A PROSPECTIVE STUDY OF THE VALUE OF NEUROLOGICAL AND RADIOLOGICAL EXAMINATIONS IN PREDICTING BLADDER FUNCTION IN PERSONS WITH THORACOLUMBAR FRACTURES AND SPINAL INJURY

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Of

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CERTIFICATE

This is to certify that this thesis entitled "**The value of Neurological and Radiological Examinations in Predicting Bladder Function in Persons with Thoraco-Lumbar Fractures and Spinal Injury"** is the bonafide work of Dr. M. Santhosh Kumar and was conducted at the Department of Physical Medicine and Rehabilitation,

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CONTENTS

Introduction

Spinal Cord Injury (SCI) is a devastating medical condition which results in decreased sensation below the level of injury, decreased motor power and decreased bladder and bowel control. "An ailment not to be treated" is what is written in the Edwin Smith Surgical Papyrus,[1] written in Egypt between 2500 and 3000 B.C regarding Spinal Cord Injury. Thanks to Dr. Mary Varghese who did pioneering work in India by establishing a department for Spinal cord injured patients and efforts of several other leaders in this speciality across the world, we are now able to treat persons with spinal cord injuries and improve their quality of life.

Spinal Cord Injury (SCI) has long-term effects in many aspects of an individual's life.
Acute SCI patients commonly have two major questions for which they seek answers, one is if they can walk and the other is if they can have normal bowel and bladder sensation and control. Anxiety about one's urinary continence is often one of the major preoccupations of a person with spinal cord injury. The degree of bladder dysfunction may be related to the injury itself, the level of the spinal cord affected by the injury, and the severity of neurological impairment. Investigation techniques used to help address the issue of predicting bladder outcome in persons with acute SCI include clinical examination, X-rays of the spine, CT scan, MRI and electrophysiological examinations.

CT scan, MRI and electrophysiological examinations are not available in every medical center in our country and all cannot afford these investigations. This study was done to evaluate the use of clinical examination and x-rays, modalities widely available in our country, to predict urinary continence in persons with acute SCI.

Aims and Objectives

The aim of the study was

1. To examine the value of Neurological and Radiological examinations in predicting bladder function in persons with Thoraco-Lumbar fractures and Spinal Injury.
2. To determine if ASIA incomplete spinal lesions on clinical examination will have a better prognosis for bladder function in the form of volitional voiding.
3. To determine the role of bulbocavernous reflex in predicting the type of bladder.
4. To determine if persons with a vertebral fracture at T12 or above will have a hyperreflexic bladder and those with of L-1 and below will have an areflexic bladder.
5. To determine if those with a mild narrowing of the vertebral canal have a better prognosis for volitional voiding.

Review of literature

Incidence and Prevalence

The incidence of traumatic Spinal Cord Injury (SCI) in USA was 11,000 cases per year and the prevalence was 250,000 persons in 2004.[2] The mean age at injury was found to be 32.1 years, with the most common age at injury being 19 years.[2-4] Studies done by Bors and Connarr and Zeitline showed that there was considerable variation in the age of a person affected and showed SCI affected young males more than females, children or older men.[5, 6] Men suffer traumatic SCI much more commonly than women, at a 4:1 ratio.[4]

Level and type of injury

The most common levels of spinal injury on admission are C4, C5 (the most common), and C6, while the level for traumatic paraplegia is the thoracolumbar junction (T12).[7] The most common type of injury on admission is ASIA impairment scale A.[8]

Table1. Etiology of SCI in USA during different decades.[9-14]

The above table shows an increase in the proportion of motor vehicle accidents from 1973s to the present. Spinal cord injury (SCI) following trauma to the spinal cord results in alteration of motor, sensory and autonomic functions. Traumatic SCI most commonly causes cervical lesions (approximately 50%) followed by thoracic and then lumbosacral lesions.[8] In spinal cord injury nearly 55% of patients develop tetraplegia, while 45%

become paraplegic; neurologically incomplete injuries are slightly more common (53.8%) than complete injuries (46.2%) [Watanabe et al 1996].[15]

Injuries of the spinal column are first assessed by clinical evaluation and then by investigations, which include X- rays, and if needed either CT scan or MRI. The clinical examination is the most common method used for assessing the extent and severity of the spinal cord injury. Stauffer and Meyer have emphasized the importance of clinical examination.[16]

The extent of injury is defined by the ASIA Impairment Scale (modified from the Frankel classification), using the following categories:

Revised ASIA impairment Scale[8]

A _ Complete: No sensory or motor function preserved in the lowest sacral segments (S4/5).

B _ Sensory incomplete: Sensory but no motor function preserved below the neurologic level including the sacral segments S4/5.

C _ Motor incomplete: Motor function is preserved below the neurologic level, and more than half of the key muscles below the neurologic level have a muscle grade less than 3.
There must be some sparing of sensory and/or motor function in the segments S4/5.

D _ Motor incomplete: Motor function is preserved below the neurologic level, and more than half the key muscles below the neurologic level have a muscle grade greater than or equal to 3. There must be some sparing of sensory and/or motor function in the segments S4/5.

E _ Normal: Sensory and motor functions are normal. Patient may have abnormalities on reflex examination.

Ferreiro- Velasco et al noted in their study of 37 patients with spinal cord injury, that 51.4% of the subjects corresponded to ASIA-A, 10.8% to ASIA-B, 8.1% to ASIA-C, 29.7% to ASIA-D.[17] Sacral-sparing is the evidence of the physiologic continuity of the spinal cord in which long tract sacral fibers located more at the periphery of the cord are spared. Indication of the presence of intact sacral fibers is of significance in defining the completeness of the injury and the potential for some neurological recovery. It is better to repeat the ASIA impairment scale and define the extent of neurological involvement after the period of spinal shock is over.

With the ASIA classification system, the terms paraparesis and quadriparesis now have become obsolete. The ASIA classification, using the description of the neurologic level of injury, is used in defining the type of SCI (eg, T8 ASIA-A with zone of partial preservation of pinprick to T10).

Muscle strength is graded using the following Medical Research Council[18, 19] (MRC) scale of 0-5:

5 - Normal power

4 - Movement against gravity and against resistance

3 - Movement against gravity but not against resistance

2 - Movement with gravity eliminated

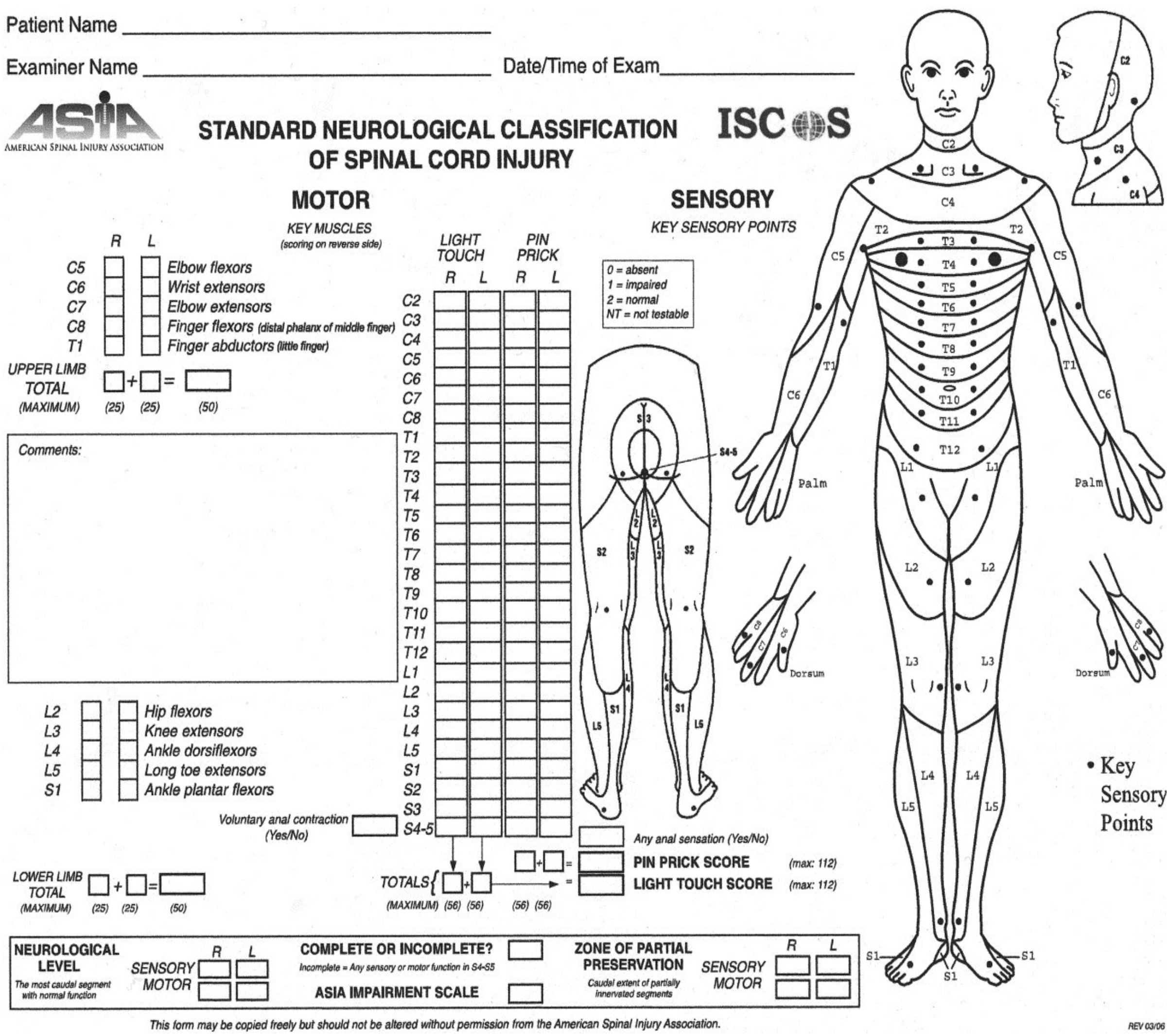
1 - Flicker of movement

0 - No movement

Muscle strength should always be graded according to maximum strength attained, no matter how briefly that strength is maintained during the examination. The muscles are tested with the patient supine.

The power of key muscles in the upper limb and lower limb that are tested in patients with SCI, and the corresponding level of neurological injury are indicated in the Figure1.

Figure 1: ASIA standard neurological classification of spinal cord injury-format.[20]



Sensory testing: Sensory testing is performed at the following sites:

C2 - Occipital protubérance C3 - Supraclavicular fossa C4 - Top of the acromioclavicular joint C5 - Lateral side of antecubital fossa C6 - Thumb C7 - Middle finger C8 - Little finger T1 - Medial side of antecubital fossa T2 - Apex of axilla T3 - Third intercostal space (IS) T4 - 4th IS at nipple line T5 - 5th IS (midway between T4 and T6) T6 - 6th IS at the level of the xiphisternum T7 - 7th IS (midway between T6 and T8)	T8 - 8th IS (midway between T6 and T10) T9 - 9th IS (midway between T8 and T10) T10 - 10th IS or umbilicus T11 - 11th IS (midway between T10 and T12) T12 - Midpoint of inguinal ligament L1 - Half the distance between T12 and L2 L2 - Mid-anterior thigh L3 - Medial femoral condyle L4 - Medial malleolus L5 - Dorsum of the foot at third metatarsophalangeal joint S1 - Lateral heel S2 - Popliteal fossa in the midline S3 - Ischial tuberosity S4-5 - Perianal area (taken as one level)

Sensory scoring is for light touch and pinprick, as follows:

0 - Absent

1 - Impaired or hyperesthesia

2 - Intact

A score of zero is given if the patient cannot differentiate between the point of a sharp pin and the dull edge.

Motor level – is determined by the most caudal key muscles that have a muscle strength of 3 or above while the segment above is normal (= 5)

Motor index - Using the 0-5 scoring of each key muscle with total points being 25 per extremity and a total possible score of 100, the motor index is the score obtained after examination of the patient's limb muscles compared to the absolute score possible.

Sensory level - Most caudal dermatome with a normal score of 2/2 for both pinprick and light touch.

Sensory index - Total sensory score determined by adding each dermatomal score. The maximum score possible is 112 each for pinprick and light touch. The sensory index is the score obtained after examination of the patient's key sensory sites verses the absolute score.

Neurologic level of injury – is the most caudal level at which both motor and sensory levels are intact, with motor level and sensory level as defined above.

Zone of partial preservation – is the index used when the injury is complete and denotes all segments below the neurologic level of injury with preservation of some motor or sensory function.

Skeletal level of injury – is the level of greatest vertebral damage on the radiograph.

Complete injury- is the absence of sensory and motor function in the lowest sacral segments.

Incomplete injury- is the preservation of motor or sensory function below the neurologic level of injury that includes the lowest sacral segments.

Sacral sparing- is the presence of motor function (voluntary external anal sphincter contraction) or sensory function (light touch, pinprick at S4/5 dermatome, or anal sensation on rectal examination) in the lowest sacral segments.

