaedics Page: 175: 30, 1983
41.Moberg E, Surgical treatment for absent single-hand grip and elbow extension in quadripelgia
Journal of Bone & Joint Surgery Page: 57A: 196, 1975
42.Peckham P H, Marsolais E B & Mortimer J T, Restoration of the key grip and release in the C6 tetraplegic patient through functional electrical stimulation
Journal of Hand Surgery Page: 5: 462, 1980
43.Brindley G S, Electroejaculation: Its technique, Neurological implications and use.
Journal of Neurology, Neurosurgery & Psychiatry Page: 44: 9, 1981
44.Geisler W O, Jousse A T, Wynne-Jones M & Breithaupt D, Survival in traumatic spinal cord injury
Paraplegia Page: 21: 364, 1983
45.Harris P, Karmi M Z, McClemont E, Mathloko D A & Paul K S, The prognosis of patients sustaining severe cervical spine injury (C2-C7 inclusive)
Paraplegia Page: 18: 324, 1980
46.Wagner F C J & Chehrazi B, Early decompression and neurological outcome in acute cervical spinal cord injuries
Journal of Neurosurgery Page: 56: 699, 1982
47.Wilmot C B & Hall K M, Evaluation of the acute management of tetraplegia: Conservative versus surgical treatment
Paraplegia Page: 24: 148, 1986
48.Rossier A B, Foo D, Shillito J & Dyro F M, Post-traumatic cervical syringomyelia
Brain Page: 108: 439, 1985
49.Vernon J D, Silver J R & Ohry A, Posttraumatic syringomyelia
Paraplegia Page: 19: 67, 1981
50.Williams B, Terry A F, Jones F & McSweeney T, Syringomyelia as a sequel to traumatic paraplegia
Paraplegia Page: 19: 67, 1981