Radiological examination after acute spinal injury

Radiological investigations done for patients with SCI include anteroposterior and lateral radiographs of the cervical, thoracic, and lumbar spine. Because of the high prevalence of contiguous and noncontiguous associated spinal fractures, comprehensive radiographic evaluation, including the entire cervical, thoracic, lumbar, and sacral spine, is recommended for any patient who has sustained a high energy injury and in whom a spinal injury is suspected. Specific injury mechanisms and fracture patterns should trigger a targeted search for commonly associated nonspinal injuries. Chance fractures or flexion-distraction Chance variants are strongly associated with potentially life-threatening intraabdominal injuries. Computed tomography scanning is generally the next step after plain radiographic evaluation. The canal at the injured segment should be measured in the anteroposterior and transverse planes and compared with the levels cephalad and caudad to it. Alexander R. Vaccaro and colleagues found the most clinically useful measurement to be the ratio of the sagittal to the transverse canal diameter[21] using Computed tomographic scans. In their study, a smaller midsagittal diameter and a greater transverse diameter (a widened interpedicular distance) suggests higher energy injury and correlated with an increased risk of neurological deficit.[21] In the absence of neurological injury Magnetic resonance imaging scans usually are not required for thoracolumbar injuries in the acute setting. They can occasionally be helpful for identifying a ligamentous lesion that is suspected but not confirmed on plain radiographs and computed tomography scans. When a patient has a neurological deficit, however, magnetic resonance imaging is recommended to identify any ongoing spinal cord compression, evaluate cord anatomy, and rule out an epidural hematoma.[20]

Mechanical failure of the spinal column following high-energy trauma frequently occurs at the thoracolumbar junction as a result of its transitional anatomy and biomechanical environment. The most common fracture patterns at the thoracolumbar junction include compression fractures, burst fractures, flexion-distraction injuries, and fracture-dislocations. These injuries can be classified with use of either the anatomical three-column model of spinal stability described by Denis[22] (Fig. 2) or the mechanistic classification system of Ferguson and Allen.[23]

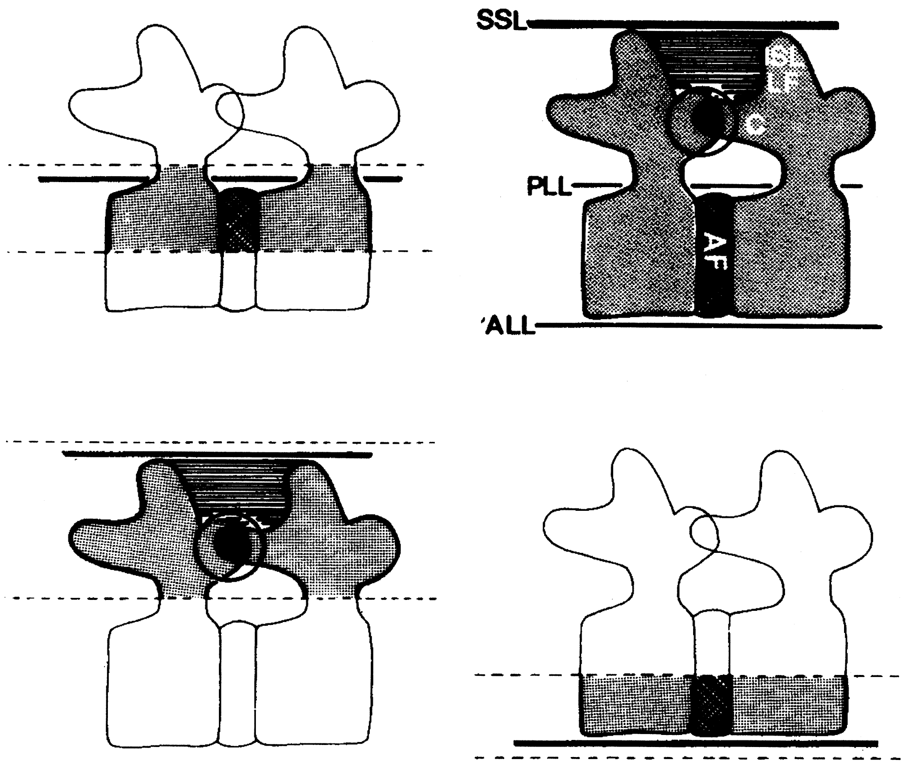


Figure 2: The Denis three-column model of spinal injury. The anterior column consists of the anterior longitudinal ligament (ALL), anterior half of the anulus fibrosus (AF), and anterior wall of the vertebral body. The middle column consists of the posterior longitudinal ligament (PLL), posterior half of the anulus fibrosus, and posterior wall of the vertebral body. The posterior column consists of the posterior osseous arch, supraspinous ligament (SSL), interspinous ligament (ISL), ligamentum flavum (LF), and facet joint capsule (C). Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine. 1983; 8:818.

In the anatomical three-column model described by Denis, the anterior column includes the anterior longitudinal ligament and the anterior half of the vertebral body and the annulus fibrosus, the middle column includes the posterior half of the vertebral body and the annulus fibrosus along with the posterior longitudinal ligament, and the posterior column includes the bone and ligamentous structures posterior to the posterior longitudinal ligament. With the three-column model, thoracolumbar fractures are differentiated on the basis of the pattern of injury to the middle column. Compression fractures involve failure of the anterior column in compression without injury to the middle column, whereas burst fractures result in compression failure of both the anterior and the middle column. Injury to the middle column is considered to be a potentially unstable fracture pattern in this classification scheme. Failure in distraction is characteristic of Chance fractures and Chance variants,[20] whereas any translation or rotation through the middle column indicates a high degree of instability, characteristic of a rotational burst injury or a fracture-dislocation.

Bladder

The urinary bladder wall consists of three layers:

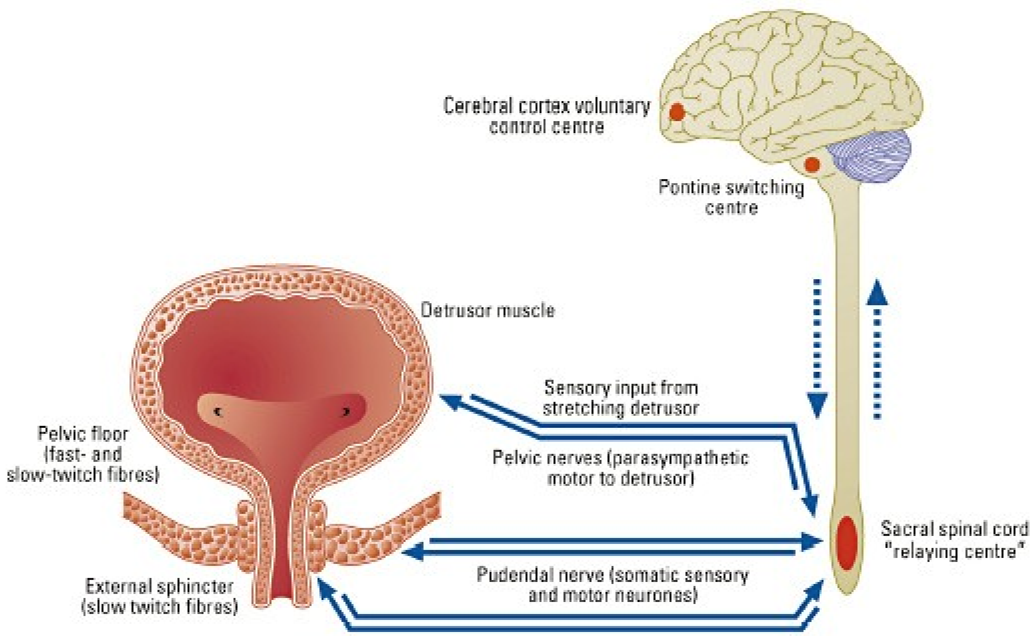
1. Outer adventitium of connective tissue
2. Middle smooth muscle layer
3. Inner mucous membrane

Peripheral Pathways:

The detrusor muscle is controlled by the autonomic nervous system and is richly innervated by four groups of nerves namely Cholinergic, Adrenergic, Nonadrenergic-noncholinergic (NANC), and Somatic.

Kluck[24] Daniel et al[25] supported the view of an extensive cholinergic innervation of the human bladder body smooth musculature. Parasympathetic or cholinergic innervation is provided by the sacral parasympathetic pelvic nerves (S2-4). The nerotransmitter for the cholinergic system is acetylcholine and it stimulates bladder evacuation. Mobely et al[26] described adrenergic fibers in the anterior wall of the human bladder. The sympathetic nerves originate in the intermediolateral grey columns of the thoracolumbar spinal cord from at least as high as T10 down to L2. Another group is nonadernegic noncholinergic (NANC) sensorimotor nerves containing a variety of putative neurotransmitters (principally peptides), which can be identified by immunoflurescent techniques - their precise role in controlling the human bladder is not clear.[27] There seem to be a parasympathetic supply to the urethra resulting in relaxation, although this is mediated by non cholinergic transmitters.[28] Somatic innervation to the pelvic floor and muscles originate in the Onuf's nucleus in the inferior horn of S2-4 segments of the spinal cord. They form the pudendal nerve that supplies the pelvic floor muscles and striated urethral sphincter.[29]

Figure 3: Shows a diagram of bladder and its peripheral and central connections.[30]



Central Pathways:

Although afferent nerves synapse with preganglionic cell bodies of both autonomic divisions in the spinal cord, the most important neural circuit in normal humans appear to be through a small area in the rostral pons, the nucleus locus coerleus.[31] Lesions of the central nervous system above this point do not appear to alter the characteristic neurophysiological features of a voiding detrusor contraction. Suprasacral cord lesions below this point not only alter these characteristics but also cause a loss of coordination between detrusor and sphincter behaviour. The function of the urinary bladder can be divided into two phases: storage phase and voiding phase.

The Storage Phase:

The bladder is able to hold increasing amount of urine without a corresponding rise in intravesical pressure, at least in part, by virtue of the elastic and viscoelastic properties of the bladder wall. There is a recurrent inhibition of preganglionic neurones by inhibitory interneurones in the intermediolateral grey columns, which are active at low bladder volumes but are suppressed during voiding contraction. The parasympathetic ganglia act, as "filters" so that when preganglionic activity is low impulses are not transmitted. Again, this effect is reversed during voiding. Also there is sympathetic inhibition of the parasympathetic ganglionic transmission alluded to above.[32]

Urethral closure pressure rises in humans, with progressive bladder filling, with a change of posture from lying to standing, when intraabdominal pressure increases, with physical activity and when the pelvic floor musculature is voluntarily contracted.[33] Sustained "Tonic" discharge of the lissosphincter by excitatory alpha-adrenergic sympathetic influence appears to be the crucial factor in urine storage.[34] For adequate urine storage good bladder compliance is necessary which allows the bladder to fill progressively to its capacity with minimal increase in its pressure.

Voiding phase

Voiding is achieved by a rise in intravesical pressure, which is sustained until the bladder is empty, with a synchronous fall in urethral pressure that returns to normal when intravesical pressure has fallen to resting levels. A voiding detrusor contraction is caused by a burst of efferent activity in the postganglionic parasympathetic nerves. For this to occur, all the neurological mechanisms, which keep these nerves quiescent during the storage phase, must be inhibited. On voiding contractions of the detrusor, continent closure of the urethra is replaced simultaneously by a freely open urethral conduit, this involves suppression of contractile rhabdosphincter activity as well as one or both of the two probable mechanisms that achieve the same result in the urethral muscularis; one inducing beta - adrenergic inhibition of urethral muscularis and the other involving parasympathetic muscarinic - cholinergic inhibition of excitatory alpha adrenergic sympathetic influence on urethral muscularis via cholinergic and adrenergic axoaxonal synapses.[34]

After injury to the spinal cord or nerves controlling bladder function, the bladder can be a hyperreflexic or hyporeflexic, which can be assessed by four techniques. Urodynamic evaluation is an important modality because Urodynamic studies measure the storage and the voiding phases and evaluates functions of the lower urinary tract. Comprehensive urodynamic evaluation plays an integral part in the management of spinal cord injury patients. Not only do urodynamic results help define type of neurogenic bladder present, but also provide prognostic information to help delineate follow up surveillance testing and periodicity.[35]

These are the four basic subsets of urodynamic testing. They are

1. Uroflowmetry
2. Cystometrogram
3. Urethral pressure profile
4. Combinations with video fluoroscopy and sphincter EMG study

The basic tool of urodynamics is the Cystometrogram (CMG); no urodynamic evaluation is complete without a CMG. The Cystometrogram measures vesical pressure as a function of bladder volume. It is a interactive test that answers a number of important questions: 1) What is the Cystometric bladder capacity, 2) are bladder sensations normal,

3) what is the magnitude and duration of involuntary detrusor contractions, 4) is bladder compliance normal, 5) is the patient aware of the involuntary detrusor contractions, 6) can the patient abort the involuntary detrusor contractions? 7) leak point pressure,

8) Voiding pressure

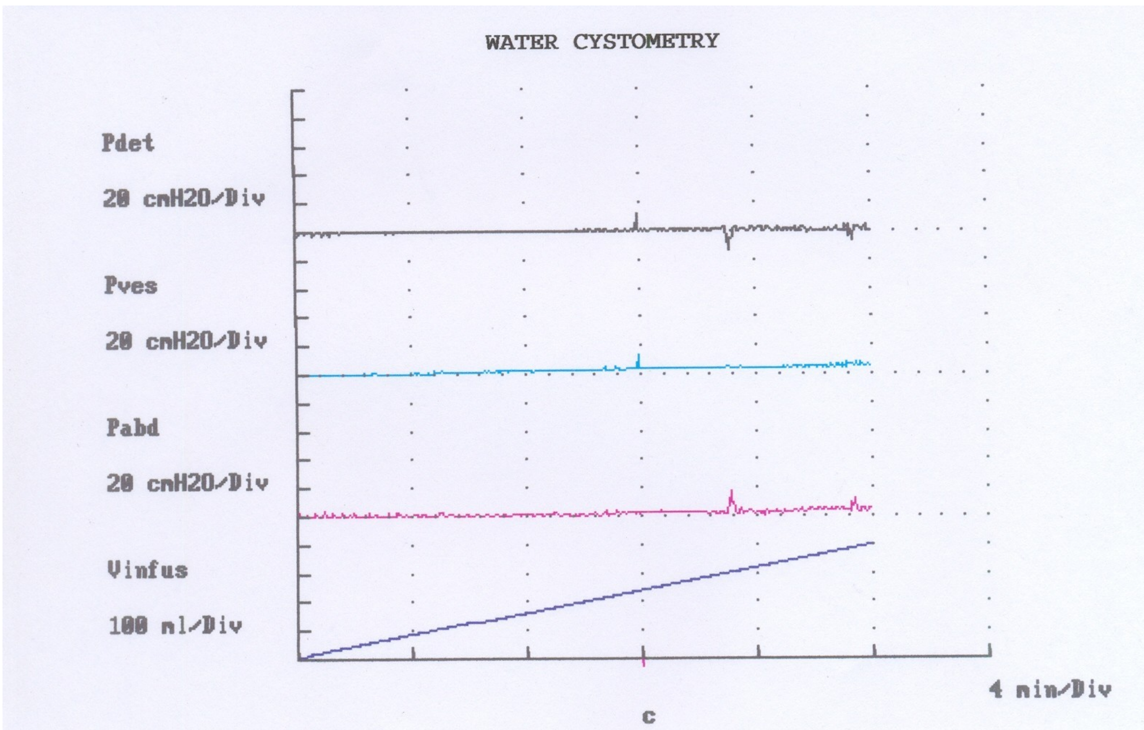


Figure 4: Shows water cystometry in an areflexic bladder where the pink line represents abdominal pressure, the blue line represents vesical pressure and black line represents detrusor pressure.

Cystometric findings

During CMG important observations are made during bladder filling related to bladder capacity, contractions and compliance.

1. Bladder capacity/ Cystometric capacity

On Cystometrogram, bladder capacity can be defined as that volume above which the pressure-volume curve changes from a flat tracing to a linear relationship between increasing bladder pressure and volume. This represents the point at which the bladder can no longer accommodate increasing fluid volumes without over stretching its vesicoelastic tissues. The capacity of the bladder is estimated by using a formula: bladder capacity (in ounces) equals the age of child (in years) plus two.[36] Functional bladder capacity, which represents the amount of urine actually voided or held in the bladder prior to voiding, is often less than the anatomical bladder capacity and depends on the patient's ability to suppress the micturition reflex. In unstable bladder contractions, the functional capacity may be reduced by nearly 50%.[36]

2. Involuntary contractions/ Detrusor hyperreflexia

According to the International Continence Society[37, 38] detrusor activity may be either normal or overactive. The overactive detrusor is characterized by involuntary detrusor contractions that may be spontaneous or provoked by rapid filling, coughing, or other triggering maneuvers. When involuntary detrusor contractions are caused by neurologic disorders, the condition is called detrusor hyperreflexia.[39]

3. Compliance

Bladder compliance indicates the change in volume for a change in pressure. It is calculated by dividing the bladder volume change by the change in detrusor pressure during that change in bladder volume. Compliance is expressed as ml/cm of water (H_2O). Vesical pressure (Pves) is pressure within the bladder. Abdominal pressure (Pabd) is the pressure surrounding the bladder. In current practice, it is estimated from rectal pressure measurement.

Detrusor pressure (Pdet) is that vesical pressure that is created by subtracting abdominal pressure from vesical pressure (Pdet = Pves – Pabd). The simultaneous measurement of abdominal pressure is essential for the proper interpretation of the vesical pressure tracing.

4. Leak point pressure

The detrusor leak point pressure is measured during filling cystometry as the vesical pressure at which urine leakage occurs. Patients with an elevated detrusor leak point pressure are at high risk for developing vesicoureteral reflux, hydronephrosis, stones, and urosepsis. In McGuire's[40] initial studies, 40 cm H_2O was considered the cut-off; in Blaivas[41]and Chanceller's experience,[42] it is often lower, of the order of magnitude of 25 - 30 cm H_2O. One of the most important concepts to be put forth in recent years is that "adequate storage at low intravesical pressure" will avoid deleterious upper urinary tract changes in patients with bladder outlet obstruction and / or neuromuscular lower urinary tract dysfunction. McGuire and coworkers have shown that upper tract deterioration is apt to occur when storage, even though adequate in terms of continence, occurs at sustained intravesical pressure greater than 40cm H2O. Application of this concept to patients with storage problems caused by decreased compliance has resulted in the concept of the "leak point" as a significant piece of urodynamic data.[41, 42] Patients with leak point pressure more than 40 cm of water are at high risk of complications.

Correlation between initial Neurological examination and bladder outcome

Weiss DJ, et. al[43] in 1996 reported on a study of 19 patients with spinal cord injury and showed 70% of those with preserved pinprick voided volitionally at 1 year post injury, whereas 30% needed assistance. 75% of those with preserved position sense were voiding volitionally on their first year anniversary, whereas 25% were not volitionally voiding. These differences were found to be statistically significant. On the other hand 100% of those with absent sacral pinprick or great-toe proprioception at initial examination required assistance with their bladder emptying and this difference was also statistically significant.[43]

Armin Curt et. al[44] stated in 1997 that ASIA impairment scores and SSEP recordings were useful in predicting the recovery of bladder function in patients with acute, traumatic spinal cord injury. The patients were examined following admission to the rehabilitation centre both clinically by the ASIA scores and electro physiologically by tibial and pudendal SSEP recordings. The recovery of somatic nerve function (external urethral sphincter function) involved in volitional voiding was correlated to both the initial ASIA scores and SSEP recordings ($P<0.001$). However they also found that the initial clinical and electrophysiological examination were not indication of urodynamic impairment.[44]

Brigitte Schurch[45] in 1999 studied the relationship of voluntary contraction of the plantar flexors of the toes and the restoration of voiding function in SCI patients with thoraco-lumbar fractures. She found that the voluntary contraction of the toes correlated well with voluntary contraction of the external anal / urethral sphincter but did not correlate with the neuropathic bladder type.[45]

In 2003 Schurch B et. al[46] stated that in SCI patients with thoracolumbar fractures, neurogenic voiding dysfunction cannot be predicted by the sensory evaluation alone. However in patients with an SCI at the thoracolumbar level absence of perineal pinprick sensation predicted poor bladder recovery. The presence of perineal pinprick sensation did not predict an improved voiding function.

Correlation between radiological findings and bladder outcome

In spinal cord injured patients, the initial imaging is frequently used to describe the structural stability of the spine. Vaccaro AR et. al[21] emphasized the significance of thoracolumbar spinal canal size in spinal cord injury patients. There are no anatomic factors at the thoracolumbar junction that predispose to neurologic injury after burst fracture.[24] The shape of the canal after injury, however, as determined by the sagittal-to-transverse diameter ratio, was predictive of neurologic deficit.[21]

Punjabi and White described clinical instability as loss of the ability of the spine under physiological loads to maintain relationship between vertebrae.[47]

Kim et al[48] noted The average percentage of canal compromise was higher in the patients with neurologic deficit (52%) than in the patients with no neurologic deficit (35%). The degree of neurologic impairment was higher in the group with disruption of the posterior elements (62.9%) than in the group with intact posterior elements (29.8%). The degree of neural improvement was greater in the group with disruption of the posterior elements (60.7%) than in the group with no disruption of the posterior elements (25%), which was statistically significant ($P < 0.05$).

Matsurra et al[49] have stated that in injuries to the cervical spine, patients with neurological deficit have a significantly smaller sagittal diameter and large transverse diameter on CT. It is not the absolute size of the canal but the shape of the canal that determines the susceptibility. An accurate index of the shape of the cervical spinal canal, which does not require standardized measurement and which effectively detects predisposition to spinal cord injury in the cervical segments, is the ratio of sagittal to transverse diameter of the spinal canal. The smaller the sagittal to transverse-diameter ratio of the cervical spine, the greater the predisposition to spinal cord injury of the cervical segments.

Kang et al[50], in a study of fractures and dislocations of the cervical spine, used plain-radiographs to demonstrate significant correlation between the space available for the spinal cord at the level of injury and severity of the neurological deficit.

They noted that there was significant association between the actual space available for the spinal cord at the level of the injury and the severity of the injury. A sagittal diameter of the spinal canal at the level of the injury that was thirteen millimeters or less as measured on a lateral radiograph was highly associated with an injury of the spinal cord. In addition, the patients who had a more severe injury had a significantly narrower sagittal diameter of the canal and a significantly smaller Pavlov ratio at the uninjured levels than the patients who did not have an injury of the spinal cord. Patients who have a larger sagittal diameter of the canal may be more frequently spared permanent injury of the spinal cord after a fracture or dislocation of the cervical spine than those who have a narrower canal.

Mohanty et al[51] in 2002 did a study with X-rays and CT scans showed that degree of spinal canal compromise assessed from computed tomography scans and neurological recovery and found that the mean canal compromise in patients with neurologic deficit was 46.2% while in patients with no neurological deficit it was 36.3%. The mean spinal canal compromise in patients with neurological recovery was 46.1% and 48.4% in those with no recovery. Even though patients with incomplete injury to the cord or the cauda equina initially had better chances of neurological improvement than patients who initially had complete cord injury, their study showed that there was no correlation between the neurologic deficit and subsequent recovery with the extent of spinal canal compromise in thoracolumbar burst fractures.

Miyanji F et al[52] in 2007 did a study on acute traumatic cervical cord injury with Magnetic Resonance Imaging and formed correlation with neurologic outcome. That is, patients with substantial maximum canal compromise were more likely to have a complete motor and sensory SCI.

Ryan et al[53] in 2002 did a study on cervical spine stenosis measures in normal subjects. He used 2 methods of determining cervical spinal stenosis: Torg ratio (canal body ratio), and space available for the cord [SAC] using magnetic resonance imaging (MRI). He concluded that the SAC measure relies more on the spinal canal compared with the Torg ratio and, therefore, may be a more effective indicator of spinal stenosis. This is relevant clinically because neurologic injury related to stenosis is a function of the size and shape of the spinal canal and the spinal cord, not the size of the vertebral body.

Materials and Methods

<u>Inclusion criteria</u>

Twenty consecutive patients with thoracolumbar fractures and spinal injury, admitted in the Department of Physical Medicine Rehabilitation, Christian Medical College, and Vellore within three weeks of injury, were recruited into the study.

<u>Exclusion criteria</u>

1. Patients with non-traumatic paraplegia were excluded.
2. Patients with pre-existing thoraco-lumbar scoliosis were also excluded as evaluating the x-rays for canal size would be difficult.

Methodology of the study:

- Initial neurological examination was performed immediately after admission and final neurological examination between 16 -20 weeks after the injury.
- Sensory system: Sensations for both pin prick (Spinothalamic) and soft touch (Posterior column) were examined. Preservation of superficial and deep anal sensations was recorded.
- Motor System: Neurological motor level was assessed. Anal tone and 'Voluntary Anal Contractions' were noted.
- Reflexes: Lower limbs/ Anal wink/ Bulbo/ Clitoro-cavernous reflexes were noted.
- American Spinal Injury Association's (ASIA) Standard Neurological Classification of Spinal Cord Injury form was completed.
- Lateral and antero-posterior X-rays of the spine were done to measure the anteroposterior and transverse diameters of the spinal canal as well as the canal-body ratio at the level of the lesion. The spinal fractures were classified based on

Denis classification.

- Bladder function was assessed between 16 -20 weeks following the injury clinically and by Urodynamic study.
- Cystometrography: Medications which affected detrusor and sphincter function were stopped two days before the cystometrography test.
- Final Neurological Examination: After sixteen weeks of injury, detailed neurological evaluation of the individual was repeated along with the Cystometrography study.
- The bladder outcome was divided into two categories: first category was volitional voiding, defined as no collecting devices, no medication, and no surgical intervention. The second category was assisted bladder emptying, which included intermittent catheterization, condom catheterization, indwelling Foley catheterization, or suprapubic tubes. This category also included all patients taking bladder medications or who had required surgical intervention.

CMG Technique:

Cystometrography machine used for recording was a Dantec, Menuette. This is a multichannel recorder with a weight transducer for measuring volume of infusion into the bladder. The intravesical pressure was read by pressure transducers and the flow was recorded by a rotating disc transducer.

Figure 5: The figure shows CMG being done on a patient with a Dantec, Menuette Machine.

This machine had internal zeroing facility, to atmospheric pressure. Resting intravesical pressure ranged from 5 - 15 cm water when patient was supine and 15 - 40 cm water when sitting.

All the connecting tubes were emptied of air and filled with saline, before the start of the test. Patients were asked to empty the bladder as completely as possible. The bladder was catheterized by a sterile technique using a double lumen tube introduced per urethra till the urine flowed freely, and the bladder was emptied. Residual urine was collected and measured. The tubes were anchored by adhesive tape to the thigh, to prevent them from slipping out during the procedure. The catheter was connected to the transducer and calibrated. The zero pressure reference was the upper edge of the symphysis pubis. A size 8 infant feeding tube, with a split condom attached to the distal end to prevent blockage of the tube with faeces, was passed 5-7cms into the rectum, after lubricating with Xylocaine jelly. This served as an indicator of the intra abdominal pressure.

Intravenous infusion normal saline was infused into the bladder via a volume recorder in the CMG machine through the 8 French size urethral catheter. Intravesical pressure recording was done by the pressure transducer in the machine, which was connected to the urethral catheter. The detrusor pressure was derived by subtracting the rectal pressure from the total bladder pressure and was displayed automatically by the machine. Saline was infused into the bladder at a rate of 20ml per minute. The infused volumes at which patient experienced first desire; normal desire, strong desire and urgency to micturate were recorded on the CMG infusion curve.

During the urodynamic procedure the following were carefully noted:

1. First desire to void which normally occurs at a bladder volume of 50 - 400 ml.
2. Bladder pressure during filling: This helps to determine compliance of the bladder.
3. Detrusor hyperreflexia or areflexia.
4. Leak point pressure (the lowest detrusor pressure at which leakage occurs).

Statistics

- After data collection it was subjected to statistical analysis using SPSS software Vs. 11.0.
- Data were expressed as number (%) and mean +/- standard deviation for categorical and continuous variables.
- Chi-square/Fisher's exact tests were used for group comparisons.
- Independent t- test (for normal data) and Mann-Whitney test (for non-normal data) were performed to compare the mean scores.

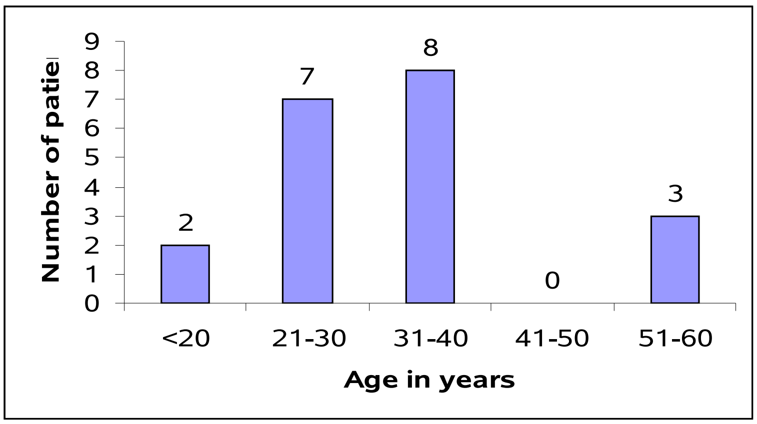
Results

A total of 20 consecutive subjects satisfying the inclusion criteria were enrolled in the study.

Demographic data

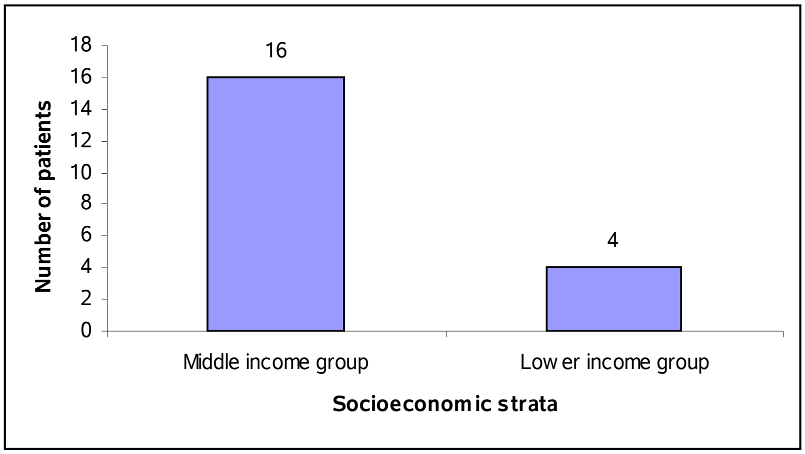
Age distribution

Figure 6: Age distribution of patients recruited into the study.



The patients with SCI ranged from 20 to 56 years of age, the average was 33.45 years and Standard Deviation 10.72. Out of 20 SCI patients 7 were in the third decade (age group of 21-30 years) and 8 in the fourth decade (age group of 31-40 years). There were 3 patients above 50 years and two patients were less than 21 years.

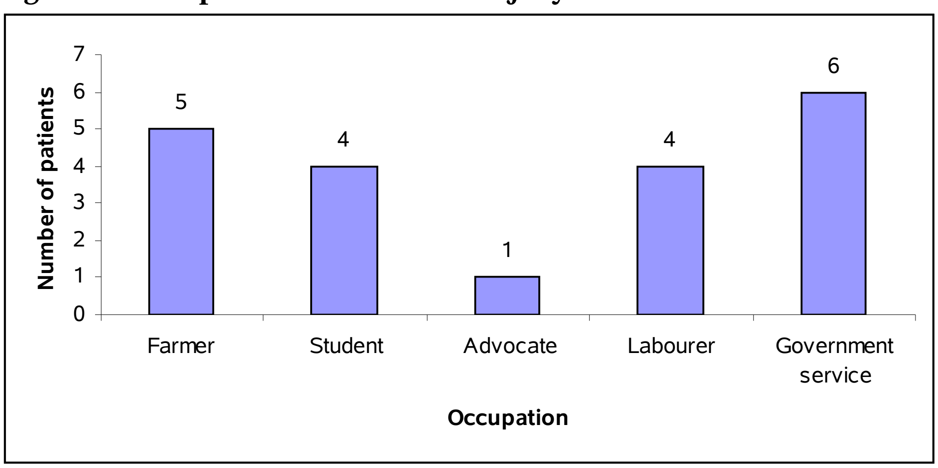
Figure 7: Bar diagram showing Socio-economic status of the patients.



The majority (16 out of 20 patients or 80%) belonged to the middle income group while 4 patients (20%) were in the lower socioeconomic strata. There were no patients from the higher socioeconomic strata except one person was an un-employed law graduate.

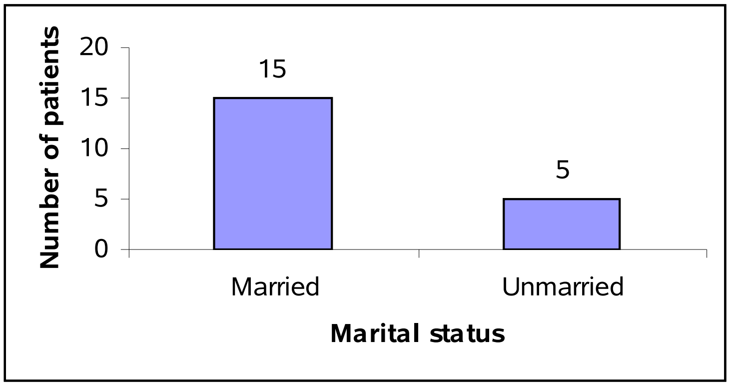
Gender: All the patients recruited were males; there were no female subjects in the study.

Figure 8: Occupation at the time of injury.



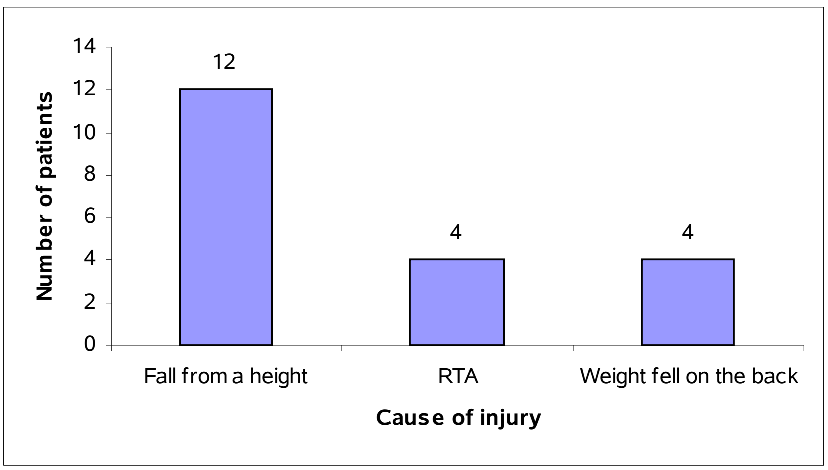
Six patients were employed by the state electricity board and an almost equal number (five) were farmers. Four patients were manual labourers and four were students, and one person was an unemployed advocate as shown in Figure 8.

Figure 9: Marital status of the patients.



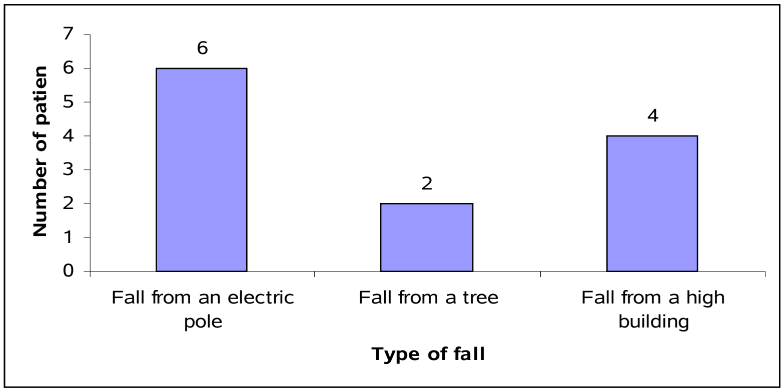
Of the twenty patients 15 were married and 5 were unmarried.

Figure 10: Bar diagram showing causes of injury.



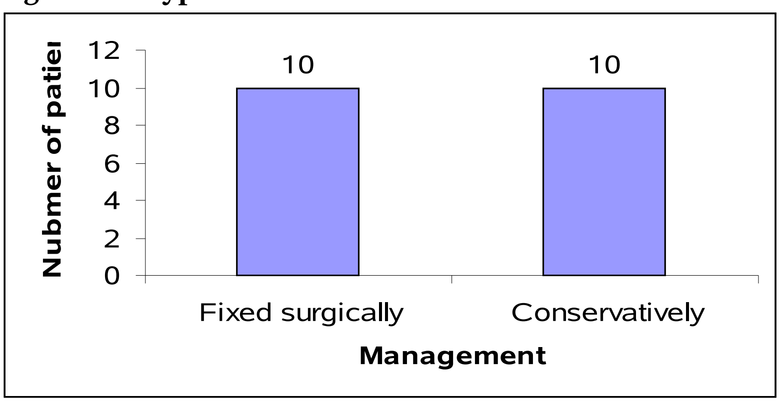
The commonest cause of SCI in this study population was fall from the height 12 (60%). Four patients (20%) had SCI following road traffic accident (RTA) and an equal number had heavy objects falling on their back. Of the twelve who had "fallen from a height" six fell from an electric pole, four from a cliff and two fell from trees as shown in Figure 10 and Figure 11.

Figure 11: Bar diagram showing different types of fall.



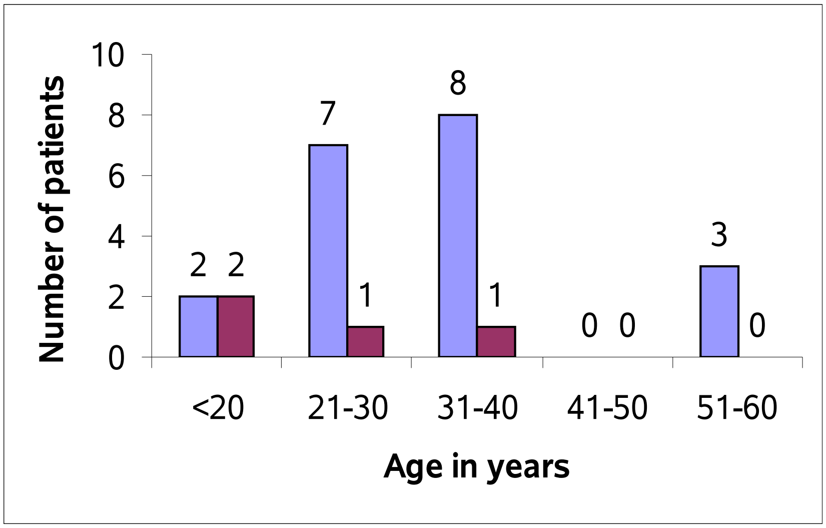
Out of the 12 people who fell from a height 3 patients were able to do volitional voiding and one out of three persons who had road traffic accident improved but these numbers were statistically insignificant.

Figure 12: Type of treatment.



Ten patients (50%) were treated conservatively; the remaining 10 patients (50%) underwent surgical intervention of their spinal column after sustaining SCI.

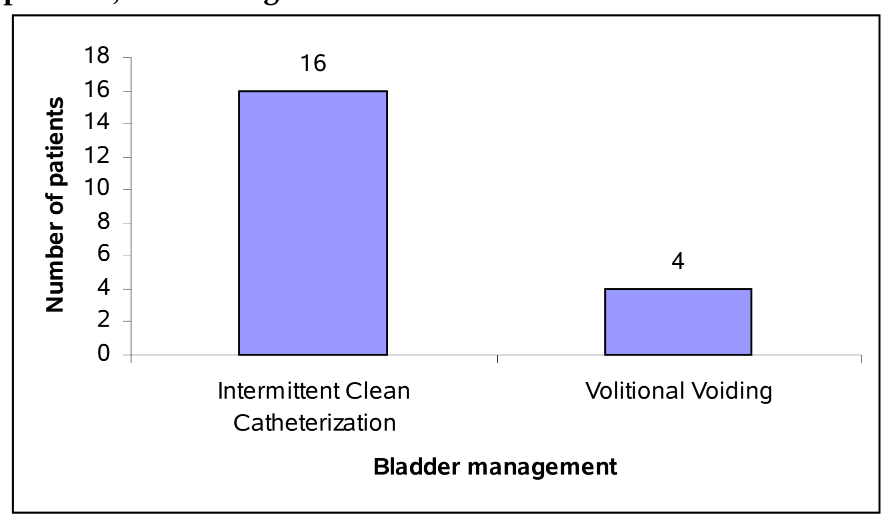
Figure 13: Distribution of volitional voiding among the different age groups.



The bar diagram in Figure 13 shows that younger patients had a better chance of recovery to volitional voiding but this difference was not found to be statistically significant.

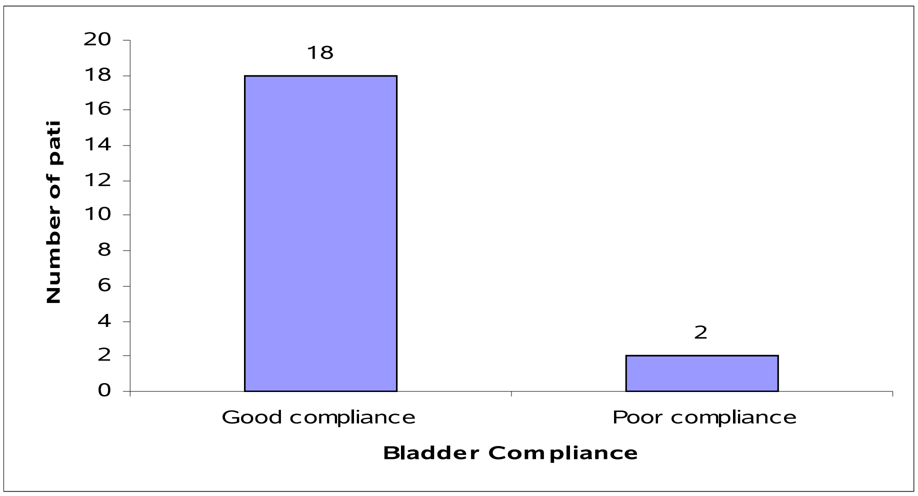
Bladder outcome

Figure 14: Distribution of different type of bladder management among the patients, at discharge.



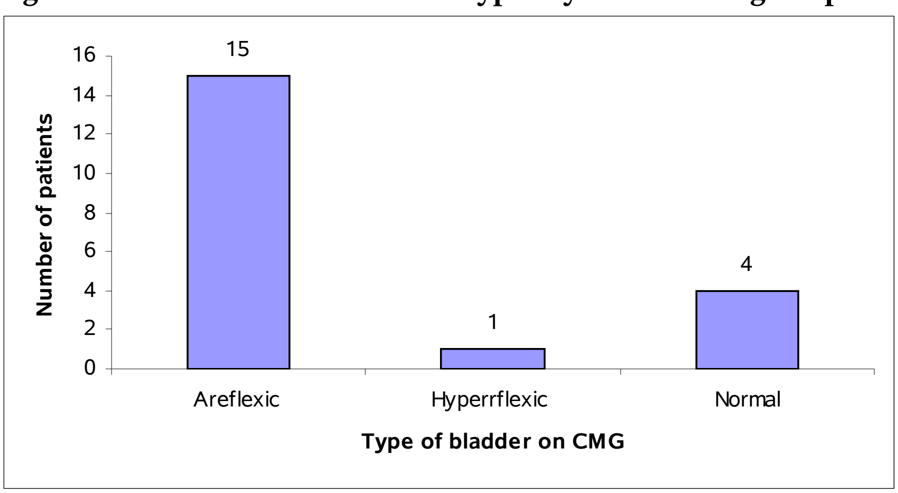
Of all the patients in the study sixteen patients were doing Self Intermittent Clean Catheterization and four were able to do volitional voiding at 16 weeks post injury.

Figure 15: Distribution of different types of compliance of the bladder among the patients, at discharge.



Only two patients had poor compliance and rest had good compliance on urodynamic evaluation of the bladder at discharge.

Figure 16: Distribution of bladder types by CMG among the patients.

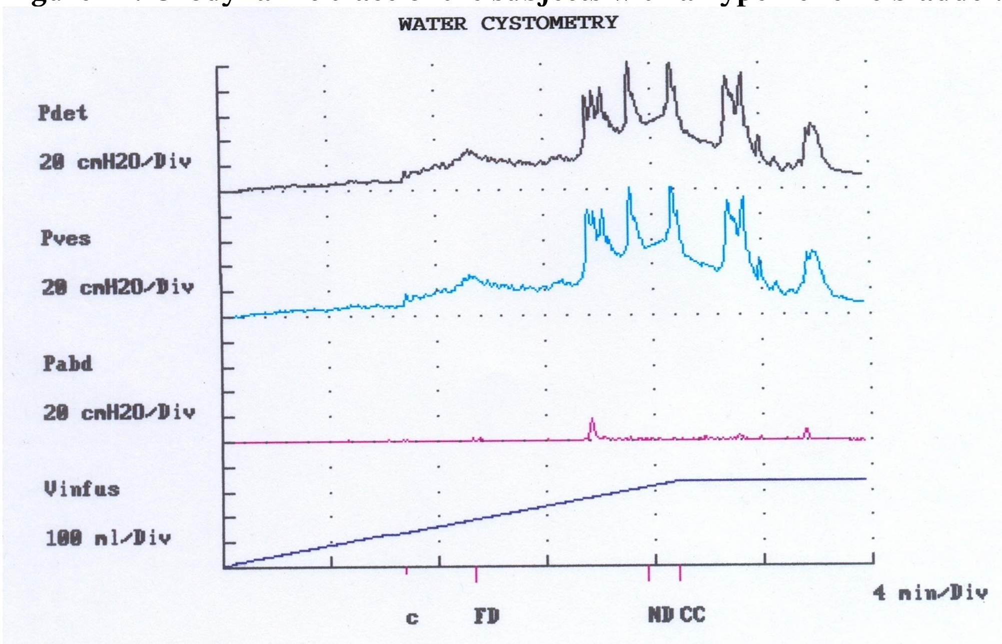


One patient had hyperreflexic bladder and the sample CMG trace is shown in Figure 17;

15 patients had areflexic bladder and a sample CMG trace is shown in Figure 18;

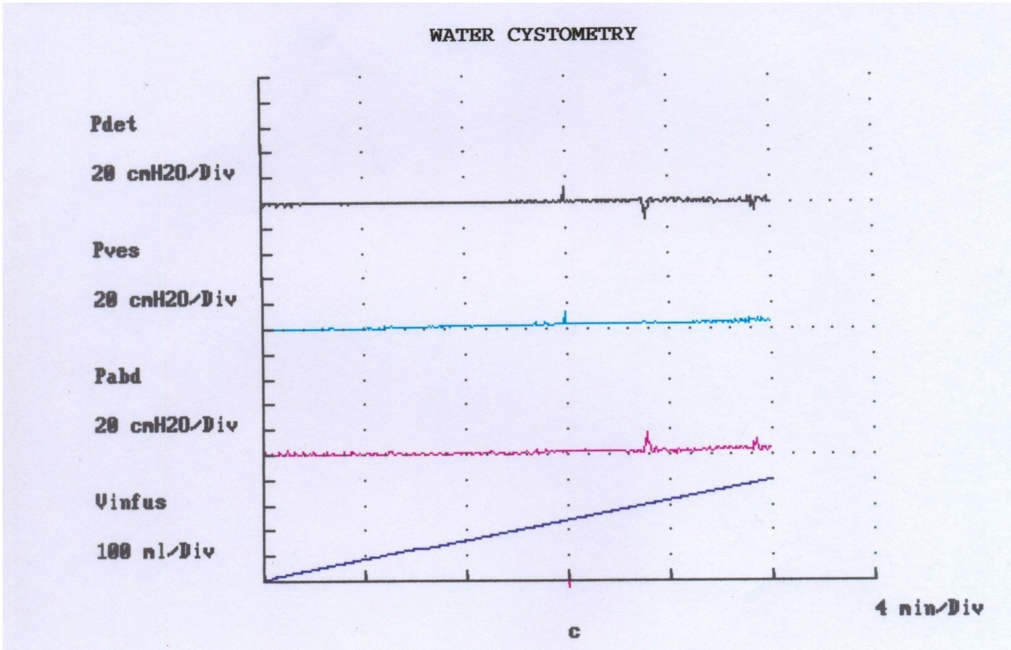
4 patients had normal bladder on CMG as a sample trace is shown in Figure 19.

Figure 17: Urodynamic trace of the subjects with a hyperreflexic bladder.



The Figure 17 shows the trace of a hyperreflexic bladder. The black line represents Detrusor contractions; the sky blue line represents vesicular pressure with pink line representing abdominal pressure.

Figure 18: A sample urodynamic trace of an areflexic bladder.



The above graph is shows the tracing of an areflexic bladder with no detrusor instability even after infusion of 400ml.

Figure 19: A sample urodynamic trace of a subject with a normal bladder.

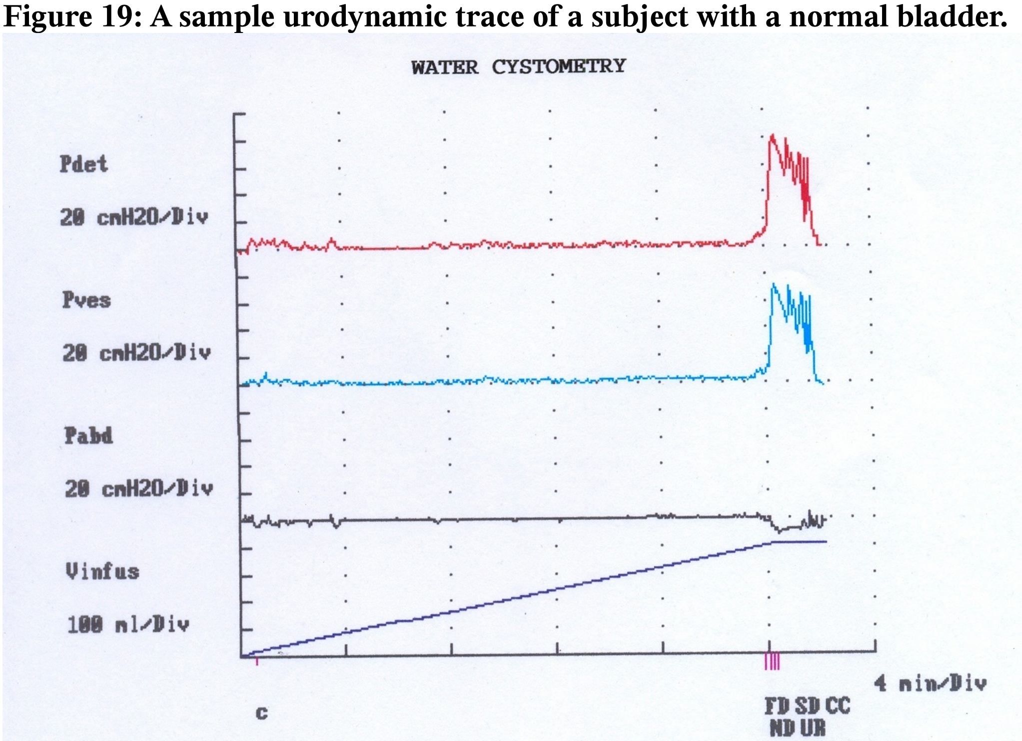
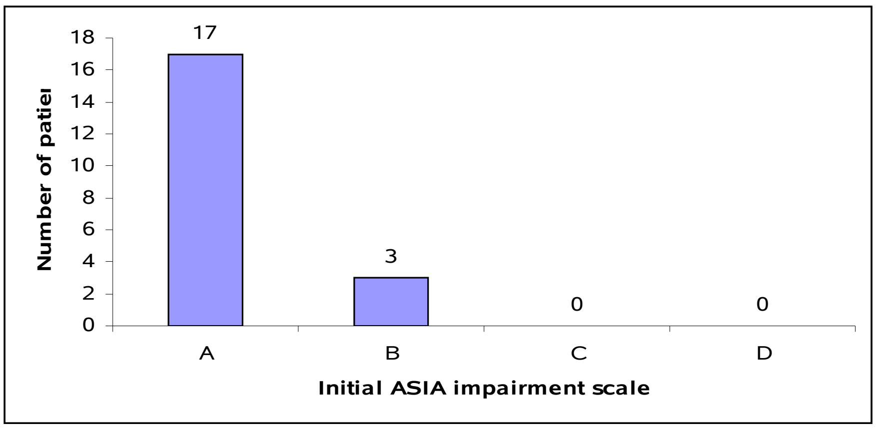


Figure 19 shows the tracing of normal bladder contractions- note that there is no Detrusor hyperreflexia during filling of the bladder. The Detrusor pressure rises only when the patient is asked to void.

Bladder outcome prediction

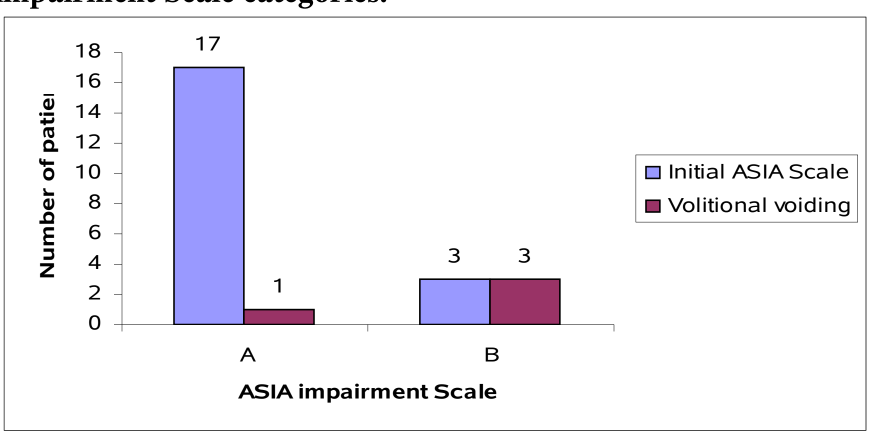
Neurological prediction

Figure 20: Distribution of patients according to the initial ASIA impairment Scale.



At initially neurological evaluation there were 17 patients in ASIA- A and 3 in ASIA- B impairment scale. There were no patients in the ASIA-C or ASIA- D categories.

Figure 21: Distribution of Volitional voiders among the different initial ASIA impairment Scale categories.



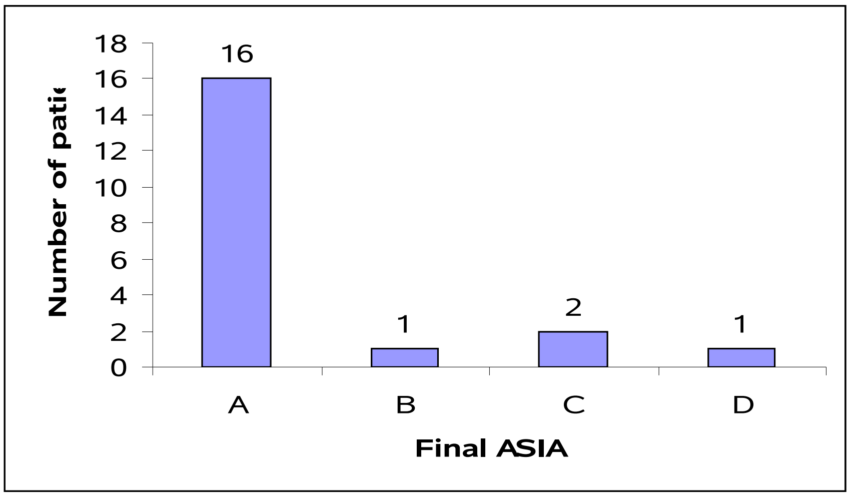
One person with ASIA- A had volitional voiding whereas all the three incomplete ASIA-B had volitional voiding which was statistically significant as shown in Table 2.

Table 2. Showing distribution of assisted and volitional voiding among the different ASIA impairment scale categories.

ASIA impairment scale	Assisted Voiding	Volitional Voiding	P Value
ASIA-A	16	1	0.004*
ASIA-B	0	3	

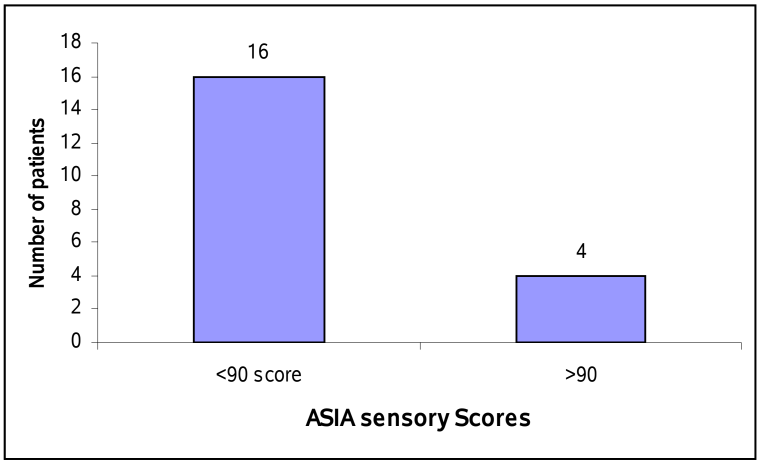
* $P<0.05$

Figure 22: Distribution of patients according to the Final ASIA impairment Scale.



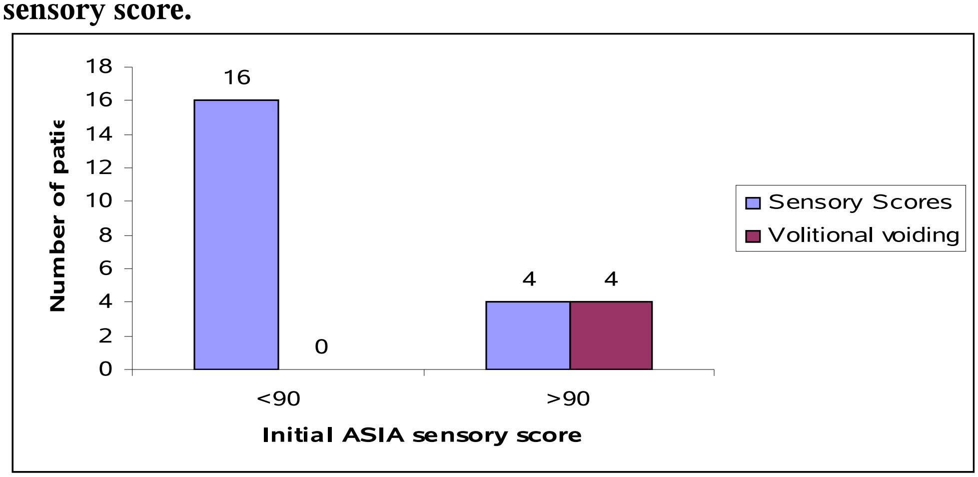
At the end of 16 weeks one ASIA- A had become ASIA- C, where as out of initial ASIA- B one remained the same, two had become ASIA- C and one ASIA- D. The percentage of bladder improvement was 6% in the ASIA A category and 67% in the ASIA B category.

Figure 23: Distribution of patients according to their Initial ASIA sensory score.



16 patients had ASIA sensory scores less than 90 and 4 had more than ninety.

Figure 24: Distribution of volitional voiding among the groups with different initial sensory score.



All who had an ASIA sensory score more than 90 had volitional voiding.

None of those with an ASIA sensory score less than 90 had volitional voiding. This difference was statistically significant as shown in Table 3.

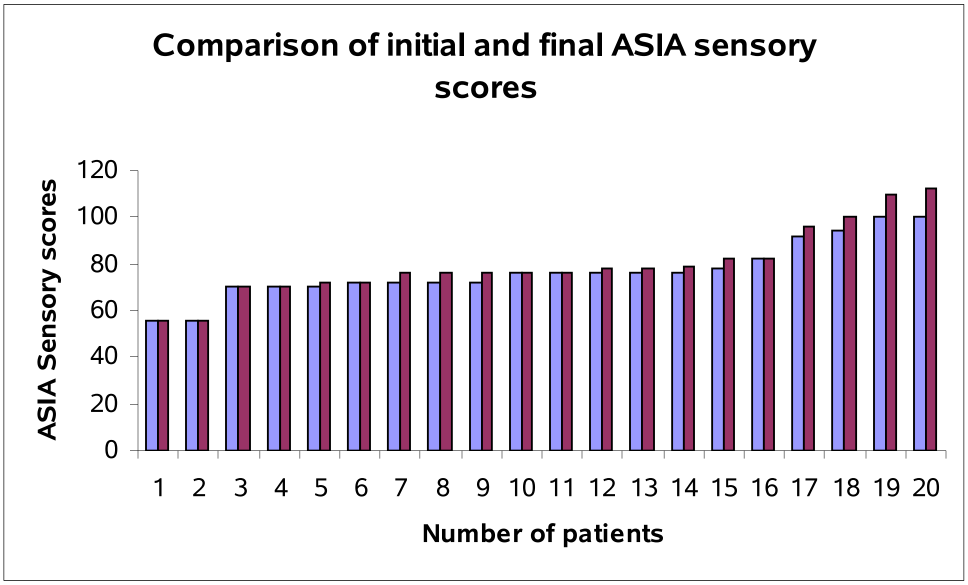
Table 3. Distribution of assisted and volitional voiding among the groups with different ASIA sensory score.

Initial ASIA sensory score	Assisted Voiding	Volitional Voiding	P value

Sensory <90	16	0	
Sensory >90	0	4	0.0002*

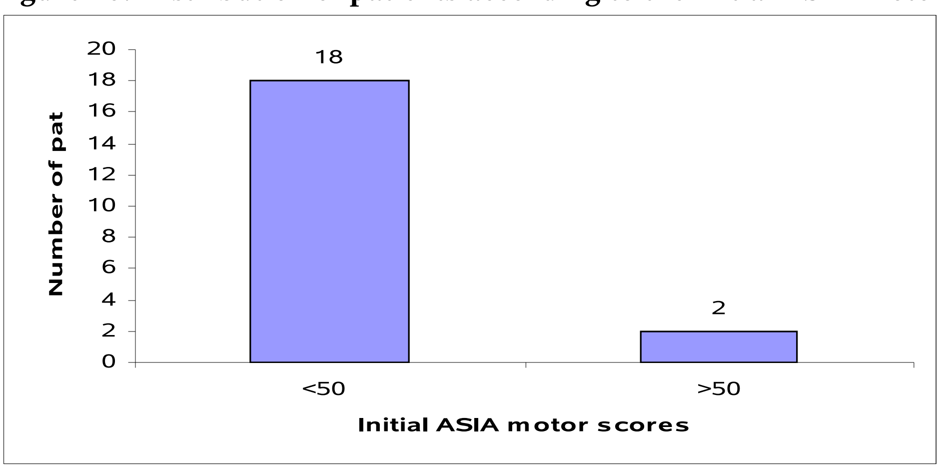
* *P*<0.05

Figure 25: Comparison of initial and final ASIA sensory scores



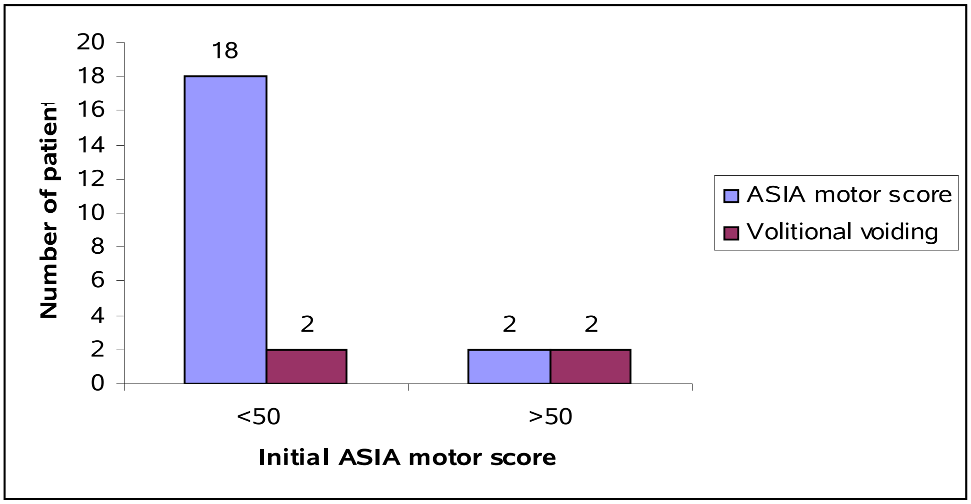
The above graph shows definite improvement in final ASIA sensory score in patients with higher initial ASIA sensory score.

Figure 26: Distribution of patients according to the initial ASIA motor score.



There were 18 patients who had less than 50 motor score on initial examination. Two people had scored more than 50.

Figure 27: Distribution of volitional voiding among the groups with different initial ASIA motor score.



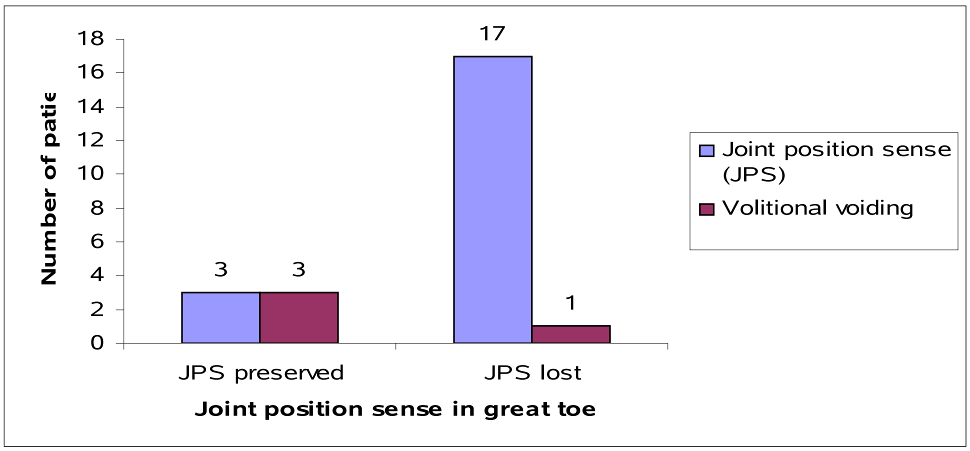
Two out of 18 patients (i, e.11.1%) who had ASIA motor score less than 50 improved to volitional voiding and two out of 2 (i, e.100%) patients who had an ASIA motor score more than 50 improved. This difference was statistically significant as shown in Table 4.

Table 4. Distribution of assisted and volitional voiding among the groups with different ASIA motor score.

Initial ASIA motor score	Assisted Voiding	Volitional voiding	P Value
Initial motor score < 50	16	2	0.03^*
Initial motor score > 50	0	2	

* *P<0*.05

Figure 28: Distribution of the volitional voiders among the different groups with joint position sense preserved or lost.



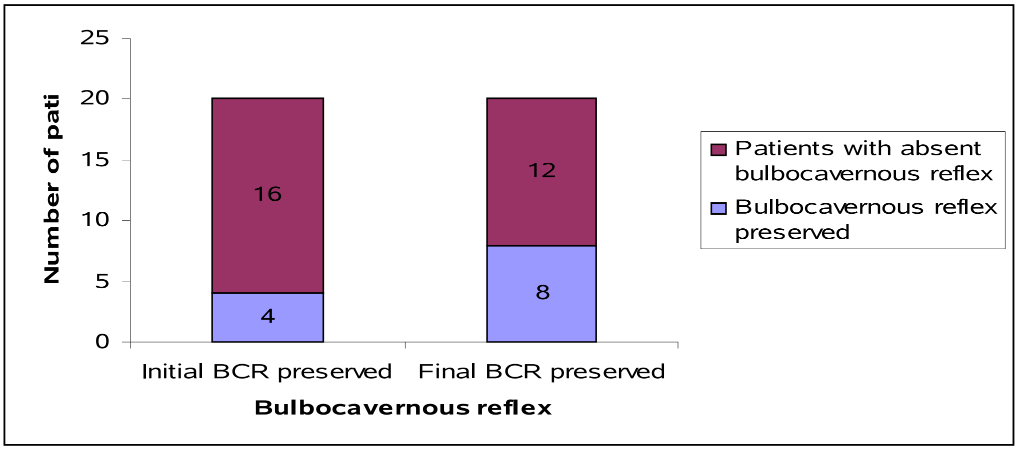
Three patients who had their joint position sense in the great toe preserved on initial examination (i, e.100%) had volitional voiding and one out of the 17 who did not have joint position sense (i,e.5.8%) later developed volitional voiding. This difference was statistically significant as shown in Table 5.

Table 5. Showing the distribution of assisted and volitional voiding among the groups with joint position sense preserved and lost.

Joint Position Sense in the great toe	Assisted Voiding	Volitional Voiding	P value
JPS Preserved	0	3	0.0035*
JPS Lost	16	1	

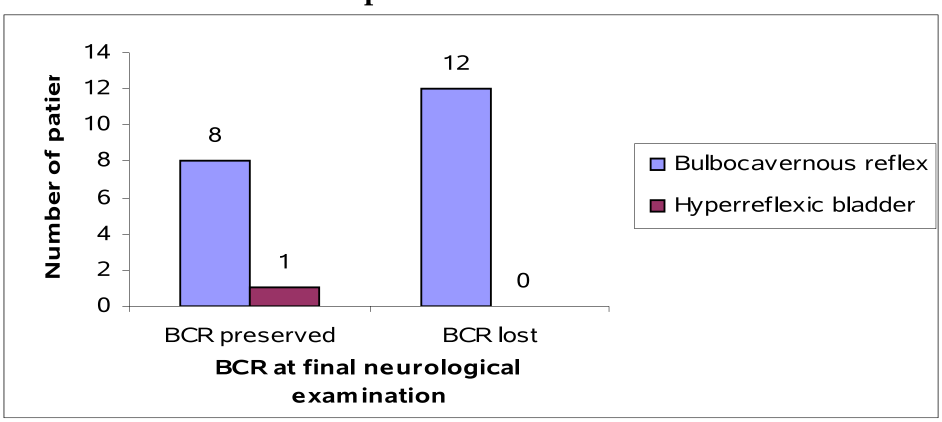
* $P<0.05$

Figure 29: Distribution of the presence of the Bulbocavernous reflex at initial examination and at 16 weeks.



There were four patients who had Bulbocavernous reflex preserved at initial examination and 8 persons at 16 weeks.

Figure 30: Distribution of hyperreflexic bladder among the different groups with the Bulbocavernous reflex preserved and lost at final examination.



One person out of 8 who had Bulbocavernous reflex positive had a hyperreflexic bladder.

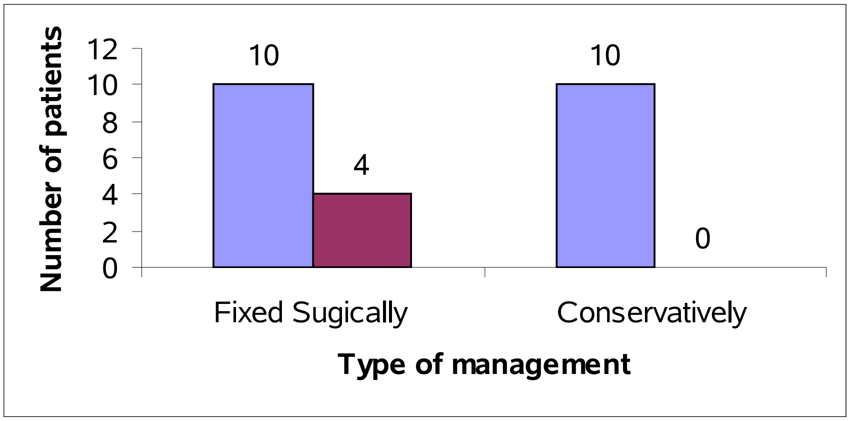
Table 6. Distribution of hyperreflexic and areflexic bladder among the different groups with Bulbocavernous reflex present and lost.

BCR at Final Neurological examination	Hyperreflexic Bladder	Areflexic bladder	P Value
BCR present	1	7	

BCR lost	0	12	0.4

<u>Radiological prediction</u>

Figure 31: Comparison of type of management with volitional voiding.

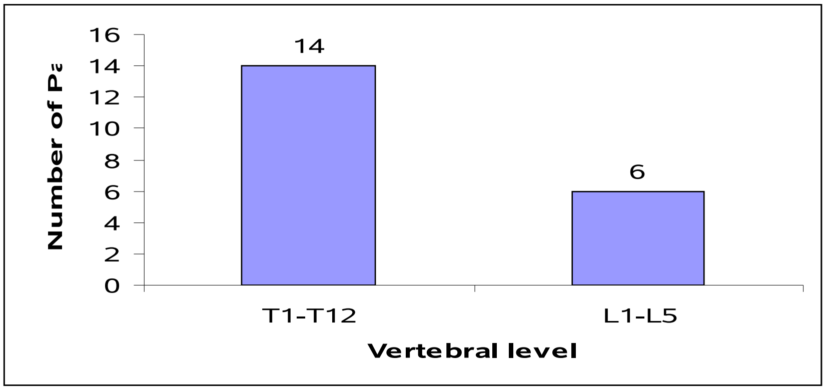


Out of the 10 people who underwent surgical fixation 4 had volitional voiding compared to none managed conservatively. This difference was statistically not significant as shown in Table 7.

Table 7. Showing distribution of assisted and volitional voiding among the surgically fixed and conservatively managed spinal fractures.

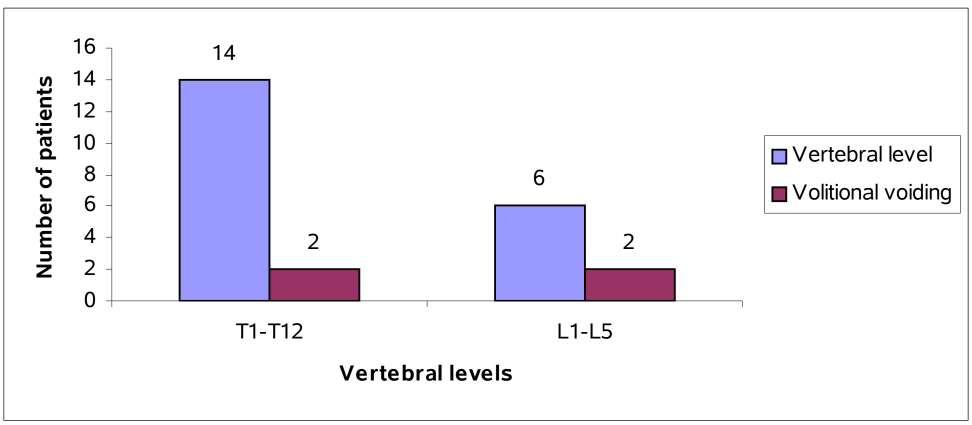
Spinal fracture treatment	Assisted Voiding	Volitional Voiding	P Value
Surgically fixed spinal fractures	6	4	0.087
Conservative managed fractures	10	0	

Figure 32: Distribution of the patients by the level of vertebral fracture.



In 14 patients (85%) thoracic (D1-L2) vertebral fracture was present. In six patients (10%) upper lumbar vertebral fracture was present.

Figure 33: Distribution of the volitional voiding among the groups with fracture at different vertebral level.

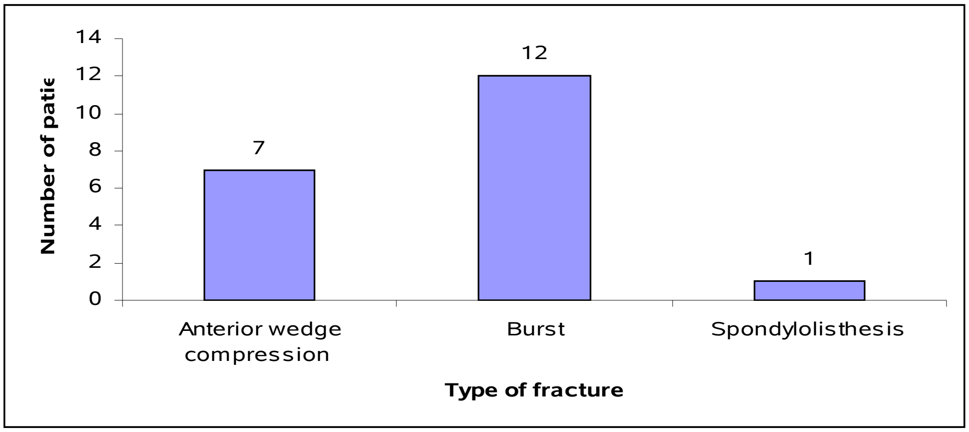


Two out of the 14 thoracic vertebral fractures and two from lumbar fractures had volitional voiding but this difference was not statistically significant as shown in Table 8.

Table 8. Distribution of assisted voiding and volitional voiding among persons with fractures at different vertebral levels.

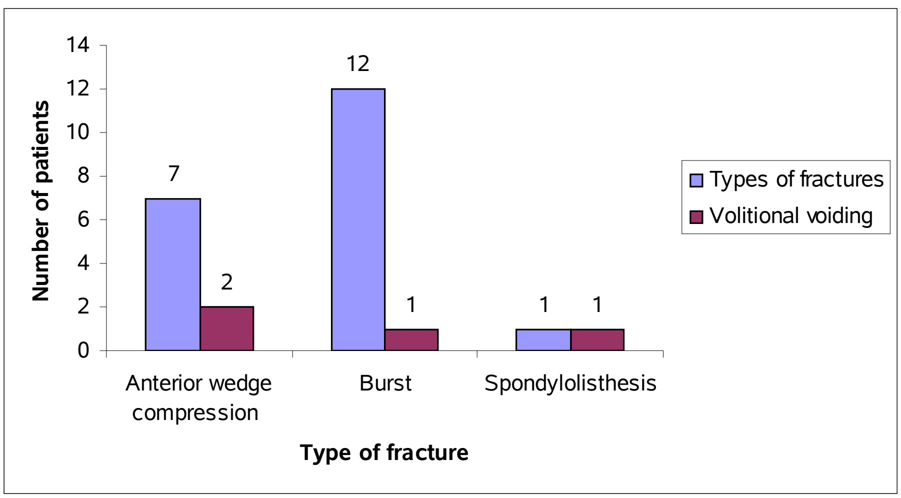
Vertebral levels	Assisted Voiding	Volitional Voiding	P value
Thoracic	12	2	0.85
Lumbar	4	2	

Figure 34: Distribution of different types of vertebral fractures.



Of the 20 subjects 7 had anterior wedge compression fractures, 12 had burst fractures and one person had a traumatic spondylolisthesis.

Figure 35: Distribution of the volitional voiding among persons with different types of vertebral fractures.



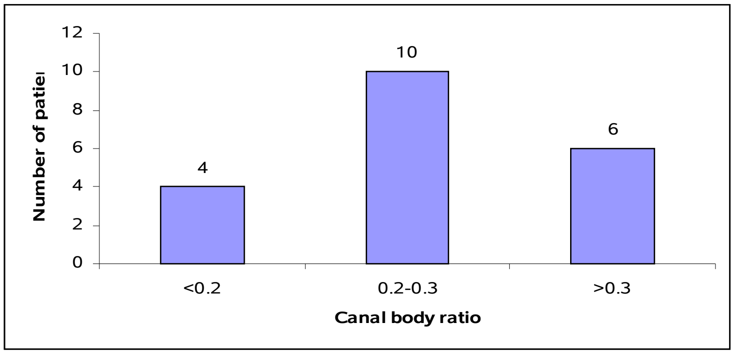
Two patients who had anterior wedge compression fracture had volitional voiding where as one each from burst type and spondylolisthesis had volitional voiding as shown in Table 9. These differences were not statistically significant.

Table 9. Distribution of assisted and volitional voiding among persons with different types of vertebral fractures.

Bladder Function	Ant. Wedge compression	Burst fractures	Listhesis	P value
Assisted Voiding	5	11	1	0.069

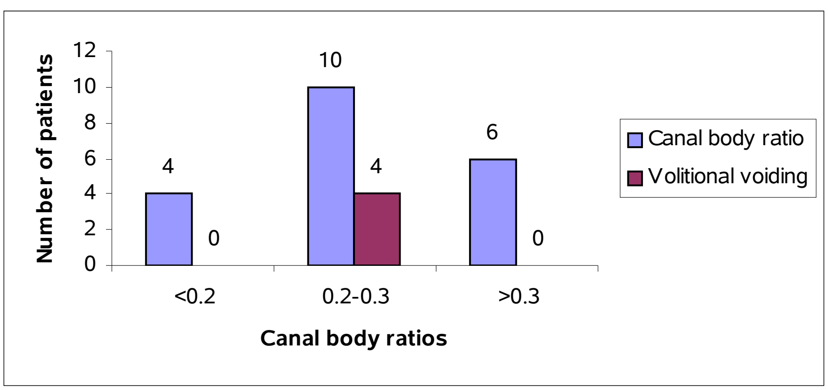
Volitional voiding	2	1	1	

Figure 36: Distribution of the different Canal Body ratios at the level of vertebral fractures among the patients.



The canal body ratio was divided into three categories: < 0.2 (i, e. severe compression), 0.2- 0.3 (i, e. moderate compression), > 0.3 (i, e. mild compression). There were 10 patients with moderate canal compression, 6 with mild canal compression and 4 with severe canal compression.

Figure 37: Distribution of volitional voiding among the persons with canal body ratios.



4 patients who had a canal body ratio in the moderate compression group had volitional voiding. None of other groups had any person with volitional voiding but these differences were not significant as shown in Table 10.

Table 10. Distribution of assisted and volitional voiding among persons with different vertebral Canal-body ratios.

Bladder Function	Vertebral Canal-body Ratio			P value
	<0.2	0.2-0.3	>0.3	
Assisted Voiding	4	6	6	0.082
Volitional voiding	0	4	0	

Discussion

The possibility of permanent loss of bladder and bowel control and mobility is a catastrophy for people with spinal cord injury (SCI).[54-57] Recovery from SCI requires substantial coping by the patient and their carers, and an accurate prediction of outcome soon after the onset can be useful for the patients and carers to cope.

The ages of the 20 SCI patients recruited in this study ranged from 20 to 56 years as shown in Figure 6. The average age was 33.45 years. The average age of patients published by Mohanty et al.[7] was 35.6 years. The average age of patients published by Guttman[58] was 32.59 years. Bors and Comarr [5] pointed out that SCI mainly affected young males; this was true for this study as well: all the recruited patients were males. The largest group among the subjects studied belongs to the middle-income group. Out of the middle socioeconomic group 30% were state employees and an equal percentage were farmers as shown in Figure 8. 20% of patients were students at the time of injury. 20% of patients were from the lower socioeconomic group and they were daily wages labourers. 75% of the patients were married and 25% were unmarried. This supports the data of Guttman[58] who also found that SCI occurs mainly among active young males in the peak of their productive life.

The commonest cause of injury, as shown in Figure 10, was fall from a height. This was also found by Mohanty et, al [7] in their study done in India. This is different from the data from western countries where road traffic accidents are the commonest cause.[59] Out of the 12 people who fell from a height 3 patients were able to do volitional voiding and one out of three persons who had RTA had volitional voiding, however these differences were not statistically significant. A large number of injuries (6 patients) were electricians who were working on electric-poles when they had an accidental fall as shown in Figure 11. This data needs to be examined carefully in a larger population, as accidents at work must be prevented. Out of the 20 patients 50% were managed conservatively and the rest underwent surgical fixation of their spinal column, as shown in Figure 12. Out of the 50% patients who were surgically stabilized four patients (40%) improved in bladder function in the form of volitional voiding but none of those managed conservatively improved. This difference was however not statistically significant as shown in Figure 31 and Table 7. This reminds us that there is as yet no evidence that surgical fixation improves the neurological outcome in persons with thoraco-lumbar fractures and spinal cord injury.

Bladder management

The bladder assessment of the 20 patients recruited was done at 16- 20 weeks of injury. There were sixteen patients on Self Intermittent Clean Catheterization (SICC) and four were able to do volitional voiding as shown in Figure 14. On urodynamic study two patients had poor compliance and the rest had good compliance bladders as shown in Figure 15. One patient had a hyperreflexic bladder on Cystometrogram, 15 patients had areflexic bladders and 4 had normal bladder as shown in Figure16. Patients aged less than 40 years showed better bladder recovery but this difference was not statistically significant as shown in Figure 13.

Relationship between Initial Examination and Bladder Recovery

A significant correlation was found between improved bladder function and the ASIA impairment scale obtained during the first neurologic examination (Fisher's exact tests, $P<0.05$). These results are similar to that in the study done by Weiss et, al[43]. Patients who improved in bladder function (n=4) had higher scores in all their initial sensory evaluations than patients who did not improve (n=16). These findings were similar to that in the study done by Armin Curt et al.[44] In other words patients with incomplete cord lesions (i, e ASIA B to E) have a better chance of volitional voiding than those with complete lesions (ASIA A). Among the 4 patients whose bladder function improved, all but 1 (85%) had perineal pinprick sensation at initial examination.

Patients who improved their bladder function tended to have higher initial sensory ASIA scores (Fisher's exact tests, $P<0.05$), Figure 24. Those with ASIA motor score > 50 had a statistically significant improved chance of volitional voiding as compared to those with ASIA score < 50, as shown in Figure 27 and Table 4. The three patients who had joint position sense of the great toe from the beginning had a good bladder outcome as shown in Figure 28 and Table 5. This finding was similar to the study done by Weiss et al.[43] In other words, patients who have an initial ASIA sensory score >90, ASIA motor score > 50 and preserved joint position sense in the great toe have a statistically significant chance of volitional voiding. These findings are important, as this study has shown that a careful clinical neurological examination at the initial stage after SCI can be a useful tool for predicting bladder function.

There were 4 four patients who were Bulbocavernous reflex positive at initial examination and at 16 weeks there were 8 persons who were Bulbocavernous reflex positive as shown in Figure 29. Among the 8 patients who were Bulbocavernous reflex positive, only one patient had a hyperreflexic bladder. All patients who were Bulbocavernous reflex negative had an areflexic bladder (100%). It was interesting to note that an absence of the Bulbocavernous reflex has negative predictive value for patients with areflexic bladder. Brigitte Schurch et al corroborate this finding in their study published in 2003.

Relationship between Radiological parameters and Bladder Recovery

It is generally accepted that patients with incomplete injury to the cord or the cauda equina with less canal compromise initially have better chances of neurological improvement than patients who initially have complete cord injury.[48, 60, 61] This study also demonstrated this phenomenon. Of the 17 patients with complete neurological deficit, only one recovered (5.8%), while out of 3 patients with incomplete deficit, all three improved (100%). These findings are supported by Rosenberg et al[62] who stated that the initial impact to the spinal cord determines the future neurological outcome regardless of the spinal segment injured.

Fourteen patients had thoracic (D1-D12) vertebral fracture and six patients had lumbar vertebral fracture. Out of the 14 thoracic vertebral fractures two had improved bladder function and two from the 6 lumbar fractures but this was not statistically significant as shown in Table 8. There were a total of 12 of burst fractures, 7 anterior wedge compression fractures and one person had spondylolisthesis as shown in Figure 34. Two patients who had anterior wedge compression fracture had improved bladder function where as one each from the burst type and spondylolisthesis type of injury had improvement. None of these were statistically significant.

Although the canal body ratio is different for different age groups and different genders and different also for thoracic and lumbar regions it is accepted that a ratio of 1: 2.5 to 1: 3 is normal. In this study there were 10 patients with a canal body ratio at the level of vertebral fractures with moderate canal compromise; 6 were with mild canal compromise and 4 with severe canal compromise group. Four of the ten patients who had moderate canal compromise had volitional voiding but this was not statistically significant as shown in Table 10.

Various authors have reported a relationship between the degree of canal compromise and the extent of neurologic deficit.[48, 60; 63-66] Others have noted that there is no correlation between the initial neurological impairment and the degree of spinal canal narrowing.[67-70] Therefore this parameter is not universally accepted as a good predictor.

Limitations of the study

Bladder assessment with Cystometrogram was performed between 16-20 weeks after injury. Long-term follow up studies on these patients would provide more data regarding neuropathic bladder function. Many patients were from far off discharge, so their follow up was difficult

There was heterogenesity in the management of the fracture spine as some had surgical fixation done, and some were conservatively managed.

This study could have been done with a larger sample size.

Summary and Conclusions

In this study a possible association between initial neurological evaluation and radiological findings and bladder function at discharge in SCI patients with thoracolumbar fractures was tested. Neurological examination included sensory evaluation, joint position sense in the great toe, motor examination, and voluntary contraction of the external anal sphincter and bulbocavernous reflex. Radiological examination was done using plain X- rays and the canal body ratio and sagittal transverse ratio were calculated.

20 patients with thoracolumbar fractures who fulfilled the inclusion criteria were admitted in the study and the following conclusions arrived at:

1. A significant correlation was found between ASIA impairment scale obtained during the first neurological examination and volitional voiding (Fisher's exact test, $P<0.05$).
2. A significant correlation was found between ASIA motor scores more than 50 obtained during the first neurological examination and volitional voiding (Fisher's exact test, $P<0.05$).
3. A significant correlation was found between ASIA sensory scores more than 90 obtained during the first neurological examination and volitional voiding (Fisher's exact test, $P<0.05$).
4. A significant correlation was found between joint position sense of the great toe preserved during the first neurological examination and volitional voiding (Fisher's exact test, $P<0.05$).
5. The presence of Bulbocavernous reflex did not predict the type of bladder

dysfunction on Urodynamic evaluation (P> 0.05). However an absence of Bulbocavernous reflex predicted an areflexic bladder.

6. The level of fracture did not correspond to the type of bladder.

7. The use of Canal body ratio at the level of vertebral fracture on plain radiographs was not useful in prediction of volitional voiding. (P> 0.05)
8. Therefore plain radiography was not found to be a good predictor of bladder function in persons with thoracolumbar fractures and with spinal cord injury.
9. Therefore the parameters: initial ASIA Impairment Scale from B to D, ASIA motor score > 50, ASIA sensory score > 90 and preservation of joint position sense of the great toe may be used to predict volitional voiding in persons with thoracolumbar fractures and spinal cord injury.

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APPENDIX I

PROFORMA

Value Of Neurological And Radiological Examinations In Predicting Bladder Function In Persons With Thoraco-Lumbar Fractures And Spinal Injury.

NAME HOSP NO
AGE: GENDER OCCUPATION
ADDRESS

DOI
MOI
DOSURGERY
DO ADMISSION

RADIOLOGICAL FINDINGS

X-RAY FINDING
TYPE OF FRACTURE
VERTEBRAL LEVEL:
AP
TRANS
AP TRANS RATIO
BODY CANAL RATIO

NEUROLOGICAL EXAMINATION:

DATE OF INITIAL NEUROLOGICAL ASSESSMENT:

ASIA FORM ENCL:

MOTOR

	R	L
HIP		
Flex		
Add		
Abd		
Ext		
KNEE		
Ext		
Flex		
ANKLE		
Df		
PF		
TOES		

Ext
Flex

SENSORY:
Deep Anal Sensation: Y/N

JPS	R	L
GREAT TOE		

REFLEXES ON ADMISSION

DEEP:	KJ	AJ
R		
L		

SUPERFICIAL
Anal Reflex:
R L

Bulbo/ clitoro cavernous Reflex:
R L

DATE OF FINAL NEUROLOGICAL ASSESSMENT

ASIA FORM ENCL:

MOTOR

	R	L
HIP		
Flex		
Add		
Abd		
Ext		
KNEE		
Ext		
Flex		
ANKLE		
Df		
PF		
TOES		
Ext		
Flex		

SENSORY:
Deep Anal Sensation: Y/N

JPS R L
GREAT
TOE

REFLEXES ON DISCHARGE

DEEP: KJ AJ
R
L
SUPERFICIAL
Anal Reflex:
R L

Bulbo/ clitoro cavernous Reflex:
R L

ULTRASOUND AT 16 TO 20 WEEKS:
KIDNEYS

	RIGHT	LEFT
DIALATATION		
VOLUME		
CORTEX		

COMMENTS:

BLADDER:
PREVOID: ml
POSTVOID: ml

CALCULI

URODYANAMICS AT 16 TO 20 WEEKS:
PRINT OUT ENCL

INITIAL ASIA (DATE)

ASIA

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

	R	L	
C2			
C3			
C4			
C5			Elbow flexors
C6			Wrist extensors
C7			Elbow extensors
C8			Finger flexors (distal phalanx of middle finger)
T1			Finger abductors (little finger)
T2			
T3			
T4			
T5			
T6			
T7			
T8			
T9			
T10			
T11			
T12			
L1			
L2			Hip flexors
L3			Knee extensors
L4			Ankle dorsiflexors
L5			Long toe extensors
S1			Ankle plantar flexors
S2			
S3			
S4-5			Voluntary anal contraction (Yes/No)

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
NT = not testable

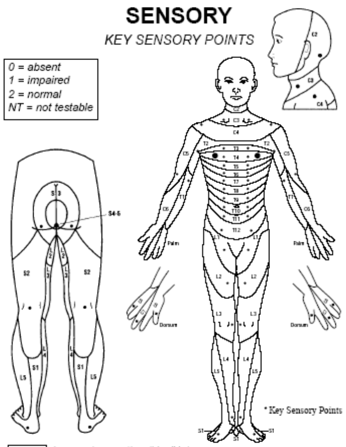
TOTALS ☐ + ☐ = ☐ **MOTOR SCORE**
(MAXIMUM) (50) (50) (100)

SENSORY

KEY SENSORY POINTS

	LIGHT TOUCH R	LIGHT TOUCH L	PIN PRICK R	PIN PRICK L
C2				
C3				
C4				
C5				
C6				
C7				
C8				
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				
T11				
T12				
L1				
L2				
L3				
L4				
L5				
S1				
S2				
S3				
S4-5				

0 = absent
1 = impaired
2 = normal
NT = not testable



Any anal sensation (Yes/No)

TOTALS ☐ + ☐ = **PIN PRICK SCORE** (max: 112)
☐ + ☐ = **LIGHT TOUCH SCORE** (max: 112)
(MAXIMUM) (56) (56) (56) (56)

NEUROLOGICAL LEVEL — *The most caudal segment with normal function* — SENSORY R ☐ L ☐; MOTOR R ☐ L ☐

COMPLETE OR INCOMPLETE? ☐ — *Incomplete = Any sensory or motor function in S4-S5*

ASIA IMPAIRMENT SCALE ☐

ZONE OF PARTIAL PRESERVATION — *Caudal extent of partially innervated segments* — SENSORY R ☐ L ☐; MOTOR R ☐ L ☐

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2000 Rev.

FINAL ASIA (DATE :   )

ASIA

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

	R	L	
C2			
C3			
C4			
C5			Elbow flexors
C6			Wrist extensors
C7			Elbow extensors
C8			Finger flexors (distal phalanx of middle finger)
T1			Finger abductors (little finger)
T2			
T3			
T4			
T5			
T6			
T7			
T8			
T9			
T10			
T11			
T12			
L1			
L2			Hip flexors
L3			Knee extensors
L4			Ankle dorsiflexors
L5			Long toe extensors
S1			Ankle plantar flexors
S2			
S3			
S4-5			Voluntary anal contraction (Yes/No)

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
NT = not testable

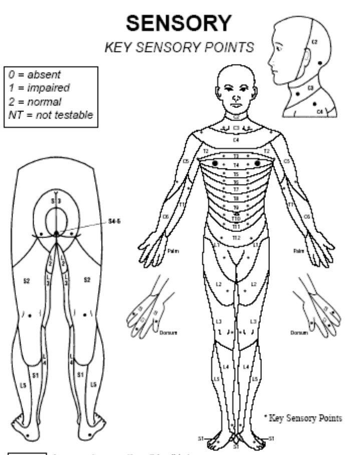
TOTALS ☐ + ☐ = ☐ **MOTOR SCORE**
(MAXIMUM) (50) (50) (100)

SENSORY

KEY SENSORY POINTS

	LIGHT TOUCH R	LIGHT TOUCH L	PIN PRICK R	PIN PRICK L
C2				
C3				
C4				
C5				
C6				
C7				
C8				
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				
T11				
T12				
L1				
L2				
L3				
L4				
L5				
S1				
S2				
S3				
S4-5				

0 = absent
1 = impaired
2 = normal
NT = not testable



Any anal sensation (Yes/No)

TOTALS ☐ + ☐ = **PIN PRICK SCORE** (max: 112)
☐ + ☐ = **LIGHT TOUCH SCORE** (max: 112)
(MAXIMUM) (56) (56) (56) (56)

NEUROLOGICAL LEVEL — *The most caudal segment with normal function* — SENSORY R ☐ L ☐; MOTOR R ☐ L ☐

COMPLETE OR INCOMPLETE? ☐ — *Incomplete = Any sensory or motor function in S4-S5*

ASIA IMPAIRMENT SCALE ☐

ZONE OF PARTIAL PRESERVATION — *Caudal extent of partially innervated segments* — SENSORY R ☐ L ☐; MOTOR R ☐ L ☐

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2000 Rev.

INFORMED CONSENT DOCUMENT.

I _____________, confirm that I have consented to undergo the cystometrogram for the purpose of participating in a research study to determine the association of neurological assessments and x-ray findings with recovery of bladder function in individuals with thoraco-lumbar fractures and spinal injury. I understand these tests will only be used for the research purposes and will not harm me in any way. I understand that I can withdraw from the study at any time without losing any benefits of care that would have normally been provided to me.

Signature of Patient: ……

Place

Date:

APPENDIX II

				MASTER CHART									
S.No	H.No	Age	Mode of injury	Initial ASIA	C/ IC	Sensory level	DAS	JPS	Motor level	movementGreat toe	VAC	BCR	AW
1	866970-C	35	Fall from an Electric pole	A	C	T6	-	-	T6	-	-	-	-
2	856432-C	24	RTA	B	IC	L1	+	+	T12	-	-	-	-
3	773639-C	29	Fall from a tree	A	C	L3	-	-	T12	-	-	-	-
4	742535-C	21	RTA	A	C	T10	-	-	T10	-	-	-	-
5	746882-C	35	RTA	A	C	T6	-	-	T6	-	-	+	+
6	774174-C	35	Fall from an Electric pole	A	C	T12	-	-	T12	-	-	+	+
7	750525-C	40	Fall from a height	A	C	T10	-	-	T10	-	-	+	-
8	756679-C	56	Fall from an Electric pole	A	C	T9	-	-	T9	-	-	-	-
9	792780-C	38	Weight fell on back-coal mine	A	C	T10	-	-	T10	-	-	-	-
10	767078-C	31	Fall from a tree	B	IC	T12	+	+	T12	-	-	+	+
11	971930-C	25	Weight fell on back-coal mine	A	C	T12	-	-	T12	-	-	-	-
12	990721-C	29	Fall from a height	A	C	T10	-	-	T10	-	-	-	-
13	932090-C	20	Fall from a height	A	C	L1	-	-	T12	-	-	-	-
14	895454-C	39	Fall from an Electric pole	A	C	T10	-	-	T10	-	-	-	-
15	926928-C	30	Fall from an Electric pole	A	C	T12	-	-	T12	-	-	-	-
16	920995-C	51	Fall from an Electric pole	A	C	T10	-	-	T10	-	-	-	-
17	915586-C	20	Fall from a height	B	IC	L3	+	+	L3	-	-	-	+
18	923663-C	23	RTA	A	C	T6	-	-	T6	-	-	-	-
19	914151-C	54	Weight fell on back-coal mine	A	C	T12	-	-	T12	-	-	-	-
20	956820-C	34	Weight fell on back- in company	A	C	T11	-	-	T11	-	-	-	+

		MASTER CHART				
S.No	Fx Level	Type	AP	Trans	canal/body ratio	Sagg: trans canal ratio
1	D8	Burst	40	40	14:40	14:18
2	L2	Listhesis	40	50	12:40	12:20
3	L1	Burst	33	45	12:33	12:23
4	D12	Burst	35	47	10:35	10:17
5	D11	Ant.Wedge	36	40	10:36	10:17
6	D12	Ant.Wedge	45	45	14:45	14:20
7	D11	Burst	47	41	16:47	16:19
8	D12	Ant.Wedge	51	47	10:51	10:20
9	L1	Ant.Wedge	43	51	13:43	13:23
10	D12	Ant.Wedge	41	40	9:41	9:23
11	L1	Ant.Wedge	49	42	5:49	5:22
12	D12	Burst	42	55	16:42	16:32
13	L4	Burst	35	52	7:35	7:31
14	D11	Burst	34	41	12:34	12:20
15	D12	Burst	34	40	10:34	10:22
16	D12	Burst	48	44	10:48	10:21
17	D12	Ant.Wedge	36	44	10:36	10:27
18	D7	Burst	37	34	10:37	10:24
19	L1	Burst	57	59	9:57	9:35
20	D12	Burst	42	45	6:42	6:27

			MASTER CHART											
S.No	Final ASIA	C/ IC	Final Sensory Level	DAS	JPS	Final Motor Level	MovementGreat Toe	VAC	BCR	AW	Type of bladder	Compliance	Volitional Voiding
1	A	C	T6	-	-	T6	-	-	-	-	Areflexic	Good	-
2	B	IC	L1	+	+	T12	+	-	+	-	Areflexic	Good	+
3	A	C	L3	-	-	T12	-	-	-	-	Areflexic	Good	-
4	A	C	T10	-	-	T10	-	-	+	+	Areflexic	Good	-
5	A	C	T6	-	-	T6	-	-	+	+	Areflexic	Good	-
6	A	C	T12	-	-	T12	-	-	+	+	Areflexic	Good	-
7	A	C	T10	-	-	T10	-	-	+	+	Areflexic	Poor	-
8	A	C	T9	-	-	T9	-	-	-	-	Areflexic	Good	-
9	A	C	T10	-	-	T10	-	-	-	-	Areflexic	Good	-
10	C	IC	S5	+	+	S2	+	+	+	+	Areflexic	Good	+
11	A	C	T12	-	-	T12	-	-	-	+	Areflexic	Good	-
12	A	C	T12	+	-	T12	-	-	+	+	Hypereflexic	Poor	-
13	C	IC	L3	+	+	L3	-	-	+	-	Areflexic	Good	+
14	A	C	T10	-	-	T10	-	-	-	-	Areflexic	Good	-
15	A	C	T12	-	-	T12	-	-	-	-	Areflexic	Good	-
16	A	C	T10	-	-	T10	-	-	-	-	Areflexic	Good	-
17	D	IC	S2	+	+	L4	+	-	-	+	Areflexic	Good	+
18	A	C	T6	-	-	T6	-	-	-	+	Areflexic	Good	-
19	A	C	T12	-	-	T12	-	-	-	-	Areflexic	Good	-
20	A	C	T11	-	-	T11	-	-	-	+	Areflexic	Good	-

TITLE OF THE ABSTRACT:

The value of Neurological and Radiological examinations in predicting bladder function in persons with Thoraco-Lumbar fractures and Spinal Injury.

DEPARTMENT : Physical Medicine and Rehabilitation

NAME OF THE CANDIDATE : Dr. M. Santhosh Kumar

DEGREE AND SUBJECT : M. D. P.M.R

NAME OF THE GUIDE : Dr. Suranjan Bhattacharji

OBJECTIVES:

The aim of the study was

- To examine the value of Neurological and Radiological examinations in predicting bladder function in persons with Thoraco-Lumbar fractures and Spinal Injury.
- To determine if ASIA incomplete spinal lesions on clinical examination will have a better prognosis for bladder function in the form of volitional voiding.
- To determine if persons with a vertebral fracture at T12 or above will have a hyperreflexic bladder and those with of L-1 and below will have an areflexic bladder.
- To determine if those with a mild narrowing of the vertebral canal have a better prognosis for volitional voiding.

METHODS:

After data collection it was subjected to statistical analysis using SPSS Software Vs. 11.0.

Data were expressed as number (%) and mean +/- standard deviation for categorical and continuous variables.

Chi-square/Fisher's exact tests were used for group comparisons.

Independent t- test (for normal data) and Mann-Whitney test (for non-normal data) were performed to compare the mean scores.

RESULTS:

- There was a significant correlation found between ASIA impairment scale obtained during the first neurological examination and volitional voiding.
- There was a significant correlation found between ASIA motor scores more than 50, ASIA sensory scores more than 90, joint position sense of the great toe preserved obtained during the first neurological examination and volitional voiding.
- The use of Canal body ratio at the level of vertebral fracture on plain radiographs was not useful in prediction of volitional voiding. Therefore plain radiography was not found to be a good predictor of bladder function in persons with thoracolumbar fractures and with spinal cord injury.

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